MUSICAL SYNAESTHESIA IN SYNAESTHETES AND ITS MANIFESTATION AS A WIDER PHENOMENON

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Acknowledgements

While claiming full responsibility for the work contained in this volume, and consequently request that the work be acknowledged as mine when used for future academic research, and permission sought in all other cases, its production would not have been possible without much support, formal and informal, technical and academic and cooperation.

While the sources of such assistance are too many to list on this page and while this thesis is no exception to the assertion that every piece of academic writing has its story-of-the-making to tell, I feel it especially appropriate to thank Eric Clarke, my supervisor in the Music Department for his guidance.

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Finally, every thesis relies on outcomes which in turn generally depend on empirical research. This requires people who used to be called 'subjects' but who we now refer to as 'participants'. I believe that this change of language is a good thing since it encourages experimenters not to take them for granted and to ensure that their experience in the experimentation room is a possible one. I hope that I have succeeded in this with all my participants (five invaluable contributors with synaesthesia, 20 for the semantic differentiation study, 53 for the key colour experiment and sometimes numbers in the hundreds for minor surveys) and am very grateful to them. I give special thanks to the five synaesthetes that I worked with, Tony Bennett, Aiden & Andy Cassidy, Stuart Haynes, and Stephen Hoskisson.

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SUMMARY

This thesis has been titled 'Musical Synaesthesia in Synaesthetes and its Manifestation as a Wider Phenomenon', in order to give an indication of the broadness of the subject area that it addresses. It looks at ways in which types of association normally associated with one of the five sensory channels sometimes make connections with, and produce stimulation of, any combination of the other four. Although the thesis touches on most known perspectives of this large topic, all of which are interconnected, it focuses on just two of these areas.

Firstly, it deals with a condition which affects a small minority of the population known as 'synaesthesia'. 'Synaesthesia' is derived from the Greek combining *syn* meaning to combine and *aesthises* meaning perceived by the senses. This word was coined in the 1870s, probably by Fechner. People with synaesthesia experience involuntary sensations that do not exist in the external world but which are triggered by sensations which belong to another sensory channel. There are, for example, synaesthetes that who hear sounds as colours, taste textures, or hear odours. The first of these three examples is, by far, the most common type of synaesthesia and is especially relevant to this thesis since it deals with musical synaesthesia. Musical synaesthesia usually involves strong and specific colours in connection with musical sounds.

This introduces the thesis' second focal point, that of music. Coloured sensations in the absence of coloured stimuli are especially frequent as responses to music and musical material is used in this thesis to test such responses. It seems likely that Messiaen was a synaesthetic musician, and possible that Skryabin was also.

In a more general way, the notion of music being coloured is not confined exclusively to synaesthetes. Numerous non-synaesthetic people maintain that certain keys, intervals, chords or sounds of certain musical instruments are coloured.

Given that there are more non-synaesthetic people than there are synaesthetic people, it seems likely that the former group are predominantly responsible for the gravitation towards coloured music and towards musical paintings during the second half of the second half of the nineteenth century. Therefore, the term 'synaesthesia' might arguably be used to define this phenomenon with as much validity as it is used to define the neurological condition.

It is from the above standpoint that we can gain a greater understanding of a certain prevalent spirit of the late nineteenth and early twentieth century's 'age of synaesthesia'. Although this standpoint is not convincing from a neurological point of view, it is relevant to the study of the internal worlds of several musicians, writers and painters. This is my justification for writing about synaesthesia as a wider phenomenon.

1. Introduction.

References to images belonging to one sensory channel to refer to attributes of another sensory channel are far more common than we might at first think. How often, for example, do we refer to colours as being loud or sounds as being dull or heavy or, for that matter, 'seeing' what someone means (when we mean that we understand what they mean)?

When we make these references we imply the existence of some uniting factor between the two stated properties despite their never being experienced by the same sense. In short we are making 'metaphor' (the subject of Chapter 10 of this thesis). For a small minority of people, however, experience of shimmering sounds, heavy colours or some other cross modal entity is a powerful reality. When such people encounter certain stimuli, which may be visual, auditory, olfactory, gustatory, tactile, or concepts such as numbers or days of the week, they have other sensations associated with another sensory channel that are not triggered directly by external reality but are triggered internally in addition to the normally triggered sensations. Such people have a condition known as 'synaesthesia' (noun 'synaesthete'). Synaesthesia is thought to affect one person in 25000 according to Cytowic (Cytowic 1997), while other estimates vary about fivefold either way. The condition is not disabling to a normal lifestyle in the majority of cases but it must surely make the subjective experience of being a synaesthete quite different from that of the rest of us. The pseudo-hallucinatory sensations, for which I will use Cytowic's terminology 'secondary sensations', can also be those associated with any one of, or any combination of the senses: A synaesthete might, for example, taste shapes, see sounds or have coloured odours.

The chapter in the thesis concerning neurological theories of synaesthesia (Chapter 12) elaborates on the essential qualities of the condition but a brief summary which distinguishes synaesthetic experience from what Jewanski (2001) called 'intermodal construction' and 'associative thinking' will suffice here. Firstly, synaesthesia is innate, never acquired. Secondly, cross modal secondary sensations remain constant over a person's lifetime. Thirdly they will always occur and the synaesthete has no voluntary control over them. The fourth point is that the triggers, or primary sensations, are unique to each synaesthete, and the final point is that synaesthesia feels totally real yet qualitatively quite different from external reality.

It is, of course, impossible to tell for certain whether any one person's subjective experience of the world resembles that of the next person's in any way at all. It can be ascertained, however, that we are all constantly creating subjective meaning out of the concrete reality in which we live. This rather esoteric issue highlights one of the greatest barriers to our understanding of synaesthesia: the subjective awareness that makes all of our subjective interpretation possible is quite likely to be a product of preconscious processing. Cytowic provides evidence suggesting that synaesthesia is thought to occur not only in synaesthetes but also in non-synaesthetes who are unaware of synaesthetic experience because their higher cortical functions block it out.

In order to obtain a clear idea of what I mean by 'subjective construction', it is helpful to explore a form of such 'mental embroidery' that occurs in most people rather than one confined to a small minority of cases, as synaesthesia does. The example that some of the first few chapters of this thesis deals with is colour. The phenomenon that begins in the eyes as relative stimulation ratios of three types of cone (which Land found varied to a large degree in any case) is then translated into this subjective construct called 'colour' which affects the emotions directly and has a vast expanse of non-verbal meaning for each one of us.

Colour is of further relevance as an introduction to the study of synaesthesia, since colour constitutes part of the secondary experience in the majority of synaesthetes (the triggers are usually sounds). Therefore, the chapters about colour help to define both the concept of colour and the individual colours in preparation for the references to colours from coloured hearing synaesthetes in the final chapters.

Synaesthesia is thought, according to the neurological model, to be an all or nothing condition. It is believed that while everyone's middle brain creates a world of sense, of feeling and a more emotional and direct form of experience from the one that most of us are aware of, this is filtered or else processed beyond recognition in those people considered not to be synaesthetic. It seems to me, however, that this model does not account for the existence of and the vast variety in the ability of non-synaesthetes to associate certain concepts, odours or sounds with colours or other kinds of sensation, sometimes in a way that is almost involuntary, and often in a way that is consistent over time. It can also be quite 'meaningful' thereby fulfilling Cytowic's fifth criterion. Nor does the neurological model take into account the common cross modal transfers that are evidenced by synaesthetic metaphor and formulated into Marks' 'Unity of the Senses' theory (Marks 1978). Is red really a warm colour and blue a cold colour as a result of some universal mental linkage or should the connection be attributed to pure convention? The experiments reported in this thesis appear as if they are measuring synaesthesia, as experienced by the one in 25000, or something very akin to it, as being present in non-synaesthetes under certain experimental conditions. If this is the case it forces us to modify the model outlined above.

A main interest for musicians regarding the topic of synaesthesia is synaesthetic composers. The most well known synaesthetic composer is Messiaen. The issue of how to listen to a synaesthetic composer and whether despite most of us not being synaesthetic there is anything to be gained in our appreciation of their music by attempting to understand their secondary sensations is an issue of great debate. The issue can be extrapolated into the more general issue of extramusical ideas, programme music; that is, extraneous ideas in music. Although the term 'programme music' usually refers to musical dramas or 'painting a picture' with music (a category only some of Messiaen's works fall into), Schenker and Stravinsky classified its antonym, 'absolute music', as requiring objectivity and structure (Scrutton 2001).

Understanding Messiaen's synaesthesia in relation to his music is, by the above classification, to treat his output as other than absolute music; that is in an extramusical way. If, on the other hand, we claim to be able to legitimately isolate his colours and regard them as extraneous to musical process, then we have no grounds to stop this extravagant claim there - factors such as religious persuasion, nationalistic feelings, and the consequences of deafness finding their way into a composer's works must also be regarded as extramusical. The same is true of any expression or emotional content that may be considered to be present in the music. If the above definition of absolute music is to be accepted then it is an approach that is probably better avoided and the subjective world of the composer concerned explored. Rare perceptions such as synaesthesia, nationalistic convictions, mystical experiences and afflictions of the senses are all part of certain individual's subjective worlds and must be included in any representative study of a composer's works. Synaesthesia, on this account, can be seen as a powerful example of the importance of studying the whole of works of art, or people for that matter, rather than examining exclusively what conforms to convention and expectation.

2. What is Colour?

INTRODUCTION

Although this is not a thesis on colour per se, discussion about colour forms a great part of it. This is justified partly because the main type of synaesthesia that we are addressing, chromaesthesia, involves colour by definition, but more generally because colour is, as I will argue, an intangible phenomenon. Despite colour's intangible nature, it is, for most people, a constant experience. Insofar as achromatic colours (black, white and grey) are included in the term colour, as I will later argue that they should be, we become aware that we cannot imagine a form or object that does not possess colour. The idea that perceived colour characterises all objects is summarised by the Colliers encyclopaedia definition of colour which states 'The study of colour is concerned with all visual sensations except those involving the perception of shape, size, surface texture and motion of the objects we see' (Katz 1935, p15). According to this definition, all objects must have colour. This definition does not really say what colour is, only what it is not. Colour is therefore a 'miscellaneous-cupboard' consisting of any aspect of visual perception that cannot be given another label. Such a definition is the visual equivalent of 'timbre' which is often referred to as 'tone colour'. It is defined by the Acoustical Society of America as that which distinguishes two sounds of the same perceived pitch and loudness (Campbell 2001). While the intensity of the various partials (frequency components) is the main determinant of most timbres, it is by no means the only one (Ibid).

In a study of colour it is necessary to use phrases like 'perceived colour' and 'appears to possess a colour' since properly speaking colour is not a physical phenomenon insofar as it does not exist out there in the external world but is the subjective construct of a perceiver. This chapter illustrates the non-physical nature of colour by looking first at colour problems which would be paradoxical were colour assumed to have a constant physical state.

We then look at some phenomenological colour theorists from the fifth century BCE to the present day. The chapter ends by discussing colour classification - leaving the door open for the following psychophysical study concerning what makes red-red and green-green.

COLOUR IS NOT IN AN OBJECT.

Collier's definition of colour defines it in terms of what colour is not. Similarly the first negative sub-definition of colour that I offer is that colour does not belong, strictly speaking, in an object itself. We call grass green, and for everyday purposes may continue to do so, but grass is only seen as green in limited circumstances and to the colour-normal observer. At night when only rod vision is active, it arguably appears grey and to a red-green colour blind person it may appear brown. This suggests that a physical object itself is not wholly responsible for colour and that colour is constructed in the eyes. Colour therefore requires an adequate amount of light of the right quality as well as an observer's eyes that can see colour. All that a physical object possesses by way of colour, therefore, is a certain physical make-up which given 'normal' circumstances elsewhere in the process will result in our seeing of its usual colour. Unlike other visual attributes which can be verified by other senses, colour cannot, suggesting a non-physical view of colour.

The physical make-up of colour depends on chromaphores; groups of atoms which absorb light rays of certain wavelengths and are therefore responsible for certain wavelength absorption more than others. NO_2 (One atom of nitrogen linked to two atoms of oxygen) is an example of chromaphore. It absorbs most heavily those light rays of wavelengths shorter than about 550 nanometres (approximately the single wavelength corresponding to emerald green) and absorbs the extreme long wavelengths more than moderate long wavelengths, thereby providing the sensation of orange in normal light (Adler 1962, pp 80-81).

It must be emphasised that an object consisting predominantly of NO_2 chromaphores will look orange only where the appropriate range of light rays are available. Therefore, although the properties of chromaphores remain constant, the colour depends on the light and the eyes of the viewer.

Even with a white light source and normal colour vision, certain liquids with complex pigment (chromaphore) make-up do not consistently appear as one definite colour; instead the colour varies according to the thickness of the sample being viewed. This is called 'dichromaticism' (meaning literally possessing two colours) and is a result of the extent to which light-rays of different wavelengths are absorbed (Chamberlain 1980, p10). Green Chartreuse liquor appears yellow-green when viewed at about five or six inches depth but appears red at much greater depths due to differential absorption of different wavelengths of light.

It is therefore unsatisfactory simply to say that colour exists within a substance when a different quantity of this substance can change the colour that is seen. Surely the observed colour is the one which must pass for the actual colour. We cannot properly call either the red Chartreuse sample or the green Chartreuse sample optical illusions, and it must therefore be accepted that colour is a variable property as opposed to a stable one (Chamberlain 1980, p3).

COLOUR IS NOT IN THE REFLECTED LIGHT FROM AN OBJECT.

So far most of the examples of the non-permanent colour of physical objects result from changes in the reflected light from an object. I made occasional reference to colour vision defects. If reflected light rays in a mixture normally associated with green enter the eyes of someone who is colour blind, the person may not see them as green: they may (depending on which receptors remain) perceive the rays as brown, yellow or blue. Although this is attributed to faults in the eye, it can still be held that this is optical truth and that the so-called colour blind person's interpretation of the light rays before us is as valid as anyone else's.

From the example of someone who is colour blind, we can conclude that the perceived colour depends on the eye and that different people see colours differently. I will now proceed to explore the ways in which it is not even ultimately the eye that sees colours but the brain. However, since before to the birth of psychology in the nineteenth century, philosophers, physicists and other theorists had little concept of the brain as a separate entity, when discussing such investigators the word 'eye' will be used to refer to eye and/or brain.

I suggested at the outset of this chapter that the perception of colour is an example of a complex and multi-layered mental process in the same way in which synaesthetic perception is. We create the colours in which we see our world: a process that I will go on to describe in this chapter. This is a form of 'idealism', a term given to those doctrines that suggest that the material universe is created by the perceiver. In the case of synaesthetes, common sense suggests that their internal sensations are 'not real' because no-one else sees them, but the only difference between these sensation and those of colour, which is also internally created, is that most people share similar apparatus which translate specific chains of atoms known as chromaphores into what we call colour.

Socrates was the first to suggest that the object, the light and the eye all work together. Galen in the second century CE substituted the notion of light rays for a notion of visual spirits which he suggested that the eyes responded to. He was interested in the dynamics and motion of the supernatural and of emotions. Galen would speak of a green object being envious or a blue object being sad due to the visual spirits that they send out to the eyes. He suggested that at night objects appeared as black and white because the visual spirits were temporarily paralysed and therefore unable to reach the eyes (Birren, p.56). Alhazen eight centuries later also attended to the notion of the eyes producing the colour, he suggested that the eyes made an object coloured by actively reflecting back colour into the object (Ibid, pp 57-58).

While Galen and Alhazen both recognised the role of the eyes in actively translating what comes into the eyes to produce colour, Socrates had already hinted at the right answer but without the faulty assumptions about the properties of light. Sir Isaac Newton (1643 (1642 by old calendar) – 1727) in his book Optiks put Socrates suggestion more formerly when he said of light 'The rays are to speak properly not coloured, in them there is nothing else other than a certain power' (Newton 1952, p33). This insight influenced the Chambers Encyclopaedia definition of colour in 1741.

> Colour is a property inherent in light whereby according to the different sizes of its parts, it excites different vibrations in the fibres of the optik nerves which propagated to the sensorium affect the mind with different sensations.
>
> (Katz 1935, p15)

When colour vision is discussed later in this chapter we discover by way of both theory and investigation that there is no simple one to one relationship between this 'property inherent in light' and the different sensations produced internally, rather the limitations of our colour receptors, an intelligent but often preconceived brain and fairly resourceful intermediate systems all contribute to creating the colours we know in the contexts in which we know them. In order to do understand these it is first a good idea to look at the way that different colours are mapped by theorists in order to provide a clearer picture of the nature of colour.

COLOUR CLASSIFICATION

As early as 360 BCE Aristotle proposed a classification system for colour, based on the, now discredited theory that all colours are a mixture of black and white. A more useful way of representing the different saturated hues and their relationship to one another is by a colour circle - a circle filled with sectors of different hues arranged in such a way that adjacent hues have a similar appearance and hues 180 degrees apart appear most unrelated. Depending on the discipline in which colour theorists are concerned, they are likely to use one of two types of colour wheel, both having six basic colours on them. For painters, most designers and many colour consultants the circle is likely to run clockwise with red, orange, yellow, green, blue, purple-violet and back to the red (so that red is opposite green, blue-orange, yellow-purple or violet). However for printers, those designing patterns on a computer and anyone else concerned with process inks or cathode ray tubes, the basic colours are in colour circle order red, yellow, green, cyan, blue, magenta and back to the red (opposites being red and cyan, yellow and blue and green and magenta).

These differences are caused by the 'primary' colours chosen and neither of them demonstrates subjectively equal colour transformations throughout. In neither case do the three primary colours look mutually similar (120 degrees apart) to each other, to the normal observer - regarding the painter's primaries yellow and blue look too dissimilar and red and yellow too similar, while the cathode ray tube primaries have red and green as too dissimilar and green and blue as too similar.

A colour wheel that seems to work better for the measurement of colour similarity which Theo Gimbel uses in 'Healing With Colour' (Gimbel 1980) has eight basic colours, each 45 degrees apart, which working clockwise are red, orange, yellow, green, turquoise, blue, violet and magenta. The opposites that this produces that, generally speaking, prove near enough to satisfy both visual artist and those involved in electronic colour displays or printing. The first seven colours can also be the 'colours of the rainbow' with magenta as the effect of mixing the longest and shortest wavelengths.

Some colour circles consist of gradually changing colours and represent all the colours of maximum saturation. They do not, however, represent light, dark and toned down versions of each hue. A world which consisted only of bright colour circle hues, however varied, would not only be very glaring to the eyes, but would also be strangely monotonous. Many of the colour sensations that we experience are in fact not middle value saturated hues but light saturates (tints), dark saturates (shades) and non-saturates (tones). For practical purposes a light saturated object reflects as much of the light as is practically possible in between one and two thirds of the visible spectrum (as does a medium saturate) but also reflects significant amounts of the remainder (unlike a medium saturate). Pink, lilac, peach and aquamarine are common names for light saturates. A dark saturated colour absorbs as much as possible of one to two thirds of the visible spectrum (as does a medium saturate) and absorbs some of the remainder (unlike a medium saturate). Dark brown, navy blue and tree green are examples of dark saturated colours. A light saturate is therefore saturated with respect to reflection but not absorption and a dark saturate is saturated with respect to absorption but not reflection. A colour which is neither of the above is unsaturated, greys being the least saturated colours, and is called a tone. This is the system that Munsell uses (Birren 1969, pp 48-49).

Colour can be represented in three dimensions, one of which is represented by the colour circle, namely hue. The second of these dimensions is darkness or lightness. This dimension does not affect saturation as a purely dark colour still absorbs the rays that its middle saturated equivalent did and a purely light colour still reflects what its middle saturated equivalent does. In the Munsell colour solid the colour circle is on the outside in the wide middle portion of the construction, the light colours are represented above the colour circle converging upwards with the light colours above the saturated colours, converging to white at the top, and the dark colours are represented below, the saturated colours, converging to black at the bottom. Towards the mid-grey centre, the saturation of colours decreases and tones occur. Munsell devised this solid as a theoretical construction which contains 100 hues and as many saturation degrees, tints and shades as can be distinguished by the eye. He later produced some of the colour chips but printing technology was inadequate to produce the full set, as it still is today. He also devised a colour spinning wheel where different portions of different basic colours can visually blend together to produce a required colour standard for the purposes of matching an object. The Munsell spinning wheel is today used in the food industry to standardise food colours (Chamberlain 1980, p24).

Having defined what colour is, how different colours are classified, how they relate to one another and how colour classification may be applied, we are now ready to examine in some detail how colour is seen in terms of eye and brain mechanisms. Colour classifications such as the Munsell or Ostwald ones are as useful to describe the colours of a chromaesthete's secondary sensations as they are those of real objects since, as I have suggested, colour is a synthesised entity whether applied to external objects or not.

COLOUR VISION

Since colour is an internal phenomenon, a study of the eye and brain mechanisms of the perceiver and study of the way in which we use colour can be said to constitute the entire study of colour itself. Studying pigment chemistry, physics of light and the technology of food colouring or television are both of use and interest, but are not equivalent to the study of colour. All the above does is highlight how it is that colour is not a phenomenon that can be described in words to someone who does not have any experience of colour, any more than synaesthetic experiences can be communicated to those with no conscious experience of synaesthesia... We now move closer to the study of colour by looking at the way in which the eye decodes the impressions that we call colour.

THE TRICHROMATIC THEORY OF COLOUR VISION

While Sir Isaac Newton discovered that white light was composed of different hues ranging from red through to violet, he did not explain how diverse colours are seen by the eyes. It was only in 1801 that Thomas Young suggested that the colour vision that we experience can be explained by just three kinds of receptor each predominantly sensitive to a different part of the spectrum. This was suspected by observing the limited discrimination of the eye, the fact that three colours of paint sufficiently far apart in hue (e.g. crimson, yellow and aquamarine) will produce, for most of the colours that we can see. These pigments cannot, of course, produce every combination of reflectance in the visible spectrum. This demonstrates that the eye relays a simplified version of the wavelength properties of the world. Three types of such receptor have since been discovered, initially by Hermann von Helmholtz in 1851, and are called 'cones' owing to their shape. The reflectance (response) curves of the three types of cone overlap somewhat so that different hues may be distinguished by different response ratios.

It is these ratios are what facilitate colour discrimination. The long wave cones are most sensitive to the yellow part of the spectrum and only respond to the shorter visible wavelengths at 'background' level. The medium wave cones, having their peak nearer to green than the long wave cones, combine with the long ones to allow discrimination of colours in the red-green half of the spectrum. The short wave cones are much weaker than the other two types, for reasons discussed below, but having a different response curve again they facilitate further colour discrimination.

Late in the nineteenth century Christine Ladd-Franklin argued that the three types of cone evolved at different times and for different reasons (Mollon 1995). She suggested that the light absorbing molecules in the retina underwent a qualitative split over time to give first monochromatic vision (when the cones were all the same), then dichromatic vision (when they could be split into short wave and medium wave), and finally trichromatic vision which is the type described above. Mollon describes how the different types of cone evolved for different purposes (Mollon 1995), starting with the development of one type of cone. Since colour vision requires comparison between receptors with different peaks this allowed only monochromatic vision. Then a small number of receptors evolved with a peak sensitivity to short wave light. This second type of cone being small in number did not significantly improve vision as such but facilitated comparison between the two types of cone. A third type of receptor probably resulted from faulty copies of the medium wave receptors. The 'faulty' copies of the receptor had a peak slightly biased towards the red end, which increased survival chances as animals were able to find orange fruit against green dappled backgrounds that dichromats missed. Assessing the development of colour receptors, as distinct from that of higher colour processing, which is discussed below, illustrates how colour perception is a multi-levelled process. Synaesthetic colour, by contrast, results only from psychological processes: - a red synaesthetic sensation results from processes similar to the signaling of a high low: medium cone stimulation ratio.

I suggested that of the three types of colour cones, the short wave cones are somewhat weaker than the other two types and do not on their own offer much spatial resolution but serve the main purpose of furnishing our colour vision with a third dimension. The lack of violet cone resolution can be demonstrated by the extreme difficulty in reading words on a surface, where the words and surface both have similar reflectance with respect to the long and medium cones and the main difference in brightness lies with the violet cones (such colour combinations include black and violet, white and lemon yellow, and grey and pale violet). The weakness of the violet cones further explains why, as Goethe (1749-1833) and Kandinsky (1866-1944) both observed, yellow is naturally the lightest hue and blue-violet is naturally the darkest hue, since short wave cones do not relay much brightness information to the brain (Goethe 1970, p 126), (Kandinsky 1977, p36). Mollon suggests that the reason for the sparseness of violet cones is to provide a greater uniformity of focal point between the different wavelengths of light reaching the eyes. Light converges at different focal lengths depending on its wavelength. As only a small about of light is received by the eyes at the shorter extreme of the spectrum, the eye focus on an object's longer wavelengths. The shorter wavelengths are treated only to a comparison with the other wavelengths to provide the third (yellow-violet) dimension of colour.

The idea of three dimensions of colour vision is supportive of the nineteenth century opponent process colour theory of Ewald Hering (Birren 1963, p93). Hering's view of colour was like Goethe's in the respect that he was interested in the way in which colours subjectively appear to us but unlike Goethe he was interested in physical mechanisms of colour in the visual system. He observed that we see four basic colours which form contradictory pairs, so that we cannot conceive of a yellowish blue or a greenish red whereas we can conceive of, for example, a reddish blue (purple) or a greenish blue (turquoise or aqua).

Hering therefore speculated that the human colour vision system consisted of tug-of-war opponent process systems, red versus green and yellow versus blue to which he added brightness or white versus black. Like the dimensions long, medium and short, and hue, brightness and saturation, Hering's three dimensions of colour allow any conceivable colour to be measured (Chamberlain & Chamberlain 1980 p. 7).

Hering rejected Young's theory of colour vision on grounds not dissimilar to Goethe's rejection of Newton's theory, in this case with the objection that the notion of three primary colours did not relate to subjective experience whereas four basic colours organised in two pairs did (Ibid, p. 9). As late as the early twentieth century, reports on colour, colour vision and colour blindness could be divided into those of physical theorists, and those of phenomenological theorists. Since the early 1950s, however, it has become accepted that while there are three types of colour receptor at the back of the retina, they relay colour information to visual cortical cells by dividing colour experience into red versus green and yellow versus blue, and additionally relay brightness. Thus we have the Young-Helmholtz theory and Hering's theory incorporated into our modern understanding of colour vision (Birren 1963, p94).

This still leaves the opponent process theory with one problem. The phenomenalists, as they can appropriately be called, turned to theories like the opponent process theory by observing how things appeared subjectively, in this case the way that most people would agree on red, yellow, green and blue being prime colours. Unfortunately, the particular hues of these four colours that would be signalled according to the above are not what most people would call the pure or unique colours. The yellow signalled seems to be a lime yellow, blue is violet, the red is slightly orange and the green slightly blue. It could be argued that our notion of unique red, yellow, green and blue are the result of a more complex coding from the three types of cone. The opponent process theory developed on false premises, but like so many such scientific 'discoveries', it has facilitated the formulation of the right theories.

Having established some theories of colour vision we are now able to briefly discuss colour blindness, something that will assist the enquiry outlined at the outset, since asking what the colour blind see raises some interesting points and questions about the nature of colour itself. A severe degree of colour-blindness (dichromacy) is where one of the three types of cones is missing. A dichromat lacking either long or medium wave cones sees the world in blue, yellow, black and white. Green blindness (deutranopia) is fairly common (affecting 1.1% of males but only one in 10000 females). A similar situation occurs in total red blindness (protonopia). Violet blindness (tritonopia, very rare) deactivates the blue-yellow system of colour vision completely while the red-green system remains intact.

In the less severe forms of common colour-blindness, three different cone types exist in the retina, but the long wave and medium cones have response curves that are closer together in frequency response than in those with normal colour vision. Where the anomaly is in the long wave cones, the condition is called 'protonamolous'; and where the anomaly is in the medium wave cones, the condition is called 'deutranomolous' (Nassau 1993). Partially colour blind people in these categories, called 'anomalous trichromats' have three dimensions of colour vision, but the anomaly probably gives rise to a reduced or lower resolution red-green signalling. Such people can distinguish a saturated red from a saturated green but may confuse a red-grey with a green-grey or a saturated yellow-orange with a slightly darkened mid yellow, for example.

That even a small difference in these two types of cone can be taken advantage of is demonstrated by studies of New World Monkeys. As a species these can best be described as dichromats. All the males in the species see only in two colour dimensions as they only have one type of receptor for short wave light and another for long and medium wave light.

Since the latter is coded on an X chromosome - as it is in all mammals -, females have two copies of the long wave pigment to the males' one. More often than not, but not always, the two versions that a female inherits of the long pigment are subtly different allowing them a third dimension of colour vision which, although more limited in resolution than normal human trichromatic vision, allows them to carry out tasks useful for survival, that the males are unable to carry out. It seems that they are designed to map colour in just three dimensions. The New World Monkey studies provide a suggestion regarding anomalous trichromacy in humans, namely that it seems probable that we are able to perceive in the red-green dimension provided that as the long and medium wave cones in our retina are at least slightly different. The question as to whether or not the reduction in the response ratios in an anomalous trichromat between these two types of cone results in correctly identified bright reds and greens appearing less vivid, however remains subjective: any report on colour can only, at the end of the day tell us what colours can be distinguished and not how they will actually look to the person reporting.

This situation led Mollon & Jordan to suspect that female carriers of anomalous trichromacy might have a fourth type of colour receptor and that they would not match colours as readily as trichromats do: they would need four and not three coloured lights to match all the colours that they see. They presented them with adjustable mixtures of single wavelengths of light (orange and green on one panel and red and yellow on the other). Each light consisted of a single wavelength so that the mixtures could never be physically the same but would produce matches for trichromats. None of the women tested were reluctant to make any matches at all, which would have indicated tetrachromacy, but some accepted slightly less matches than trichromats and also accepted other trichromatic matches with slight reluctance as if they felt the matches to be slightly wrong in a way in which they could not pinpoint (Mollon 1995). It is possible that that they had found women who were physically tetrachromatic but that the brain is only equipped to code for three dimensions.

The above study suggests that colour can only be coded in the visual areas of the brain in three dimensions but this cannot be proven. Colour perception is now understood to a large degree but it still has many mysteries surrounding it. In several years time we might be in a similar situation with synaesthesia, understanding what it is roughly, yet from time to time uncovering areas that we will probably never understand.

The differences between psychologically perceived colour and the codings for colour produced by processes in the eye were elaborately illustrated by Edwin Land in the 1950s. In one experiment he took two slides of the same object, one with a red filter and one with a green filter, and projected the two images together on a screen covering the light of the red image with a red filter and projecting the other with white light. Our understanding of light and of eye processes would lead us to assume that this would produce an overall pink picture, with reds appearing red and greens appearing whitish. What actually happened (that is subjectively, according to the human observer), is that a fully and truly coloured picture emerged. (Sacks 1995) What made the original greens appear green when the light projected was white? More amazingly, how could just two images produce full colour when classical colour theory states that three are needed?

The above findings mean that we need to look at a level of colour perception in the visual areas of the brain, in the areas where what makes us call a colour red or blue are more closely related to what makes a synaesthetic sensation red or blue. In 1977 Zeki found regions within the visual cortex of rhesus monkeys that respond to colour, show colour constancy and seem to 'see' colours much the same as we do (Zeki 1993). Quite how these areas work is not properly understood and the cortical areas that he discovered are simply labelled *V4* and *V4A* denoting the fourth colour areas (the first being the cones in the retina, the second being the opponent process coding in the ganglion cells and the undiscovered third thought to process further for basic colour constancy, as a result of contrast detection).

There are deeper visual areas than this still that are yet to be properly understood, if that will ever be possible. Should these post *V4* areas ever be better understood, then it is felt that some new insights into chromaesthetic synaesthesia, at least will emerge.

Oliver and Robert Wasserman in 1987 reported a case of an artist, Jonathan I who completely lost his colour vision as a result of a road accident (Sacks 1995). The nature of Mr. I's loss was the complete opposite of the types of colour blindness described above. His full compliment of cones was still intact and the signals from them were still providing information about the wavelengths of light. What he lacked was the areas of *V4* and beyond, discussed above, to convert the ratio patterns of the three types of cone into colour, and further, he lacked any living memory of colour despite having seen and used colour for 65 years of his life. This meant that he ceased to dream in colour and his well preserved imagery of objects was without colour as well. Most significantly, Mr I experienced chromaesthesia before the accident, which also disappeared. In place of colour, Jonathan I saw everything as 'disgusting', 'dirty' and 'moulded out of lead', seeing signals from the first and possibly second visual areas which then failed to be processed any further. He seemed to lack basic colour constancy, which is an intermediate process, and described how colours 'fluctuated' as a result of changing light quality.

What Jonathan I had lost, therefore, provides an insight into the workings of the higher cortical areas in processing colour. It supports the idea that colour is no more produced in the physical eye than it is by light rays as Mr. I was colour normal at the optical level. It is almost certain that there are areas concerning colour in the brain which go deeper than the *V4* and *V4A* areas and while even the *V5* areas are just now in the infancy of their discovery, the deep functions of higher colour centres and their connections with language and emotion centres can be discussed on a totally abstract level. Chapter 3 addresses the conventional associations and deeper senses of meaning which constitute how we utilise the entity of colour and the meanings and significance that colour has for us.

3. What Does Colour Mean To Us?

Colour is very important to every aspect of our lives, so much so that anyone suffering a sudden and dramatic loss of colour, as Oliver Sacks' subject did, would find every aspect of the world dramatically altered. In 'The Artist's Guide to Composition', Webb writes 'Colour's magnificence makes a joy out of the painter's work; It blesses the most humble subject' (Webb 1997, p75). Throughout history people have always attributed meaning to colour and have attempted to express this meaning in language. Phrases such as 'red alert' and 'green with envy' are in everyday use now and their metaphoric content is seldom thought about but they all had their origins as a result of people wishing to attach linguistic meaning or emotional loading to experiences that are otherwise unutterable. We cannot be certain as to how uniform these colour attributions are between different cultures but there is much evidence in studies of colour that some universal aspects exist. The issue of meaning behind the colour language that people tend to use shares a difficulty of interpretation of synaesthetic reports; in each case it must be bound by language. In the case of synaesthesia, it is quite probable the real experiences of synaesthetes are heavily adulterated by the limitations of language, even before reaching consciousness.

One such universal aspect seems to be the evolution of colour terms. 35 years ago Berlin and Kay (Berlin & Kay 1969) did research on the use of basic colour terms in different cultures. Basic colour terms are those that are universally understood, not terms that are subsets of other colours (e.g. not crimson because it is a red) and terms that are used to refer to any kind of object. According to this English has, arguably, eleven basic colour terms.

The study examined 60 or so different languages and found that all languages have a minimum of two colour names, one to describe a light colour and one to describe a dark colour in their extreme these being black and white respectively. Most languages have, added to these, a third colour name which is 'red' in every case. Berlin & Kay called languages with three colour names (white, black and red) level two; such languages are quite common in primitive cultures. The Tiu language of Nigeria is an example of such a system; it uses the third colour word *Nyian* to cover all the colours which we would call warm while the so-called cold colours are called *ii* (dark) or *pupu* (light). If a language has a fourth colour name, then that will either be green or yellow or occasionally a single term centred on green and yellow. Such a system is referred to as level three. One example of such a language is Somali, having terms for black, white, red and green. Languages with five colour names are described as level four systems and have terms for both green and yellow. In such languages, which are common among the indigenous people of Central America, blue is usually called 'black' if dark or 'green' if medium or light. The sixth basic colour term to evolve in any language seems to be 'blue', at which stage a language is described as level five, followed by 'brown' where it is described as level six. The highest language level is level seven. Level seven colour systems occur in developed cultures where combinations of the names 'grey', 'orange', 'pink' and 'purple' are used as well as the more basic seven colour terms. A level seven language, therefore, has eight to eleven terms, although in practice most languages that develop any of the above four terms develop all of them, so that most sophisticated languages have eleven basic colour terms and eleven only.

Berlin and Kay thereby claimed to have found that colour terms developed in a neat hierarchical way, although they did discover a few unusual cases which went against the model. Vietnamese, for example, has no basic term for blue (it has one term to cover green and most blues) despite having terms for brown, pink, purple and grey, all of which are above blue in the Berlin & Kay hierarchy. Russian and Hungarian seem to have twelve basic colour terms having, two distinct words for different blues in the former case and two for different reds in the latter. In general, however, the researchers seem to have made a valid and useful contribution to the way in which different colours are defined and their order of eleven colours seems also to reflect the order in which we learn colours (Berlin & Kay 1969 p47).

An interesting question that this study raises is whether the availability of colour names in a language at a given stage determines how colours are seen. In other words, do the speakers of a language whose colour system is at one of the less advanced levels have a more restricted appreciation of colour than do speakers of a stage seven language. This question has its counterpart in relation to synaesthesia, as indicated above; is synaesthetic experience, as even a synaesthete 'knows' it, partly determined by vocabulary? Most evidence seems to suggest that this is not the case, although it does, by definition, affect the colour language use. Compared to the West, people of South east Asia and Papua New Guinea and around have more yellow pigment in the lenses of their eyes (no doubt for added protection from the suns rays) which results in (relative to the Western reader) a partial violet blindness, increasing the similarity of green and blue.

This provides the linguist with a possible explanation for the absence of a separate basic term for blue despite having separate more advanced terms. However, other languages in this part of the world have terms for blue. Furthermore Vietnamese make a linguistic distinction between red and purple which the yellow pigmentation explanation suggests that they may not.

That different colours have different effects which are nearly universal was first formally proposed by Goethe in 1802 (Goethe 1970). The first two colours which Goethe talks about are blue and yellow. These colours he said are stark phenomenological opposites, blue being the colour which provokes rest and turning inwardness since dark blue is the colour that has always heralded night, and yellow being the colour which provokes activity or adventure and stepping outwards towards new possibilities. Goethe's theory of colours has been taken up by other phenomenologists. At the start of the twentieth century Kandinsky referred to blue as the colour of concentric motion and yellow as eccentric motion and Steiner used the image of a snail creeping in, and out of its shell respectively. It is observed that this first division into blue and yellow is contrasting in terms of dark and light, blue being a naturally dark colour and yellow a naturally light colour. Goethe also claims that this division of colours separates warm and cool colours, the yellow of day being warm and the dark blue of night being cool, an idea again taken up by Kandinsky in 'Concerning the Spiritual in Art' (1977, p36). Many theorists outside this line of German philosophy have suggested that it is red and not yellow that is responsible for the warmness of a colour. While red may play a part in this, it must be recalled that, phenomenologically speaking, pure yellow contains not a trace of red and yet many people call it a warm colour. Green on the other hand is called a cool colour, while its lack of blueness or yellowness would, according to this theory, make it neutral.

Red is, in fact given a third attribute, vigour or potentiality of the concentric or eccentric motion (Kandinsky 1977, p36).

Goethe introduces the colour red third, after the polar opposites of yellow and blue, and treats green as a secondary colour throughout his writing. Kandinsky, on the other hand, introduces green as the third colour, arguing that its combination of the eccentric motion of yellow and the concentric motion of blue, here, cancel each other out so that green is temporarily immobilised (Kandinsky 1977, pp 38-39). This he contrasts with grey - a mixture of black and white which is more permanently immobilised since the colours in grey do not have any motive power. Red, the fourth hue that Kandinsky introduces is argued to be in opposition to green since red represents mobility in either of the two directions in contrast to green's immobility. Warm red, (e.g. Vermilion) according to Kandinsky is energetic in beaming outwards and cool red, e.g. crimson is energetic in beaming inwards. He goes on to argue that orange, being between red and yellow, is the colour of an unstable and yet forceful eccentric motion and that violet, being between red and blue, is the colour of an unstable and yet forceful concentric motion; these form a further pair of polar opposites. Orange and violet are not, of course, polar opposites in the sense of their physical properties but Kandinsky suggests that they are in some non-physical and spiritual sense (Kandinsky 1977, p42). Although Goethe in his theory of colour places a scientific slant on the subject of colours and talks of orange as having the opposite effect to blue and violet to yellow, it would be a mistake to assume that there is a simple one to one relationship between physical colour properties and colour meaning.

Steiner explored deeper, and more controversially, the realms of colour psychology than Kandinsky. He talked of three 'lustres', or 'luminants', red, yellow and blue which are projected to form what he terms 'images', of which there are four; green, peach-blossom, white and black (Steiner 1992, p37). The properties of the three colours that he referred to as lustres agree, more or less, with those of Goethe and Kandinsky as does his notion of the psychological neutrality of green. Composed of the lustres of blue and yellow, Steiner stated that green radiates neither outwards nor inwards. Likewise he argued that the colour of plants is evidence of life within the soil, while the green material that the leaves are made from is no longer living. He therefore called green 'the lifeless image of the living'. The soul, continued Steiner, projects an image of the lifeless which is the absence of all illumination and is black. The spirit projects an image of the soul which consists of all of the luminants and the image is white. Finally, the living produces an image of the spirit, this time by taking the red luminant and allowing black and white to flow through it. The result of this last image is that of flesh. Because flesh is a living thing, Steiner argues, it can never be static but must constantly flow. It is impossible to produce the colour on paper; it can only be made as a result of active movement. The straight luminant, red, by contrast, asserts itself by being static. There is, according to Steiner, a shock value in seeing the lustre of the living but without any movement, thus the intense, aggressive appearance of red (Steiner 1992, p35). Different colours have in this way been given certain values by these German theorists and while these values may or may not be universally valid, they do, unlike the physical theories of Newton or Young attempt to look at colour itself, colour, that is, in the subjective, human sense.

The theories of Goethe, Kandinsky and Steiner were developed in the 1940s by the Swiss psychologist Max Luscher, who used the aspects of different colours to imply aspects of people's personalities, devising the Luscher Colour Test. This test is fairly complex and the patches are not widely available, but there is a shorter version which uses just one panel with eight colours on it, which the subjects are required to arrange in their order preference (Scott 1970). The idea here is that the colour selected first will have the attributes to which the subject gives the highest priority, the colour selected second will stand for their second highest priority, and so on right down to the eighth colour which represents attributes that the chooser would really rather avoid. The eight colours are blue, blue-green, orange-red, yellow, violet, brown, black and grey. The representation of these colours agrees with that of the German Romantic theories, blue and yellow represent concentric and eccentric motion, respectively, red, outgoing assertion, and green, confidence. Violet represents an active inturning towards a spiritual or fairyland-like nature. All the remaining three are indicative of a negative attitude to life (Scott 1970, pp26-29).

It seems like common sense that most people in a test like this select the brightest colours first and this is what has been found in surveys. According to Gimbel's survey, blue tends to be preferred to other colours in over a third of the population (Gimbel 1980, p156). This makes it about twice as popular, on this basis, as red is. Red is, however, more likely to be preferred by younger people. Research by Fantz and others has shown that the new-born, up until about 18 months, universally focus longer upon blue and red objects or lights compared to those of other colours, implying that these colours are preferred (Gregory 1990, pp200-202).

Of the other colours, around a sixth of the population tend to prefer green as a colour. Green may be less popular than red or blue generally because of its neutral and lifeless characteristics as described by the German phenomenalists, while it still has a relatively high popularity compared to less fundamental colours, reflecting its fulfilment of a basic need. The fourth of the basic colours, yellow is the favourite colour of slightly more than half of those choosing green. That it is the least popular of the basic colours is probably as a result of its low saturation and lack of 'substance' (both of these arising from its high luminosity). Although yellow is the colour of Steiner's 'snail creeping out of the shell', it is a colour of venturing out to no specified purpose and most people prefer red (by which they normally mean a warm 'fire engine' red) as it is thought to symbolise purposeful action.

Although the results of males and females combined show yellow to be the fourth most popular colour, placing all the four basic colours above any others, males seem here to show more contempt for yellow's lack of purpose than females do and as a group prefer orange over yellow. Non-basic colour choices, however, account for only about nine per cent of all colour choices and of these most are orange or purple/violet followed by any other saturated hues that the choosers may by offered (turquoise, lime, magenta etc.). Finally browns, greys, black and white are liked least of all (Gimbel 1980, p156). Although similar results have been found by other studies it has to be remembered that colours have semantic, affective and symbolic associations that vary between languages and cultures. It is nonetheless a general aim of German Romantic colour theory, from which colour research has predominantly stemmed, to try and identify psychological universals which predate cultural differences.

Assuming that the ancients had as much interest in colour as we do, it is likely that it was seen as important that we found words to describe colours. In fact it is quite amazing that some cultures have so few basic colour terms. Yet even these cultures extemporise with a wealth of more detailed and context dependent terms - as we do in more 'developed' cultures. Different individuals know and use different sets of auxiliary colour terms, and there are, of course, regional variations in their usage. The same colour will be called 'maroon' by one person, 'dark crimson' by another and by a third 'madder'. I would suggest that the improvisational nature of colour language is part of the joy of talking about colour. Referring again to Oliver Sacks' subject, Jonathan I, on losing his colour vision and colour memory, he lost a vast amount of non-verbal meaning from his life and it was, in part, this which resulted in loss of self identity. We have already recognised it as inescapable that the phenomenon that we call colour, which allows us to describe physical objects in terms of their being red, green, blue etc, should be regarded as a mental construct. This chapter has taken this a stage further by suggesting that colour's accessibility and stability have a strong dependence on language. With a different set of colour words, it is possible that the awareness of colour that surfaces in consciousness would be different; i.e. we would 'think colour aloud' differently. This point highlights the problem of synaesthesia insofar as the synaesthetic perception that surfaces to consciousness in synaesthetes is still limited by language. By the same token, language might be one of the factors which blocks synaesthetic experience in non-synaesthetes.

4. The General Use and Symbolism of Colour

Many nineteenth century Romantic cross modal connections, as well as much earlier ones, may have been derived from reports relating to synaesthesia. It seems likely that this perennial manifestation of cross modality is fossilised in Colour Symbolism throughout the ages. Ancient Greek philosophers, for example, were fascinated by the idea that knowledge of the workings of the universe could be obtained and enhanced by forming correlations between various classes of materials, attributes and properties of it (Gimbel 1980, pp28-47). They made correlations between the elements, the points of the compass, musical notes, planets and the seasons. The earliest written references to colour correlations were in relation to the planets in ancient Greece at about 400 BCE by Plato and Socrates but also reflected in and possibly invented by the Babylonians around the year 2300 BCE as reflected by the towers of Ur and Babel and the Birs Nimrow temple at Barsippa. The last of these was excavated towards the end of the Platonic revival (about 10 BCE) and still stands today. It is 272 square feet at the base and rises in seven tiers, each dedicated to one of the 'planets' and coloured accordingly. The three outer planets were undiscovered at that time, the earth was believed to be the centre of the universe, and the sun and moon were included thus making seven 'planets' or spheres in all. The colour associations were similar to those given them today in heraldry and astrology, some being based on their physical appearance (Mars red, the sun gold (yellow) and the moon silver (white)) and others being associated with the remaining colours and reflecting the personalities of the gods after which the planets were named: Venus the god of peace was green and the remaining three were black (Saturn) blue (Jupiter) and orange (Mercury). These colours became associated with metals, in alchemy which were in turn also associated with musical notes (Pederson 1993, p26). Mars, Venus, the Moon and the Sun are coloured consistently in related disciplines while the other three can vary.

While ideas concerning colour correlations with sounds, elements and planets were developed relatively late, later than those musical correlations which did not involve colour, the associations between personality and temperament and other attributes occurred as far back as historical references go. The notion of the universe, despite its apparent complexity, being composed solely of four elements goes back at least to Pythagorean times. These elements were central to Ancient Greek ideas about the universe and became linked to factors like personality through Pythagoras and later Hippocrates, the personalities being based on the properties of the four materials. Soon after the elements' discovery they were given colour values based on the sharpness of their edges with the sharper edges of the lesser faced figures being related to colours of greater stimulation. The elements were, in this way, related to the five regular solids (Birren 1963, p17). The notion of these structures was devised by Pythagoras who proved that these were the only solids that can have equal faces (These are sometimes called the Platonic solids even though Pythagoras discovered them). Fire was given the tetrahedron or pyramid (four faced solid), earth was given the hexahedron or cube (six faced solid), air was given the octahedron (eight faced solid), and water was given the icosahedron (20 faced solid). The fifth solid, the dodecahedron (twelve faced solid) was attributed to ether which was the name given to a spiritual matter of perfection, being a good balance of all four elements.

Returning to the elements but moving on in time, Isidore of Sevile (580 CE) attributed red to fire, blue to water, green to earth and white to air. In an unpublished survey of mine, I handed out sheets of paper with the names of the four elements to 150 people (all adults and approximately half male and half female, from Northampton and on an opportunity sampling basis) with instructions to allocate colours to each of them, at least two of which must be from the list red, yellow, white, green and blue. Red being allocated to fire showed the highest consensus (87.67%), followed by blue and water (81.33%). While many people agreed with green for earth (54.67%), they often completed the set of primary colours by suggesting that yellow is air (36.67%). As we have found in colour psychology, yellow is thought to be a colour without much substance, just as air has relatively little substance. Others selected green for air (30%), probably basing their choice on its calming neutrality they usually continued by giving earth soil-colour, regarding it as a dark yellow.

Proposals for connections between colours and the shapes can be traced logically from the Pythagorean era. Pythagoras placed great importance on the Platonic solids since, he believed, while any models made of them were likely to be imperfect, the theoretical geometry as calculated for the ideal form of any of them (e.g. Icosahedron 20 faces, 30 edges, twelve points and angles of 60 degrees) is of invaluable assistance for entering into the timeless purity of religion and metaphysics since each of them possesses a numerical value equivalent to the number of faces that it has got. Pythagoras and the later Greeks placed great value on number, claiming that each number had meanings which related to all things physical and non-physical, including personality: four stood for justice, for example, and twelve for metaphysical perfection (Gimbel 1908, pp 34-35).

The earliest references to colours and elements by the Ancient Greeks were rarely consistent and were probably used to help the reader picture the elements in order to appreciate their properties. Aristotle suggested that each element is a different colour depending on its stage of 'effect of object'. 'Stage of effect' is a mystical concept which flourished at the time illustrating the cyclical nature of all entities, the stage of destruction leading back into the stage of (re)birth. This is reflected in the notions of the Hindu Upanishads (about the fifth century BCE) who suggested that each element was alternately in a state of red (sun); white (moon) and black (earth) (note that their colour terms are restricted by Level II in Berlin & Kay's system) (Birren 1969, pp 27-30).

Chromotherapy (colour medicine) has its basis in the notion that different parts of the body, generally the ductless glands, sympathise with different vibrational frequencies which relate to those of light waves of various frequencies, highest for the glands at the top of the body and lowest at the sacral base. There are seven such glands corresponding to the colours of the rainbow. Turquoise is selected as the colour term rather than blue (for the thyroid gland) and blue is used as a colour term rather than indigo (for the pineal gland). The other colours and glands are violet, pineal gland, green, cardiac plexus, yellow, solar plexus or stomach, orange, adrenals and red, sacral base (Gimbel 1980, pp 58-64).

Chromotherapy is based on the idea that the appropriate colour corresponds and works on the relevant gland. It is also concerned with spiritual welfare, the idea here being that in each 'coloured' gland there are spiritual emissions of the person, these emissions being known collectively as the aura. Colour healers, like some other people, claim to be able to see someone's aura and it is by examining the balance of the seven different emissions that they are able to make a diagnosis and decide on a colour treatment for the person concerned (Gimbel 1980, p63).

The spectral colours have likewise been applied to the five Platonic solids in relation to how firmly grounded each of the forms is, so that the four faced pyramid is associated with the first spectral colour (red) and the twelve and 20 faced forms with blue and violet. These were also related to the four elements plus ether, making another five (Gimbel 1980, p34).

The idea of different shapes being suited to different colours was suggested in a different context by Kandinsky in 1914. As a painter he wished to unite colour and form and he suggested that the more acute, i.e. smaller in degrees, the angles are in a two dimensional shape, the more that its proper colour tends towards yellow and the more obtuse they are the more the proper colour tends towards blue. A circle is therefore properly blue and a triangle, yellow. The square is therefore red, halfway between blue and yellow (Kandinsky 1977, pp 29-30). Note that yellow, not red, are being treated as the warmest colour here.

Despite these theories, it is addressed below how in the world of practical artists, colour theory was reduced to having a very low importance due to the three most expensive pigments being required for only the most important subjects. They were used predominantly in Christian paintings and as a result Christ was usually painted in gold and the Virgin Mary was painted in Ultramarine blue. The duller earth colours were used to paint ordinary people. There thus evolved a symbolic hierarchy of colours which forced realism and any theoretical associations of the painter into a subordinate status. By contrast, modern painters can to a much larger extent select their colours in terms of the subjective aspects of the picture, the painter's feelings and beliefs on the subject matter, the painter's acceptance or otherwise of past theories of colour association, and to any other factor that they may wish to relate. In other words they can express themselves in colour in a way in which earlier painters could not.

That we think of Jesus' mother, Mary, as being robed in the colour blue is therefore probably a result of the aforementioned symbolism. The association is therefore mainly conditioning and generalises the ultramarine colour used in the works to any representation of purity. The Virgin Mary remained blue even when the colour could be obtained from less expensive sources since the art commissioners' expectations would have been carried down from previous generations. Despite this very practical explanation, Goethe and Kandinsky have offered explanations for the use of these colours in terms of their significance in colour psychology. Pure blue, as we have seen, has a retiring effect on the body and tends towards the otherworldly. The deepened form of this colour in ultramarine with its common tendency towards purple is, according to these theories, that of a very loyal non-human submission to a spiritual state. The colour is therefore very close to what the Virgin Mary in a painting is supposed to represent, the red tint bringing the inward motion into action and the dark element turning the blue further from humanity. The greater amount of red which occurs in Tyrean purple produces more mobility but in the otherworldly direction, which can be argued to reflect the monarch wearing it. Gold, the colour usually used to represent Jesus, is a shining, metallic yellow with a tint of orange. Yellow, you will recall, is retrospectively perceived by Kandinsky as the most earthly colour (Kandinsky 1977, p 38) and it is therefore fitting that the earthly component of the Christian Trinity is represented in such a colour removed from its most earthly form by the lustre of gold. The cheaper ochres, used for the ordinary characters, mainly contained a toned down element form of the earthly colour, yellow (although there were a few that were bluish). These dull 'ordinary' colours ranging in hue from green (immobility) to red (mobility) were used in a more representational way, being used as much as possible to imitate real colour.

Since these colourings were used in early art out of practical necessity, it is not surprising that the associations in Christian art and practice remained: the three expensive colours were preferred to represent the three components of the Trinity, God the Father taking on the most expensive and majestic blue, God the Son being yellow (gold again too expensive and specific for most churches), leaving the vermilion red to represent the Holy Spirit. More generally than that, the situation of early art meant that any saturated colour was associated with important people. As a result by the eighteenth century and following the fall of Puritanism, most churches (but not so much nonconformist chapels) had some representations, both two and three dimensional, of angels, archangels, Mary and/or other saints, painted in strong colours. Colour is therefore still as important in Christian churches today.

Christianity is not alone among religions with its high symbolic regard for colour. Colour is so important in our lives that it has always been bound to feature strongly in what many feel should be at the centre of their lives, namely religious worship. A particularly strong symbolic application of colour theory is found in the mystical Jewish Qabbalah is a tree arranged in three columns. The left one stands for strength, the middle for mildness and the right for wisdom and beauty. The branches form 22 connections which combined with ten 'globes' represent 32 nerve outlets which stem from the mind of the divine and its colours are as follows. The crown of the structure is white, from which stems black (the absorber of light) and grey, representing wisdom by encompassing both black and white. Proceeding from this triad is the triad of primary colours, blue for mercy, red for strength and yellow for beauty. These in turn combine to give orange (strength and beauty) for glory, green (beauty and mercy) for victory and purple (strength and mercy) for foundation. These colours are finally combined to give olive, citrine, russet and finally a mixture of all colours, standing as a representation of God's glory. The existence of a coloured structure which follows the rules of colour mixing reflects the interest and knowledge that sophisticated Jewish folk had in colour theory (Birren 1963, pp35-36).

Other religions where colour is particularly important include Hinduism (especially in Yoga practice), Confucianism, which has determined the conventional basic colours of Japan (red, yellow, purple, white and black) (Birren 1963, pp 23-24) and Islam.

Between the symbolism of different world religions can be seen both similarities and differences in their uses of colour. The similarities between different religions' usage may have stemmed both from the colours of nature, such as green representing earth and growth. This is inseparable from colour psychology, for example blue's representation of mercy, peace and holiness. The heavens are psychologically inward-looking in colour, especially at night, when the depth of the blue is accompanied by the presence of stars which provoked such an inward sense of wonder among the earliest observers - and still does today. On this relationship between colour and early humanity, in Chapter 2 of Ian Scott's translation of 'The Luscher Colour Test', entitled 'Colour Psychology', he states the following:

> In the beginning man's life was dictated by two factors beyond his control, day and night. Night brought about an environment where action had to cease. Day brought about an environment in which action was possible, so he set forth once more to replenish his store and forage or hunt for food. Night brought about passivity, quiescence and a general slowing down of metabolic and glandular activity; day brought with it a general increase in metabolic rate and greater glandular secretion, thus providing him with both energy and incentive. The colours associated with these two environments are the dark blue of the night sky and the bright yellow of daylight. Dark blue is therefore the colour of quiet and passivity, and bright yellow the colour of hope and activity.
>
> (Scott 1970, p9)

The passage continues by relating the psychological significance of red, green and yellow. Red is the colour of blood (as we have seen is significant in many religions), and therefore of activity, green is the colour of defence - as related to preserving oneself in tree foliage, and yellow stands for the possibility of activity. Colour in nature is therefore, according to the book, the very cause of our psychological reactions to colour and it follows that it must be so in a religious context as well.

An apparently unlikely area where colour symbolism occurred was French vowel Symbolism, a part of the so-called 'French Symbolist' movement which was started by Jean Moreas and other French writers around 1866, as a rejection of the German Romantic. While the majority of the symbolist works of used a large variety of symbols in a free, complex and aesthetic way, others were based on more consistent ciphers. Ghil (1862-1925), one of the lesser known symbolists even established a system, in 1887 which he called *Traite du verbe* which grouped various vowel endings to various emotions, to various meters and to various colours. His ideas were influenced by Rimbaud, his contemporary, Baudelaire, pre-symbolist writer, and (despite the general reaction against German Romanticism) Wagner. Rimbaud (1854-1891), is well known for his systematic use of vowels, delighting as much in the sounds (colours) themselves as the content. That, for Rimbaud, sounds related to colours is evidenced by an unusual sonnet *Voyelles* in which he writes of the five French vowels as being different colours. Apolinaire (1880-1918) in his efforts to convey colour intoned some poems in musical pitch classes. Associations between sound and colour in the 'Symbolist' movement are discussed in Chapter 9.

This chapter exemplifies the many attempts made by artists and theorists to put the ineffable values of colours into words and other symbols. While there are arguments to demonstrate that practical need shaped the psychological theory of colour, there are also arguments that the psychological effects of colour have shaped the way in which it is used. As Chapter 9 discusses, there are ways in which the qualities of different senses may be related: synaesthetes find connections between different senses to be real in a very vivid way.

5. Visual/Music Connections in Visual Art.

Prior to the turn of the 20th century, with the development of abstraction, the content of most visual art was predominantly in its subject matter: art, generally speaking featured objects and people relevant to the work's purpose. This subject matter was, on occasions, music. This is not surprising owing to the role that music played in cultures throughout the world. It many cases the artwork's music is not simply confined to the subject matter itself. Some musically connected artwork penetrates further into the structural, spatial and other elements of the work. In the same way as there are many parameters of music, in the auditory sense, there are many means by which 'visual music' can operate, besides those devised since the late nineteenth century.

The earliest available documented work which relates to music is an Egyptian painted relief featuring a blind harpist, dating from around 1300 BCE. The painting shows four musicians and a shaven priest, the latter of whom is conducting a religious ceremony, with sacrifices and incense. This, along with other representations of music in Ancient Egypt, provides clues for the music historian on the music of this culture. We know from the painting, for example, the importance of untuned percussion to accompany farming and other labour. Apart from this practical justification, it seems as if the music was, intended to be, in some way, 'heard' by its viewers since not only is the picture of the musicians animated, but the song that the musicians are supposed to be playing is given at the top of the work and would have been known to contemporaries. In this respect it is an early example of using visual stimulation to activate auditory imagination (Ucko 1964). This song is given in translation overleaf (It is at least 500 Years Older than the relief):-

And they that built their houses - their places are not.
See what has been made of them.
I have heard the words of It-em-hotep and Hor dedef.
With whose discourses men speak so much.
What are their places now?
Their walls are broken apart, and their places are not-
As though they had never been!
And there is noone who comes back from there
That he may tell his state
That he may tell his needs
That he may still our hearts.
Until we too may travel
To the place where they have gone.

REFRAIN

Make holiday, and weary not therein-
Behold, it is not given
To a man to take his property with him.
Behold, there is not one
Who departs and comes back again!

The 'music' seems to work in the following ways: The configuration of the musicians seems to be based on the simple harmonic proportions of the tetrad (i.e. frequency ratios up to 3/4 - the perfect fourth). The decision to use a harp, other than in order to depict a blind man - who was often expected to play that instrument in Ancient Egypt, could be to enable a sense of musical pitch to be subconsciously deduced by viewers by the length of the strings that the harpist is plucking. Other early examples of musicians appearing in ancient art include the painting of Dionysus by the painter of Burgos around 500 BCE which also has musical aspects about it, since a form of musical tablature is featured. Before about the sixth century BCE there is no evidence that music played a key role in Ancient Greece.

By the time of the Dionysus illustration music had gained a role in Greek education. The subject is itself musical since Dionysus was the God of music and merrymaking. He is supposedly one of the oldest of their gods and was used in story and illustration to condemn the immoral behaviour that was attributed to him. The music of the picture is combined with the animation of the appropriate dance, supposed to produce the appropriate state of ecstasy that the god is experiencing. The painting, therefore, intends to refer to a state of mind and spirit which arises from the unity of art forms, thereby making it a work that can be called cross modal insofar as it intends to produce a sense of music from visual stimulus. The state of ecstasy which forms the subject of the work also had corresponding modes which were discouraged by Socrates. In this work, the modes may have been heard in the imagination of the audience (Freund 1964).

One of the striking features of these early examples of music in art is the sense of harmony created by the grouping of people and instruments: many illustrations show very definite groups of people. In the first example given, the formality of the occasion is implied by the characters facing the same direction while the Dionysus illustration is less formal with the revellers being well distributed within a circular frame.

The first ten centuries CE provide further examples of musicians in animation whether in procession (as in a Mexican Temple Fresco of the eighth or ninth century) or with more intimately grouped people, as was common in south-east Asian examples. There are many reasons why configurations of people can be said to be musical. Music is liberally defined as 'sounds organised in time', making it quite possible in visual art for time to be replaced with space. Music is a real time art form, making time an essential and unavoidable parameter, space within the frame is generally thought to be the closest visual equivalent. A further possibility is to produce within the work proportional divisions which relate to the harmonic ratios of music. Musical intervals have been known to be expressible numerically since at least the time of Pythagoras and attempts have been made to correlate music with other entities ever since.

St Augustine in the twelfth century, along with his pupils, considered architecture to be the sister of music and tended to build on the basis of simple harmonic proportions. These were frequently applied in much church architecture, e.g. Lausanne Cathedral, Switzerland c.1220. A mathematical concept which is closely related to this is the Golden section, a ratio of about 100:162 that determines the most natural places for features to appear within a frame. The Golden Section relates to St Augustine's practices, regarding architecture as the sister of music since the, much used, ratio also facilitates simple proportions between lines, which were described as harmonious (Simpson 1964).

Developing alongside simple geometric proportions and their relationships to musical intervals were attempts to relate colours to harmony. The Ancient Greeks stated that all colours except black and white had their roots in these ratios. For Plato red and purple were the most attractive colours and he believed them to correspond to the perfect consonances of a fourth and a fifth respectively. The other used intervals were allocated orange, yellow, green and blue but their specific allocation is not known. Plato's colours, therefore, facilitated a further development of the Music of the Spheres notion (Gage 1993, p. 228).

Around the year 1075 Rudolph of St. Tront made use of the ancient ideas of colours and intervals and developed a coloured notation system for the modes using red for the Dorian, green for the Phrygian, yellow for the Lydian and purple for the Mixolydian. These colours were suggested for practical purposes rather than to suggest, for example, that the Phrygian mode *was* green; they were, however, influenced by prevailing theories concerning colours and harmonic ratios and the ideas paved the way for later theories concerning colour and music.

Gaffurious (1451-1527) added to the above scheme the notion of the four humours. Gaffurious was a leading musical influence in Milan who knew many painters, including Leonardo da Vinci, and was interested in colour theory. He opposed the Aristotelian notion that all colours were a mixture of black and white, holding correctly, as Newton was later to discover, that colours had qualitative differences which could not be accounted for by such a mixture. In the sixteenth century, Vincent of Beauvois argued that because only certain musical ratios were pleasing to the ear, only certain colours, seven in this case, were pleasing to the eye. He stated that pink and green matched the simple perfect consonances (i.e. the perfect fourth and perfect fifth) but left no details of the other five correlations (Gage 1993, p228).

From the ancients until Newton colour and music correlations lacked any real scientific basis and, of the two, music was much better understood than colour. The Ancient Greeks, for example, had in essence, reached the solutions regarding musical consonance and dissonance that are generally accepted today. By contrast, knowledge of the physical aspects of colour had to wait for the eighteenth century and Sir Isaac Newton's demonstration of a prism's potential to split white light into coloured components. This is not to say that there was no practical knowledge of colour before; Renaissance painters were able to mix suitable pigments as well as the modern artist, but regarding scientific knowledge, that of music was, by far, the more advanced.

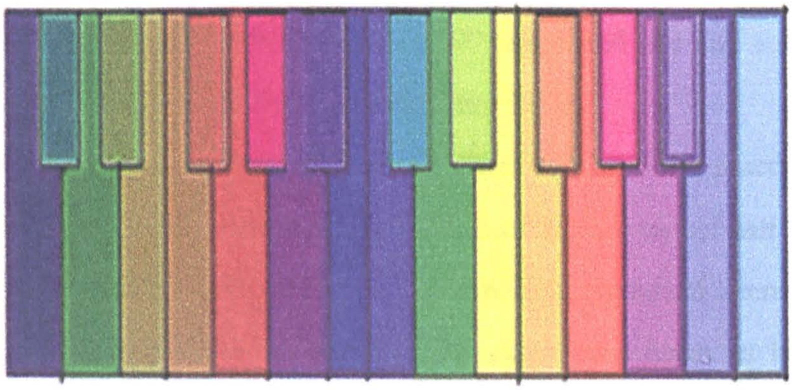
Giussippe Arcimboldo (1527-1593) envisaged a visual representation of a motet for five male voices where each voice was allocated a different colour; dark brown for alto, blue for first tenor, green for second tenor, yellow for first bass or baritone and white for low bass. It seems unusual that the darker colours were for the higher voices and the lighter colours for the lower voices since most people would associate dark with low and light with high as suggested in Chapter 7. Each voice's two octave range was represented by a darkening greyscale, according to pitch level within each of the five voices, so that, once again, higher pitches were represented by darkness. As Arcimboldo's scheme is based on Aristotle's ideas on colour, colour as a mixture of light and dark, it is surprising not to find red among the colours used since it was an important colour in Ancient Greece. At the same time as Arcimboldo was conceiving this motet Zarlino and Commananni were performing similar experiments and Marco Cremonse designed (but may not have made) a coloured cembalo. None of these people envisaged the future implications of their colour and musical pitch correlations (Gage 1993, pp 230-231).

Insightful though the works of Arcimboldo and his contemporaries were, lack of resources and technology clearly impeded their possible modes of delivery and precision. Regarding precision, Gage concludes that there was no accurate way by which to gauge colour in the sixteenth century and suggests that Aristotle's, now discredited, notion of all colours being a mixture of black and white influenced the colour-music connections made (Gage 1993, pp 229-231). The sixteenth century output, described above, should be thought of in its context; namely the Court of Rudolf II. The court was rich in intellectual activity of which Arcimboldo's contributions, involving bizarre correlations concerning shapes, human temperaments and other entities are typical. The nature of this activity is further supported by examination of the work of V A Scarmililious, in 1587. Scarmililious was a physician and, for medical purposes, made connections between simple consonances in music and basic colours.

Johannes Kepler (1571-1630) suggested that different colours have different angles of refraction which related to music. He produced a colour keyboard instrument which applied his theories in connection with the Aristotelian light and dark notion (Gage 1993, p 231). We do not have Kepler's correlations of pitch to colour, but we do have correlations from his contemporary, Cureau de la Chambre which, on account of time, place and influences, can be assumed to be similar. His correlations order coloured hues in terms of their basic lightness, allocating them numerical values. Purple was allocated eight, blue nine, green twelve, red 16 and yellow 18. These formed a basis of a theory of colour harmony, since by treating the colours as if they were auditory frequencies, according to their number, purple and green, being eight and twelve, form a perfect fifth, and were classed as harmonious. Red and yellow (16 and 18), by contrast, form a major second and were classed as dissonant (ibid, pp 232-233).

Colours, as I have implied, were first related to musical pitch in terms of their order in the visual spectrum following the splitting of light into its frequency components by Newton, who explicitly stated that any colour could be represented in a colour circle according to its spectral position. He related this to a musical scale, each of his seven colours relating to one degree of the scale. While Newton gave at least three different versions of the analogy, in 'Optiks' he gave D as red, E as orange, F as yellow, G as green, A as blue (according. modern terminology 'turquoise'), B as indigo ('blue') and C as violet (Newton 1952). The applications of Newton's physical findings of colour to music were the main influence of Louise Bertrand Castel's (1688-1757) development of the ocular harpsichord in the 1720s. This instrument, which later materialised in physical form (see page 52), used twelve discrete hues from Newton's colour circle and connected each one to each of the twelve pitch classes. This instrument is shown overleaf:-

CASTEL'S COLOUR ORGAN (1742)



It represented each hue at a higher value (brightness) with ascending octaves and in working form used filters to achieve the colours. Representation of hue at higher values for higher pitches, the more usual scheme for the relating of colour to music, has the physiological basis described later in this thesis, as stated above, is in contradiction to the scheme that Arcimboldo's motet used.

These experiments in colour music had the main appeal of visual effect, fixed correlational schemes used between colour and music being secondary. Castel's harpsichord, for example, had the, then usual, five octave F-F range 'speaking', but the keyboard, itself and the visual range continued beyond this to twelve octaves (five more than the modern pianoforte, which approximates the range of perceivable pitch), suggesting that the visual display was sometimes intended to operate alone. Castel was especially interested in colour contrasts especially those of vermilion and blue found so commonly in the work of Titian, and others, in the sixteenth century (e.g. Diana and Acteon (by Titian) 1556-9).

Quite when the above organ took a practical shape and form is not clearly established. Telemann (1681-1767) in 1739 wrote only vaguely about the instrument, indicating that nothing had yet been performed on it. A 1754 construction of the organ using candles remained, according to reports, impractical. In 1757, after Castel's death a construction was made with as many as 600 lamps and two and a half inch filters, this seems to have worked slightly better (Scholes 1983).

The technical failures when these ideas were put into practice, and which were exemplified by Castel's ocular harpsichord, resulted in a virtual halt to these activities in the second half of the 18th century. One example of continued interest was a painting by the English painter Giles Hussey in 1773 which used notes as letter symbols. Such experiments were revived in the nineteenth century, firstly as a result of improvements in technology, but also because of the insights of the physiologist, J A F Plateu. He was interested in the physical effect of colour organs, which he regarded as positive, and requested a Castelian keyboard purely for its (visual) therapeutic use.

In 1820, George Field (1777-1824), a chemist and colour pigmentologist produced a theory of the three components of the C major triad each possessing a primary colour (E red, C yellow and G blue). He added that the colours and the pitches should not be static but that there should be movement between them. The notion of colours as moving, as the eye sees them, alongside the choice of primary colours, with yellow and blue at each end and red in the middle, shows similarities with Goethe's colour theory. It seems likely, therefore, that his theory had a strong influence on him (Gage 1993, p. 218).

Colour and music was a predominant theme by the middle of the nineteenth century. Fredric Chopin (1810-1849) was probably among the first to describe compositional technique as musical reflection - a visual analogy (Gage 1993, p 236). Franz Liszt (1811-1886), in praise of the pianoforte, said that it was able to produce exactly the shade (i.e. value) required even if not always the colour (e.g. hue). The prevalence of correlation between the senses, meant that some people regarded it as an 'age of synaesthesia', an 'age', which was at its most mature at the turn into the twentieth century.

The associated aesthetic attitude was a progressive phenomenon which spread into all art disciplines. The fact that this did not occur previously is partially explained by the changing purpose of art itself, and partly by the improvements in technology referred to above. As we have seen, eighteenth century correlations between colour and music were severely hindered by technological problems, whereas more recently electricity has facilitated such enterprises as Alexander Skryabin's (1872-1915) 'Prometheus' - a work that will be addressed later in this chapter. In painting, the 'technological' advancements took the form of the increased availability of pigments. Since the middle of the nineteenth century, we have had unlimited capacity to make synthetic paints, processing the colour by 'colour deepening' (a form of frequency modulation) and azo linkage (compounding), so as to produce any colour accurately. This has enabled representation of sound in colour in accordance with to any given correlational formula, or none, allowing Wassily Kandinsky (1866-1944) to conclude -

> Colour is the keyboard, the eyes are the harmonies, the soul is the piano with many strings, the artist is the hand that plays, touching one key or another to cause vibrations in the soul.
>
> Kandinsky (1977, p 25).

Regarding this whole era ranging from the Medieval to Classical periods, colour experimentation tended to be the exception rather than the rule. As was pointed out in the previous chapter, for most court painters up until the end of the eighteenth century it was their duty to colour subjects according to their importance. Gold, Ultramarine and Vermilion being the most expensive paint materials with the finest grades of the first and second being used only for Christ and the Virgin, respectively. These were not, except for the odd bit of shading needed for perspective, mixed with other colours. The less important subjects were painted in mixed ochres (earth colours which can produce almost any hue but not to a very high level of saturation) and certain other inexpensive pigments.

Nineteenth century colour availability and the demise of the patronage system meant an increase of choice for the individual, cumulating in the notion of 'Art for art's sake'. The scope for correspondences between the senses also grew, as shown in Chapter 9. Especially relevant to this chapter is the growing interest in *audition coloure* (which is essentially visual-auditory synaesthesia), which became incorporated in certain Symbolist poetry and which suggested connections between colour and sound. As words 'frame' meanings, late nineteenth century developments that allocate certain colours to certain sounds are better documented in writing than in painting and are addressed in Chapters 10-12. Nevertheless Eugene Delacroix (1798-1863) and Vincent Van Gogh (1853-1890) both played parts in incorporating colour and music correlations into Symbolism. The Symbolist movement started in the 1880s and was characterised by the preference of imaginative suggestion over faithful representation of the world. In the above year Van Gogh took piano lessons, and his teacher reportedly dismissed his constant correlations of piano notes and painter's pigments as 'to do with a madman'. In 1888, he wrote about his wishes for painting to be witnessed like a musical concert and, when in the asylum, re-coloured works from monochromatic representations and wrote that the re-colouring was to be understood as improvisation (Gage 1993, p 236).

Symbolism, an early example of 'Art for art's sake', was a major influence on Kandinsky and the *Blaue Reiter* movement, the only other comparable single influence being James McNeil Whistler's (1834-1903) use of musical titles such as Variations and Nocturnes. For Whistler and his contemporaries musical titles were used to imply music whereas the artists of *Die Blaue Reiter* movement (mainly 1910-1915) were more direct about it. Freed from the formal constraints of many of those before them, they were able, if they wished to concentrate on representing music in their painting. There were also musicians in the movement, such as Arnold Schoenberg (1874-1951), whose activities during the first fifth of the twentieth century included representing painting in music. Kandinsky offers a correspondence between the sounds of instruments and colours which is shown in Table 1, below (Kandinsky 1977, pp 40-41). He is explicit in stating that colour, the spiritual key parameter in visual art, is analogous to music.

TABLE 1

COLOUR	SOUND	COLOUR	SOUND
Light Blue	Flute	Brown	Great Trumpet or Drum
Medium Blue	'Cello	Madder (Crimson)	Middle notes of Violin
Dark Blue	Double Bass	Pale Madder	Singing notes of Violin
Darkest Blue	Organ	Orange	Old Violin
Green	Middle Violin notes	Violet	Bassoon
Yellow	Very shrill	Orange-Red	Trumpet

These qualities are also expressed in his collection of 'Improvisations' (1911-4) where the colours stand for the expressive qualities of the instruments. Kandinsky's additional activities at the time included intermodal plays, with music, such as 'The Violet Sound' and 'The Yellow Tone'. These, like the 'Improvisations', are predominantly abstract and concerned with the relationships between sound and colour. The trans-modal approach to abstract expressionism is also manifest in Schoenberg's opera-drama *Die Gluckliche Hand*, which was first performed in 1915.

Skryabin's tone poem 'Prometheus', also first performed in 1915 (but composed in 1911), is another manifestation of early twentieth century abstraction. It has a colour organ part which follows the harmonies and tonalities of the piece, but the organ is itself silent and projects lights onto a screen which are different colours for different notes, C is Red, D is Yellow and A is Green for example, thereby depicting colour as changing over time. In this work's production the colour changed so much that the performance was found to be dazzling despite the part's only following, what is generally regarded as the, acceptable pace of harmonic progression. That coloured progressions require a slower pace than harmonic ones (for non-synaesthetes anyway) indicates that one-to-one tone to colour analogy may not have a valid basis after all. Unlike earlier productions, works such as these were able to take advantage of the latest developments in stage lighting, as much of the colour is directed to come from the filtered light, which bathes the stage.

In the 1920s, the Bauhaus, where Kandinsky and Paul Klee (1879-1940) then taught, was at the centre of colour music experiments. Klee, a violinist of a high standard, produced a painting, 'Junger Wald' (1925) with bar lines for tree trunks and patches of different colours between them to suggest different musical instruments. Kandinsky's work was also influenced by this style. Among his many works at that time were abstract compositions for the stage, which allowed him to incorporate dance into his unification of the arts. These stage compositions were generally more successful than those of a decade before, mainly due to further improvements in technology.

Around that time Piet Mondrian (1872-1944) was transcribing jazz forms into colour, making such paintings as 'Ragtime', 'Fox Trot' and, much later, the, more famous, 'Boogie Woogie' (1942/3). In the last of these the artist uses small rectangles of red, yellow and blue to express a joyful pizzicato (Gage 1993, p 243). Unlike the works of Kandinsky and Klee, which employed some rational in correlating music and colour, Mondrian's approach was a purely instinctual response to auditory experience. It was totally uninfluenced by notions of colour and music as correlated scales which fascinated, but did not always monopolise, the output of the former artists.

It can be said that in the 1930s and 1940s direct correlation between music and colour generally became less of a fascination, a change that was prompted in part by the 'failure' of 'Prometheus' in 1915, raising questions about the likelihood of any real unity of visual and auditory sensations. As the interest in colour music reduced, so the technology which facilitated it expanded. Colour film developed and improved so that animations, eventually with fixed audio tracks, could be recorded. People famous for early colour music on film include Bruno Corra, Annaldo Ginna, whose works include an early abstract film accompanying Mendelssohn's Spring Song, Alexander Laszlo and Oskar Fischinger.

Laszlo was especially influenced by Wilhelm Ostwald's (1853-1932) colour theory, a theory that focuses on the portions of equality of opposing colours and their neutralising effects and one which is very much in tune with the effects aimed at in the stage compositions of the 1910s where intensity and dynamics of colour were the focus. Generally speaking, however, those working with film, especially after 1940 gave little importance to mathematical approaches to colour and music.

Technology now meant that audio-visual facilities were abundant but in practice the audio and visual components accompanied each other, rather than formed any correlation. Such art often incorporated moving machinery, such as electric motors and moving lasers. Although the old notion of coloured music was generally considered as too dated for use, exceptions did exist. In Nicholas de Stael's (1952) painting 'The Musicians' bright, basic colours are used, to represent timbres, in much the same way as they were by Kandinsky. Joan Miro (1893-1983) named a work after Rimbaud's poem 'Voyells' but here the contrast of lines of various sharpnesses which related to vowel shapes were the main focus.

Relating various notions (colours, pitch classes, the seasons, the Ancient elements, planets, metals etc.) was once considered of primary importance to an understanding of the world around us. Alchemy involved such correlations and was based on the notion that the finest of metals could be made from inexpensive materials if we could only understand them in their elementary context. Since the Renaissance, colour-music developments have been accompanied by more scientific developments regarding colour (the science of music already being reasonably well understood as far back as the sixth century BCE). Since about 1850 the chapter has shown correlations between colour and music became more widespread. This was assisted by more able and versatile equipment, development of pigments being the main issue for painters. Further developments of technology meant that by 1940, when colour music experiments were generally discontinued, most of the experiments that could be conceived of at the time had taken place. Audio-visual technology has consequently been utilised in other ways. While the 'age of synaesthesia' seems to be, all but, temporally exhausted, our growing understanding and interest in the mind and the way it works, of true synaesthesia (a condition where a person is aware of primitive brain activity), and the minds of past artists, means that we are likely to gain insights in the future by further exploring correspondences between colour and music.

6. A Survey Of Key Usage

In the introduction it was stated that audiovisual synaesthesia is the most common form, pitch regularly playing a key role. In the case of some chromaesthetes, their colours are determined by tonality or key centre. This is also the case with the imagined colours of many non-synaesthetes, especially those with Absolute Pitch. The centrality of tonality to synaesthetic colours exists in many people despite tonality being a relatively recent development. For this reason it is worth investigating how the concept of tonality developed from the relatively simple use of keys in the seventeenth century to a symbolic and abstract use of all keys in the music of Wagner and Skryabin.

USE OF KEYS DURING THE BAROQUE AND CLASSICAL PERIODS

It is only for the last 320 years or so that it has been possible to modulate between all of the keys as a result of the adoption of systems of tuning which make pitch relationships and consonant combination of pitch classes acceptable (Lloyd & Boyle 1978). In short, with unequal temperament Eb and Ab (where the key is designated G#) not only fail to produce a clean perfect fourth ratio (3:4) but they produce a harmony far 'rougher' than the 'impure' fourth of equal temperament. Different transpositions of the same intervals therefore sounded different and it is my suggestion that these differences in roughness were not only accepted but actually positively enjoyed: One theory of the development of different keys being endowed with different properties, sometimes including colours, is that a usage of diverse keys for specific contexts was acquired during this transitional period when all keys could be quite freely used but each had distinct tuning characteristics. Corresponding conventions have, to an extent, continued until the present day.

Mark Lindley provides an account of the evolution from modality to tonality and how sixteenth and seventeenth century tuning systems resulted in each key possessing its own peculiar characteristics with C major being, on the whole the purest, and F# major the least pure (Lindley 2001). By Bach's time, the extreme keys were cleaner under the prevailing tuning system than in mean tone, while each key still preserved its own identity. It was with this in mind rather than Equal Temperament that Bach's 48 Preludes & Fugues and Scarlatti's sonatas in all keys were probably written.

The majority of pieces in C major and D major written at this time tend to suggest joy, while C minor was often used for ceremony, F major for pastoral scenes, while F# minor and G minor were, between about 1745 and 1775 used for the 'stormiest' instances of *Sturm und Drang* compositions. At about the time of *Sturm und Drang* music theory was dominated by philosophical arguments as to the relationships between keys and moods and other attributes. One debate concerning key and emotion was how the two related to each other. Philosophers were interested in whether D major possesses joy, joy possessed D major, or whether the two were in some non-physical sense equivalent (Lindley 2001). Here it is appropriate to look at how certain keys were reserved for particular moods and styles. Such key allocation is probably most apparent in that music of the Baroque period that is high in extramusical content, such as sacred music, opera or descriptive works. While later music will be addressed regarding its key and mood attachments, those of the Baroque occur with high regularity.

The regularity of key use in the baroque can be explained in two principal ways; in terms of certain keys being expected for certain types of musical expression, implying that the listeners might have had some kind of absolute pitch sense, or else in terms of practicalities regarding certain instruments being in specific keys, with better access to some notes than to others.

The latter explanation best accounts for fanfare passages, such as some of the 'Musiks' used to open or function as interludes for Purcell's semi operas being almost invariably in C major or D major. The argument runs that these were the keys in which trumpets played. However, this does not explain the use of that key in fanfare passages where no brass is required. Also, trumpets existed in other keys (notably Eb and F) but these were not used for such fanfare passages, which irrespective of instrumentation continued to be thought to require C or D. Bach's first Brandenburg Concerto uses two horns in F and the second concerto a piccolo trumpet in F. In each case the instrument's part is notably lacking in the type of writing associated with C and D trumpets, featuring instead high register melody (with closer intervals) with the low partial notes, when used, taking on a style more akin to a hunting call, involving repeated notes.

The first concerto originated as a Hunting Cantata and therefore has country-like characteristics. Because of these characteristics F major was a preferred key to C or D major, keys that were regarded as more suitable for music of a festive or pompous nature. In this way there was a key lexicon based on the pitches of the available instruments but which evolved into a complex set of conventions, although this is not to deny that there were other reasons for choice of keys including the possibility of composers being influenced by supposedly inherent properties of keys.

In a sense, the difference between D major and C major, which can be given the parallel between red and yellow, is reflected by the affective differences between the music in these two keys; D being used for joyful music (e.g. Purcell's 'Come Ye Sons of Art' and the end of Handel's 'Messiah'). C had more military associations, as is evidenced by the key's use in 'Dido and Aeneas', where Aeneas was called to battle against his desires. Pastoral pieces are often in the keys of F and G (e.g. Bach's Christmas Oratorio, Part II,).

There were few keys in regular use at the time; furthermore, both pitch and tonality were very loose and flexible at the start of the seventeenth century. Music was performed at whatever pitch suited the voices or instruments. It is for these reasons that most examples given here are confined to the middle and late Baroque, i.e. after about 1650. Corelli's Op. 6 No 8 ('Christmas Concerto') is traditionally regarded as descriptive of the Nativity pastoral scene and is in G major. Here the 'Pastoral' itself is in G minor, retaining the same key note rather than moving to the relative minor of E.

Between 1650 and 1750, the most commonly used minor keys were C, D, E, G and A. B minor was used for occasional large works such as J S Bach's B Minor Mass. The work is typical of these few instances insofar as the music has a solid feeling about it, a grandeur which is found in other works of the time in that key, even the light and flexible 'Affetuoso' movement of Bach's fifth Brandenburg Concerto (Geiringer & Geiringer 1967, p 209). The key a tone down, A minor, tends to be used for the earthly and for earth (e.g. 'Winter' in the second masque of Purcell's 'Fairy Queen'). The distinction between A minor and B minor can be said to be analogous to that between C major and D major, in the above example between the common person's lot on earth and the glories of the afterworld.

The keys of C, E and G minor are prominent in Purcell's 'Dido and Aeneas', each of which has a particular mood which is supported by the use of the keys in other Baroque works. In most works of the Baroque G minor corresponds to death, C minor, sadness and E minor, fate. While these aspects are considered to be interrelated, they are distinct themes in Baroque works. The opening of the Messiah depicts the prophecy of the coming of the Messiah, likewise the granting of the power of love by the Chinese God of Marriage towards the end of Purcell's 'Fairy Queen', is an example of the fate concept in E minor.

C minor's sadness, which characterises the opening of the tragic opera 'Dido and Aeneas' is used in similar contexts in other works. Examples of this include the Frost Scene in Purcell's 'King Arthur' and the chorus *Ruht Wohl* towards the end of Bach's St John's Passion. The use of G minor to symbolise death, as found in Dido's Lament, is probably the most widespread of these key and mood associations. Purcell made some use of this in all of the semi staged operas, even in the comical 'Fairy Queen' where the key is used for the dream music during Titania's deep sleep or faked death. Handel also uses the key whenever death is the main theme in the operas. C minor, therefore, acts as a symbol of sadness in baroque opera while G minor is thereby used to symbolise death. It is likely that audiences would have been aware of this use of keys, which does not rule out the possibility that there is a relationship that is slightly more than mere symbolism.

'Dido and Aeneas' makes use of one further minor key, which was not very commonly used at the time it was written: F minor. This key appears in the opening overture to Act II and then in a recitative passage by the Sorceress. The use of, what was a, rarely used minor key, seems to accommodate the sense of darkness, mystery and evil that is occurring in the plot at the time. This extra darkness can be thought to be partly due to the use of the key, which is an extension on the flatward side of the more usual keys. The powerful use of a key that was not used frequently enough to constitute a convention is evidence in favour of the possibility that there may be more behind key and colour connections than just convention.

The examples given here are just a few of the almost endless possible ones of key, mood and possible colour association during the Baroque. In the years following the deaths of Bach, Handel and Scarlatti, Baroque music was, with a few exceptions confined to partial obscurity (Buelow 2001). The result of this that concerns this thesis is that the line of 'convention' in this respect was modified, and therefore the symbolic significance may have changed. However, the use of different keys for different moods may amount to more than that.

Although there is much Baroque convention at work here, it does not automatically exclude the keys *possessing* quasi-synaesthetic properties, and what is more than this by assessing the extent to which the different key and mood schemes persisted at later times.

Apart from the change in convention, other factors have played a part in key and mood associations. Since music moved away from the courts, composers became freer to develop characteristic key associations of their own, along with other aspects of style. To Mozart D minor seems to have been a much heavier key than it had been regarded as previously. This is exemplified by its use in the Requiem (K 626) and the D minor Piano Concerto No. 20 (K466).

KEY USAGE IN THE NINETEENTH CENTURY AND LATER

A change concerning key choice in later periods was the increase in the use of more remote keys. I conducted a survey 800 plus pieces of orchestral and pianoforte art music written between 1830 and 1900. This was an opportunity sample based on randomly selected sheet music that was in print in 1994. It showed that the use of all keys became fairly well distributed, as opposed to the majority of pieces being in simpler keys, as was the case before. The keys which were not frequently used in 1750 but were used as frequently as any other keys by 1830 were - the majors Eb, Ab, Db, F#/Gb and B and the minors Bb, Eb/D#, G#, C#, F#. The last of these was the first to be widely used by C P E Bach and by Haydn in some of his earliest symphonies. With use of each of these ten keys (twelve or more if enharmonics are counted), they, like the other keys seemed to develop their own symbolic aspects. Their usage for certain moods ranged from conventional to the composer specific. Eb major, since Beethoven's third symphony (and possibly even since Mozart's 39th symphony) has had frequent connotations of the heroic. This is exemplified by Strauss' *Ein Heldenleben* and the key is also used as such by Wagner in *Tannhauser* (The Pilgrim's Chorus and the music approaching it).

During the nineteenth century the equal temperament tuning system predominated. There is, for example, evidence that Chopin asked for his piano to be tuned to equal temperament and he recommended that the Broadwood firm used equal temperament to tune their pianos. Equal temperament, which predated many of the previously favoured tunings in theory but was not generally applied, ensured that all keys were identical in terms of the harmonic ratios present. With tunings other than equal temperament different keys had different relationships between pitches, giving them different qualities. Equal temperament on woodwinds was standardised and furnished by Theobald Boehm who conducted experiments on musical harmony and intervals which led to the design of woodwind instruments with revised fingerings (Benade 1992, p216). These fingerings assisted in the fluent execution of in new music in addition to introducing the pitch standardisations of equal temperament. At a similar time valves were also being added to some brass instruments, which also gave an equal value to the semitone regardless of its positioning in the chromatic scale (valveless instruments remained popular throughout the nineteenth century but many late Romantic scores require notes that cannot be played effectively on them).

Schumann (not, according to Sabeenev a composer associated with colour by listeners), as a rule (Sabeenev 1929) used keys in a somewhat different way. B minor was used for intense music, some vigorous (e.g. some of the *Davidsbundler Tanze*) and some with pending mystery (e.g. *Kuriose Geschite* from *Kinderszenen*). F major, with its key note as far away from B as possible, took on a subdued quiet tone for Schumann, which is illustrated in the seventh and eighth pieces in *Kinderszenen*. His use of this key contrasts with the rustic, and sometimes humorous, characteristics of most music written in that key between 1650 and 1750, indicative of the more personal use of different keys in the nineteenth century. Schumann did, however, tend to preserve the Baroque mood of G major: most music that he wrote in that key is fast, light, and simple.

As a final example of the key use of an individual composer, we refer to the music of Skryabin. From about 1905 his music became increasingly centred on the 'mystic chord', a six note chord of altered fourths containing the pitch classes of a whole tone scale with the exception of one note being a semitone away. Examples of his latest works include 'Prometheus', 'The Poem of Ecstasy' and the late Piano Preludes. In each of these cases, the chord is arranged with A as the lowest and therefore prominent note, with the other notes being C, D, E, F# and G#. Skryabin, as we have seen from earlier chapters, clearly believed in the significance of this chord and its necessity to be in this 'key', based on the note A. As addressed previously, each key had, for Skryabin, a specific colour and for an 'A' centred set, this was green.

Db major was used during the nineteenth century for music (especially piano music) of a soft and sentimental nature. F# major was used for certain types of music by Skryabin, while music in its enharmonic equivalent, Gb, despite having its keynote, and therefore its entire pitch class set, at exactly the same pitch (in equal temperament), seems to have had its nineteenth century use in music more akin to that of Db. While this is paradoxical in many ways, it supports the notion that sharp keys have greater brightness than flat keys, which sound mellower and grander (Gamound 1968, p 132). It is probably the implications of exactly the same sets of pitches, such as [F#,G#A#,B,C#,D#,E#] and [Gb,Ab,Bb,Cb,Db,Eb,F], being of different moods, more than anything else, that throws doubt on the notion that different keys have different absolute characteristics.

We can regard the above developments as evidence that by the 1840s equal temperament was accepted by at least some musical circles. Between 1840 and 1900 different keys were used even more widely than they were during the 'unequal, circular' period and modulation between keys tended to be more rapid and to involve more diverse keys.

To a certain extent this expansion was facilitated by the growing popularity of equal temperament and the designing of musical instruments suited to such tuning, but the reverse can also be argued, that equal temperament was finally adopted reluctantly to make the new music of the day playable. Despite the freedom of modulation afforded by the new system, the 'inherited musical ear' still required a home key to a piece of music: usually, in the case of a longer work, this meant a key to be started in, ended in, and periodically revisited throughout. The choice of home key by this time varied much, partly depending on the mood of a piece. As in any period of tonal music in any style (with the sole exception of the *Sturm und Drang* compositions), major keys were used more often than were minor ones. According to the aforementioned survey, Eb major was the most common home key, used, being found as such in the case of 8% of a large assortment of music composed within the above years. Other common keys were D, C and Ab (7%) and E, Bb and G (6%): the most common minor keys are A and C (both 5%). While all of the aforementioned keys were used some were favoured more than others. This seems to support the notion of key characteristics, which are explored below.

THE KEY AND COLOUR NOTION

We have looked at the restricted use of keys in the baroque and classical periods with the more comprehensive use of keys by about 1830. These were related to the adoption of equal temperament. It has been suggested that the equal temperament system should mean that for the average listener, that is the listener without Absolute Pitch (AP), all twelve major keys (and all twelve minor keys) should sound alike, which questions notions, such as Skryabin's, that different keys possess different colours. However the counter-notion of key uniformity does not seem to apply in practice either. Were it not for qualitative key differences it would be difficult to explain why so much music is written in remote keys rather than simpler keys, for example those a semitone away.

It is true that pianists, especially, have grown to like some of the more remote keys and have developed fingering strategies that have made these keys, if anything, easier than the home keys, but the operative word here is 'grown' and keyboard players must first have been presented with music in such keys. It seems to me, at least, that compositions in the nineteenth century were written in different keys in order to produce different aesthetic effects: for example Db was used for soft atmospheric music (Bendall's *Julias Arbors a Clarens*, Chopin's 'Raindrop' Prelude) and A major was used to imply brightness (e.g. Mendelssohn's 'Spring Song', First and last movements of Beethoven's Seventh Symphony). These varying effects could, to a limited extent, - as suggested above - be rooted in the conventions of key use when tuning was unequal, but this does not explain the different qualities of remote keys which were not then used nor of the symbolism of the home keys used in Baroque opera, for example, much of which did not transfer to nineteenth century choice of keys. This observation suggests that convention is not bound by a fixed key and colour formula.

Even if such key associations are not shaped by convention, their formation can still be the part of the mental processes of abstraction. Imagined or actually perceived, colours that are determined by tonality seem, except in synaesthesia, to be shaped by experience. 'Coloured pitches' in non-synaesthetes were probably not that well developed until late in the nineteenth century when extensive coloured hearing research (e.g. Bleuler & Lehmann 1881, Galton 1883) stimulated their imagination. This implies that coloured hearing in non-synaesthetes was principally induced by environmental factors - in this case the musical environment. This is not the case for those individuals who have synaesthesia in the clinical sense of the word. Coloured hearing, in the conscious imagination sense of the word, is very common. Sabeenev compiled his table of coloured hearing (Sabeenev 1929, see Chapter 7) from a pool of Russian musicians none of whom, with the possible exception of Skryabin, had synaesthesia. Without the presence of such elaboration these results could not have occurred.

Westrup expresses puzzlement over the reality of these associations for many composers, and examines the possibility of sympathetic reverberations (of the notes C, G, D, A and E) in an orchestra by the open strings of the string section (Westrup 1955, p 253-256). This could have the effect of making keys sound different from one another, but only in performances involving strings. In a brass band performance the most reverberant notes can be assumed to be the open notes, Eb (pedal and second partial of Eb instruments), Bb (the pedal and second partial of Bb instruments and third partial of Eb instruments), and F (the third partial of Bb instruments). A slight peak may also exist from the small proportion of bass trombones which would be G and (probably negligibly), D.

That different keys have been felt best for certain purposes on the piano is probably best explained by Baggelly's imperfectly tuned piano hypothesis, which argues that different pitch classes sound different because of a difference in relative tuning. A piano tuner, the argument runs, starts by tuning the As and works upwards and downwards in fifths using third harmonic reverberations to guide the tuning, listening to the rate of the beats, to make an equal tempered fifth each time. These fifths are bound to have a slight, usually insignificant error and errors will accumulate as the process continues. This means that A octaves are going to be 'cleanest' while the Eb/D# octaves are likely to have a higher degree of roughness than octaves of any other pitch class set, although still only enough to register subliminally on the part of the listener (Baggelly 1972).

An objection with this hypothesis is that keyboards were not always tuned in this way and some still are not. C can be, and often was, used as the starting point, especially on the harpsichord (Lindley 2001). In mean tone, alternative major and minor thirds (the two steps totalling a fifth) were used as standards.

The most usual tuning procedure would start on E and then extend to C and G, so that C major is the best tuned triad. A (a minor third down from C) and B (a major third up from G) would follow, and then F and D. F sharp would be tuned next as this is a major third up from D, but the D a third down from F would be left as it had already been tuned from B and the Bb tuned from that D. The A would also be left and the C sharp tuned from it. The tuning system therefore has obvious breaks which characterises keys. Use of mean tone therefore resulted in a different hierarchy from the one proposed by Baggelly for modern piano tuning.

It may be suggested that this is not a problem since we *do* have different expectations of seventeenth and eighteenth century harpsichord music, in this respect, than we do of Romantic piano music. If the conventions of key usage became different, then it would be acknowledged, by this objection, that the keys have indeed changed their roles. Continuing that argument, however, by classing all AP key characteristics as the result of tuning, those people who have key associations will have different ones depending on whether the music is made by a string quartet, a solo flute, a full symphony orchestra, a conventionally tuned piano, and so on. This is expected to be the case, according to the theory, because each will have different resonances and will be tuned in a different way giving some notes a better tuning accuracy than others.

The above is not the general experience of key characteristics for me, nor is it for most other people who talk of such absolute key distinctions. Insofar as the tonal system is used in modern music, D major is regarded as just as joyful as it was in the time of Purcell. F major survived its old pastoral connections for Beethoven to use that key for his Pastoral Symphony. The key's use persisted to Schumann and even to Britten (e.g. 'Vigil' from 'Tit For Tat'). While there has been much change and more diversity in, what has been called, 'key symbolism' there is still too much unity between key characteristics between different composers and different instruments to discount absolute key characteristics totally.

This is evidenced by the observation that orchestrations and piano reductions do not generally get transposed to suit the new conditions. Also, keys still seem to retain their significance in early (e.g. Baroque) works in modern circumstances: a Baroque trumpet work in D major retains D major characteristics when played in that key, for example, on a Bb trumpet, at a high register for the modern instrument and without the appropriate acoustically favoured resonances that it would have in a key nearer to its home key. Did this not work so well, it would not be so frequently carried out both by professionals and amateurs. Technical explanations of key and mood correspondences, which are in this thesis extrapolated to imply key and colour correspondences, are interesting and of some potential use, but because they cannot easily be generalised to include all musical instruments nor explain how the associations for all instruments can become an inward reality: they fail to throw adequate light on the problem of colour music by themselves. The consistency of key usage, despite the differences, over time is, therefore, still wanting of some explanation.

EXPLORATION OF KEY AND COLOUR PROPERTIES

The widespread use of all keys seems to be good evidence that different keys have different moods or colours, but there is evidence from early work on AP (e.g. Bachem 1953) that most people have fixed pitch perception for larger pitch differences, even though for small intervals their pitch perception gets reset between listenings. To explain how this is so, it is necessary to examine the two different ways in which the ear analyses frequency - the chief determinant of pitch. One way in which pitch is discriminated occurs in the basilar membrane, a structure behind in the cochlea which is so shaped as for lower frequencies to stimulate it at further points than higher ones, providing a spectral analysis of the sound entering the ear at any one time. This method of spectral analysis is known as place perception. It is quite likely that place perception is limited in resolution to about a minor third (5:6) (Moore 1988).

It is thought that we also detect pitch by neurones that fire in accordance to the waveforms and it is thought to be this method that is mainly responsible for finer pitch discrimination (Howard & Angus 1996, pp 74-79). It could further be that in the case of those without AP, the latter's references get forgotten between listenings while the former's are retained so that the normal listener can easily be trained, or else is 'trained' already, to remember a pitch within a minor third. According to this theory, an average listener is capable of identifying keys approximately without a reference point, only confusing keys that have pitches close together.

To identify this limited pitch perception possessed by most people, a passage in the key of C will not be mistaken for one in F# provided the tonic can be identified since the tonic will be established as being too high for one F# and too low for the one an octave higher. C and D major may, in contrast, be confused. This is backed up by an experiment in colour and music where listeners, whether they are aware of it or not, have some knowledge of what key a piece is in, as was found by previous research on key and colour (Beaumont 1997).

The above explanation seems to go some way towards explaining why Ab major and C major (being a major third apart), for example were found to be appropriate for different types of music (Finn 2001). In this case more gentle waltzes have been written in Ab major and more marches in C major, but this does not account for the feeling that G major (a semitone lower) would not generally be regarded as adequate in the first instance whilst in the second Db instead of C would place the music in a key structure which is often thought, as evidenced by music written in these keys, to be more suited to the first type of music.

The most favoured scheme for grouping major keys for similarity, and therefore presumably associated colour for non-synaesthetes, seems to be that of a circle of fifths whereby C major is similar to G major which is similar to D major which is similar to A major but where C and A major are not terribly similar to each other. This relationship between keys a perfect fifth apart can be explained in terms of the notes that the keys have in common, E and B major, for example have six notes in common {C#, D#, E, F#, G#, B} whereas major keys two steps apart have only five in common (Eb and Db have {C, Eb, F, Ab, Bb} in common), those three steps apart have just four, those four apart, three and so on. By comparing keys to a colour circle, i.e. mapping keys on the equal temperament cycle of fifths, it is possible to suggest that the key six fifth transpositions above C major (F#) and the one six fifth transpositions below (Gb) are, when octave reduced, of the same quality. In the case of my theory discussed below both are green and in the case of Skyabin's colour scheme both were blue. This is probably a good theory to explain what keys close together on the cycle of fifths have in common, but it starts from the *assumption* that each pitch has its own separate quality rather than trying to explain how this is so. If all pitches (or at least all the pitches within a minor third range) sounded alike, in the absence of a reference point, then different diatonic pitch sets would also sound alike and so would the keys.

In conflict with the above, Block presented subjects with different pitches within an octave and required them to associate colours. Some of her subjects had AP, but others did not. Block found significant differences between the colours of notes a semitone apart within a subject, even in the absence of AP, although she did observe the results of the AP subjects to be more consistent. Isolated pitches are therefore often thought to have their own quality and might also relate to each other in terms of the cycle of fifths (Block 1983).

This theory of pitch-colour or pitch-mood acknowledges the importance of the cycle of fifths but I have reservations about using this exclusively in order to establish a pitch-colour or pitch-mood since two keys a perfect fifth apart are detectably different for the average listener in terms of place theory, as described above. Two steps round the cycle of fifths, however, results in a pitch two semitones apart and therefore a difference that is not significant in terms of place theory. It is suggested then that both the cycle of fifths and linear pitch should be taken into account in a theory of keys. The perfect fifth is close in terms of the cycle of fifths to the original pitch but distant in terms of linear pitch while the semitone is close in terms of linear pitch but diverse in terms of the cycle of fifths. The whole tone is therefore the smallest transposition when both are taken into account. This forms the basis of a potential theory on key colours, and this is presented below. According to this theory keys a tone apart are closely related. My study on key characteristics reveals that most people regard C major and D major as similar in character and this is probably due to the similarity pitch perception theory referred to above. As referred to when discussing the Baroque use of keys, C Major is a key used mainly for triumphant and vigorous music and fairly bright but robust and with purpose. In the days when military instruments were more likely to be in C as the, now more usual, Bb, it used to be the usual key for marches. It is still a fairly common key for military music today. The characteristics of the key of C major can, in this way, be likened to the colour, red. To relate red to the key of C is to create a helpful analogy between colour and sound rather than to suggest that C major is expected to produce that colour in people, which may or may not be the case. As the speculation which relates this to Kandinsky's theory does, we can make the related D major a red-related colour, like orange.

A SURVEY OF KEY CONTRASTS IN MUSIC AND COLOUR CONTRASTS IN PAINTING BASED ON THE ABOVE THEORY.

Previous chapters in this thesis have referred to colour frequently, usually encompassing a scientific approach, best concerned with how colours are distinguished from one another. However, despite attempts to address the subject from many angles, little progress has been made in regarding the issue of what colour actually is, let alone what the real differences are between one colour and another. It seems that we will probably never be able to do that because of colour's very subjective nature. Newton was unapologetic in making no attempt to explain the experience of colour when in 'Optiks' (1704) he wrote:

> To determine (...) by what modes or actions light produceth in our minds the phantasms of colour is not easie, and I shall not mingle conjectures with certainties.
>
> (Newton 1952, p 371).

Similarly Leonardo da Vinci (1442-1519) did not feel able or willing to enter into the subjective world of colour, stating that while a science of how a painter could apply colour, and even explanations of how we distinguish one colour from another, are possible, explaining the emotional aspects of colour is not. To make the task of quantifying the subjective aspects of colour all the more daunting, it is also the case that the emotional effects are not the sole ingredient of subjective awareness: - there is more to 'being' than just the affective aspects to which Leonardo was referring.

Of particular relevance to an exploration of contrast are sonata forms in music. The sonata is the most common musical formation in the last half of the eighteenth century and the whole of the nineteenth century and has appeared in various guises since. A fundamental principle of the form is that the two types of subject material are in contrasting keys, often tonic and dominant. It was the view of painter musicians such as Curlionis (1875-1911) and Klee (1879-1940) that the relationships between colours of painting had certain analogies with the relationships between keys and other attributes in music (Zimmermann 1996). In the case of tonic and dominant keys, their oppositional use in sonata form music, for example, might suggest an analogy with opposed colours. Alternatively, since tonic and dominant keys are maximally similar in terms of shared pitches, the analogy might be with two colours that are in neighbouring positions on the colour circle by analogy with the circle of fifths. Were this thesis less concerned with attempting to quantify subjective differences it would be appropriate simply to note that sonata principles work because the keys are different. Some sonata forms do, in any case, use other sets of keys such as tonic major and submediant major. Both of the above artists and several others (Kandinsky (1866-1944) and Chagall (1887-1985)) have at various times employed two basic colours to indicate two groups of material. In such cases, these colours are regarded subjectively by the painter as possessing distinctly different moods (Verity 1967, p 119). It is this kind of contrast that this thesis is investigating with respect to contrasting keys. These key contrasts are to be later compared with contrasts in abstract paintings, thereby showing the importance of contrast in both. Although such a study is necessarily subjective and the values measured to an extent, arbitrary, it is the comparison of contrasts that is the principal value in making this analogical study between key use in sonata music and certain abstract paintings that, likewise, use the contrasting colour principle.

As implied previously, the most common keys in sonata movements are tonic and dominant. However, since the first hints of sonata principles in music (dating from about 1650), the formations have gradually evolved into ever more complex and distinct constructions. As a consequence, we find the dominant minor used for the second subject group or the relative major following a first group in the minor, in the early to middle nineteenth century, in other instances. In further cases the contrasting second group is frequently in mediant or submediant keys, thereby modulating by a third from the first set of material. In subsequent music, almost every other combination of keys can be found.

To assess the variety of keys used to establish the contrast between first and second subject groups, I have examined over 150 first movements in sonata style for the relationship between the keys of the first and second subject groups. These were all written between 1760 and 1900 and were selected at random from a catalogue of available Compact Disc recordings in January 1996. I found the frequencies of each intervallic relationship to be as follows:-

TABLE 2

RELATIVE INTERVAL OF SECOND GROUP	No. OF OCCURRENCES
Minor second up	5
Major second up	0
Minor third up	12
Major third up	12
Perfect fourth up	11
Tritone	3
Perfect fourth down	73
Major third down	19
Minor third down	10
Major second down	1
Minor second down	4

The results of this process were reduced to degrees of subjective contrast according to both the 'traditional' and the 'pitch set' standards. The so-called traditional standard is one that accounts for the effective contrast between the first and second sets of material in sonata movements, such as those used by Mozart, Beethoven or Schubert. In such schemes the tonic and dominant keys is the most common contrasting pair. They are often regarded as having maximum contrast as a result of the pitch height difference within the diatonic framework. I feel, however, that the keys appear to oppose mainly because they were expected to do so at the time of the compositions while our perception of keys treat such key difference as small in other contexts, since (in major keys) such differences have six out of seven notes in common.

This latter comparison forms the basis of the pitch class criterion of pitch class contrast, where differences in key of a perfect fifth are treated as the smallest, while a semitone difference, despite the similarity of pitch height, is treated as a very large difference. Ad-hoc allocations were given and there are shown in table 3, overleaf:-

<u>TABLE 3</u>

An Ad-hoc Categorisation of the Intensities of Contrasts of Keys for the Purpose of Comparing Sonata Movements to 'Musically Inspired' Paintings.

	First Group in a major key	
Second group	Traditional concept	Pitch class concept
Tonic minor	Similar	Contrasting
Minor second up, major	Similar	Contrasting
Semitone up, minor	Borderline	Contrasting
Whole tone up, major	Similar	Similar
Whole tone up, minor	Similar	Similar
Minor third up, major	Contrasting	Contrasting
Minor third up, minor	Contrasting	Opposite
Major third up, major	Contrasting	Contrasting
Major third up, minor	Contrasting	Similar
Perfect fourth up, major	Contrasting	Similar
Perfect fourth up, minor	Contrasting	Contrasting
Tritone up, major	Opposite	Opposite
Augmented fourth up, minor	Opposite	Contrasting
Perfect fifth up, major	Opposite	Similar
Perfect fifth up, minor	Opposite	Similar
Minor sixth up, major	Contrasting	Contrasting
Augmented fifth up, minor	Contrasting	Contrasting
Major sixth up, major	Contrasting	Contrasting
Major sixth up, minor	Contrasting	Similar
Minor seventh up, major	Contrasting	Similar
Minor seventh up, minor	Contrasting	Contrasting
Major seventh up, major	Borderline	Contrasting
Major seventh up, major	Borderline	Similar

First group in a minor key

Second group	Traditional concept	Pitch class concept
Tonic major	Similar	Contrasting
Minor second up, major	Similar	Similar
Minor second up, minor	Borderline	Contrasting
Major second up, major	Borderline	Contrasting
Major second up, minor	Similar	Similar
Minor third up, major	Contrasting	Similar
Minor third up, minor	Contrasting	Contrasting
Diminished fourth up, major	Contrasting	Contrasting
Major third up, minor	Contrasting	Contrasting
Perfect fourth up, major	Contrasting	Similar
Perfect fourth up, minor	Contrasting	Similar
Diminished fifth up, major	Opposite	Contrasting
Tritone up, minor	Opposite	Opposite
Perfect fifth up, major	Opposite	Contrasting
Perfect fifth up, minor	Opposite	Similar
Minor sixth up major	Contrasting	Similar
Minor sixth up, minor	Contrasting	Contrasting
Major sixth up, major	Contrasting	Opposite
Major sixth up, minor	Contrasting	Contrasting
Minor seventh up, major	Borderline	Similar
Minor seventh up, minor	Borderline	Similar
Diminished octave up, major	Borderline	Contrasting
Major seventh up, minor	Borderline	Contrasting

For these sonata movements, using the 'traditional' allocations only two per cent of all cases are the keys similar. In nine per cent of cases they are borderline, in 26 per cent of cases they are contrasting and in most cases (63%) they are opposite.

Of the last category, the concentration of contrasting keys being used is markedly in the first part of the 140 year period, when tonic and dominant prevailed as the most usual oppositional pair. The sonata movement, as a late eighteenth century invention, with its contrasting keys stands as a counterpart to the earlier Baroque suite where the key of each movement is usually the same.

Any change of key in the former Baroque suite tends to be from major to tonic minor (or vice versa) since the shared tonic between movements preserves the unity of them. This makes them contrasting in the pitch class sense (the key signature is three notes apart) but with an identical tonic. While relative tonal centre is important in the way in which keys are heard, Levitin suggests a more widespread incidence of subconscious AP than has previously been supposed (Levitin 1994), the awareness of individual pitch classes must certainly follow. This therefore suggests that it is necessary to take the pitch class measure of relatedness into account in this survey.

For the 'pitch class' standard (see above) 80 per cent of the movements in the survey have similar keys for the two subject groups, with 18 per cent being contrasting and two per cent being opposite. In the same way that with the 'traditional' classification most of the similar key cases were concentrated in the later part of the 140 year period, with this standard, the highest diversity of pitch classes are towards the later end of the period, with all of the earliest being one or occasionally two pitch classes apart.

The main point of these findings is that contrast of key exists in one form or another in sonata movements. A comparable contrast exists in the same way that different colours exist in an abstract painting in order to make the different and 'competing' materials distinct: red and green or red and blue would, for example, be effective in an abstract painting as the principal colours for competing forms on a canvas. Red and orange produce less distinctiveness between the two groups. In the eleven per cent of sonatas that did not have intensely contrasting keys in the traditional sense, the contrast was created by intense differences in pitch class, in all except one of the pieces surveyed (the first movement of Bruckner's fourth symphony - C to Bb - and therefore marginal in pitch class and sub-similar in traditional classification).

Painting became free from the need to represent real objects and landscapes, and even if it did some of the time in practice, there developed a growing tendency to exploit colour contrasts for their own sake. I have performed a survey analogous to the music survey with paintings that treat colours in a way that is similar to that of the keys in the above study with respect to certain contrasts being used. Since the above mentioned use of colour for itself alone is important in a study of how its contrasts are used, it is necessary to restrict the types of painting used by setting out specific criteria.

The criteria decided on were as follows: firstly they either do not represent actual objects, or if they do the colours bore no resemblance to reality, or else appear distorted by the light conditions with which the artist wished to play (this is exemplified by many of Whistler's paintings that were included in the survey). This was assessed by the artists' intentions, or at least what the artists or their biographers' reported to be their intentions. Generally speaking, however, the works concerned were post-impressionist. Secondly, in each case, two colours are used in approximately equal quantities and predominate (over half of the surface area consists of one or the other of those two colours and the two colours are used with no less equanimity than a ratio of 3:2). This point is exemplified by Kandinsky's Improvisation 26 (1912) with the colours yellow and blue). Thirdly the colours are used for contrasting shapes or contrasting orientations, but with certain elements in common between the groups of material as judged from a brief visual analysis by the experimenter. Finally, there is, in each case, some analogy to the development in a sonata. The first and second coloured material is used in other colours and other areas of the canvas besides the main ones. In a large proportion of the works studied there are lines directing the eye to the material that develops from the basic elements. Again, the final assessment of this was left to the subjective judgement of the experimenter.

Although the study only looks at a limited range of the many styles of painting that exist, it does exhibit the ways in which certain types of colour harmony tend to be used more than others, and whether the levels of contrast that are most common in these paintings have a relationship with that of those key contrasts in sonata movements.

The survey of the colour contrasts of what, with this analogy, what might be thought of as the basic ideas or subjects of 100 paintings conforming to above criteria, as assessed by the formula given below (Table 4) reveals that 24 of them had 'opposite' colours, 49 of them had 'contrasting' colours, only 20 of them had 'sub-similar' colours as the basis of the visual argument, leaving the small minority of seven of the works having contrasts regarded here as 'similar'. The assignment of what is meant by these terms Table 4 below.

TABLE 4: The Level of Dissimilarity Between Different Colours for the Purpose of Paintings.

Key to colours, A- Primary Yellow, B- Saffron,, C- Orange, D- Poppy Red, E- Signal Red, F- Crimson (Purplish), G- Purple (Orchid), H- Violet (Reddish), J- Indigo, K- Cornflower Blue, L- Cobalt Blue, M - Turquoise Blue, N- Signal Green, P- Grass Green, R- Lime. Up to 3 Similar, 4-6 Subsimilar, 7-11 Contrasting, 12 Opposite.

	B	C	D	E	F	G	H	J	K	L	M	N	P	R
A	0	1	4	7	9	11	12	12	11	9	7	4	1	0
B	-	0	1	4	7	9	11	12	12	11	9	7	4	1
C			0	1	4	7	9	11	12	12	11	9	7	4
D				0	1	4	7	9	11	12	12	11	9	7
E					0	1	4	7	9	11	12	12	11	9
F						0	1	4	7	9	11	12	12	11
G							0	1	4	7	9	11	12	12
H								0	1	4	7	9	11	12
J									0	1	4	7	9	11
K										0	1	4	7	9
L											0	1	4	7
M												0	1	4
N													0	1
P														0

Although, as admitted previously, this study relies quite heavily on subjective judgement and arbitrary selection, and the figures here may not be very precise for the generalisations to the larger set of sonatas and abstract paintings, it does make the point that musical key and visual colour can both produce a distinction between different sets of ideas (in these cases, two) by means of contrast. That is, two different keys that are used in sequence can be subjectively different in the same kind of way as two contrasting colours can be. While this speculation does nothing to define the quality of colour contrast with words it has strengthened our concept of what such contrast is. The Oxford English Dictionary defines 'contrast' as 'juxtaposition of various forms, colours etc. or the degree of differentiation of various tones' (Simpson & Weiner 1989). It is this juxtaposition which is characteristic in generating the quality of 'argument' in sonata in the forms of music or the kind of semi-abstract paintings discussed here.

COLOUR AND MUSIC SPECULATION OF KANDINSKY AND OTHERS AS AN EXTENSION OF CYCLE OF FIFTHS SIMILARITY THEORY

In 1914 Kandinsky wrote that of all the basic colours, red was the easiest one to modify into a variety of expressions (Kandinsky 1977, pp 40-41). He continued to explain that red could be given warm or cool properties or transformed into brown or pink by adding small amounts of orange (or yellow), purple (or blue), black or white respectively. I speculate here that for people who have tendencies to make analogies, the basic 'colour' of C can be modified by transpositions of whole tones in a similar way to red's modifications referred to above. A passage once in C major but now transposed to D major, a tone higher, seems to me to be liberated from purpose in a way akin to Kandinsky's and Luscher's comparison of orange to red (Scott 1970, p.11). By this token, Bb, can be thought of as C major with an increased sense of purpose and depth but without some of the joy and is in this way analogous to red's admixture of violet or blue. We thus have three forms of the basic colour C major.

The colour can be further blued or yellowed by transposition of another tone up or down, E major is a more liberated D major. This key is intense and very bright but with little of the power of the C major in it, having only a trace, a memory of it manifested by the current tonic of the key being the third of the first key (E) the note rings out as strongly but is re-harmonised with the G# which is not found in C major. E major's colour is therefore yellow or gold. Ab major corresponds accordingly to an increase in blueness; again little is recognisable from C major. The key is introspective, thick and dense and it is within that (probably partly a result of its third being the tonic of C) that the 'tones' of C major resonate deeply just as red resonates in a violet-blue.

Whole-tone transposition, up from E or down from Ab major, in equal temperament results in the same pitch class set, that of F# or Gb major. One question commonly asked by those sceptical of the idea that each key has its own qualities is whether F# major has the same qualities as Gb major. Fortunately, here this is barely a problem since saturated hues form a circle. According to a circular scheme F# major (or Gb major) should correspond to green, since it is in between the yellow of E major and the blue of Ab major. According to Kandinsky's theory, this represents a paralysis arising from yellow's eccentric motion and blue's concentric motion, green being, in this respect, the opposite of red which represents motion (Kandinsky 1977, pp 36-42). This seems to be the case since in the cycle of fifths the two keys are at opposite points in the same way that green and red are opposite on the colour circle. There is, however, one difference between sound and colour under which this analogy breaks down. This is that since F# major is halfway between two keys which I am suggesting hold 'resonances' of C major (E major and Ab major), it consequently holds its own 'memories' of the colour of C major. In colour, by contrast, mixing a yellow and blue (which if pure would give a bright green) where they both have remnants of red in them would give a less saturated green, that is in colour red and green cannot coexist, a red element in a green just desaturates (greys) it.

The keys C, D, E, F#, Ab and Bb major constitute those keys with tonics within one of the two types of whole tone scale. The keys of the second whole tone scale may be introduced by suggesting that the dichotomous key of F# major divides neatly into different qualities to give the 'colours' of F and G major, a semitone lower, and a semitone higher. Both of these keys tend to be used less than the others for expressive qualities, suggesting that they may be somewhat lacking in them (although this does not exclude the possibility of skilful composers finding suitable qualities in the keys - only that they are harder to find), G major seems to be capable of superficial weight and brightness, but short on expressive qualities and as a result can sound dead and heavy, while F major reveals a superficial placidness with much less aptitude towards any weight or assertion.

Transposing the above keys by whole-tones, away from F# not only gives more adeptness to the former keys' strong 'suit' (soft serenity for F, strength and weight for G), but it seems also to increase adeptness for the weak 'suit'. A major seems to have a fuller and richer brightness than G major and also has a larger range of expressive possibilities while Eb major has depth and majesty that F major's pastoral-like serenity lacks, but it also seems to have more brightness than F major. A major is thought to sound both brighter and lighter than the more introspective Eb major, but both keys have useful degrees of both properties. In short the keys A and Eb, although a tritone apart, have much in common, according to the current theory, matching each other in usefulness if not specific quality. These two keys have more likeness to the six keys of the first whole tone scale than they do to the rest of the current whole-tone scale especially those that are adjacent cycle of fifths (D major and E major, for A and Bb major and Ab major, for Eb).

Further transposition by tones sharpens A major to B major and flattens Eb major to Db major. Since we are attributing to A and Eb a delicate yet successful balance, it fits that the further addition of brightening and darkening elements, respectively, overthrows the balance, and that the keys can be referred to as being weaker for certain purposes and this seems to be the case. Specifically, B seems to lack softness and Db hardness - the quality concerning Db major in particular is sometimes used as an advantage. In any case the skill of a composer is to use all resources at the appropriate times, which, for key choice means a palette of twelve colours, all of which can, to an extent, express a range of themes and abstractions. The generalisations that I have made about keys are summarised in Table 5 below:-

TABLE 5

My Suggested Subjective Observations of Key Characteristics.

Key	Colour Analogy and Description
C major	Red, Triumphant, bright, joyful, and purposeful.
G major	Clear and slightly hard with brightness.
D major	Orange-Red, Bright, joyful, tending towards the carefree
A major	Soft in texture with a brilliant and joyful edge. Rounded with depth
E major	Gold, Light-hearted and carefree with low substance and 'ringing'
B major	Sharp. Limited capacity for softness.
F# major	Green, Rounded, firm rather than soft or hard.
Db major	Almost a flat warmness, lacking in capacity for hardness.
Ab major	Blue-Violet, Noble, serious and firm with rich feeling.
Eb major	Hard in texture and very rounded, sometimes sombre with depth.
Bb major	Purple/Crimson, Purposeful with vigour and nobility.
F major	Serene and soft with gentle qualities but not capable of great depth.

The relationship between keys will be discussed further in Chapter 7 in relation to the key and colour experiment (Beaumont 1997). It must be borne in mind that any theory of keys has had to be based on retrospective knowledge of key use. This is so to the extent that the theory may have been predominantly steered by what is already known about key theory making it possible that what we observe could be based on self-fulfilling prophecy. It is partly for this reason that the validity of the above theory is tested throughout the section.

THE LANGUAGE CONTRIBUTION

A related theme to this which forms part of the thesis is that of the concordance of the senses. The purpose of having a theory that links keys to colours, such as the one outlined above, is founded on the idea that by sharing concepts between the senses we can increase our comprehension of intangibles such as the quality of a colour or musical pitch. Marks reports a conversation between two blind women; one of them has been blind from birth while the other had seen for the first few years of her life. The one that has previously seen attempts to communicate the quality of the four unique hues (red, yellow, green and blue) to the other one in terms of other senses; taste, smell, touch and temperature (Marks 1978, p 202).

Using the words of certainty 'are' and 'is' (yellow is like the warmth of sunshine, green is like cool mint, etc.), Marks gives the impression that the speaker is confident in the power of analogy to communicate colour contrasts to a person who has never experienced the phenomenon in her life. It is, of course, possible that she was aware that her words functioned only as metaphor, but it is doubtful that if that was the case the speaker would have had as much confidence in the statements of cross-modal analogy.

That this dialogue occurred is certainly suggestive of the 'unity of the senses' notion. It was probably established prior to the aforementioned conversation that although the congenitally blind woman could never understand colour subjectively, use of a synaestheticaly extended vocabulary could nonetheless be a powerful contribution towards the aim of grasping of the ungraspable. This last point is accommodated by a now widely accepted view of the nature of metaphor first offered by Richards, who focused on metaphor as an aid to expression – 'Epiphoria' (Richards 1965, see Chapter 10). Stimulation of the imagination by means of an extended vocabulary was used by several nineteenth and twentieth century writers to expand subjective awareness beyond what is received by the senses. Besides Poe, who is referred to in later chapters, these include Tennyson (1809-1892), the minor poet Lionel Johnson (1867-1902) and D H Lawrence (1885-1930). Similarly a congenitally visually deprived person who is exposed to elaborated speculations of what colour might be like may develop some concept of the contrasts of the four unique hues and of black and white.

Making use of synaesthetic metaphorical language to describe colour to the congenitally blind is likely to be applicable in reverse with the deaf. One can conceive of a 'conversation' similar to the one cited by Marks by an agent of acquired deafness and a congenitally deaf person about the perceived qualities of keys. The main differences between these two instances are that in the latter case language is probably less standardised than it is in the case of colour, and that most people retain absolute colour (Bachem 1955). In my opinion, however, neither of these points is so fundamental as to deter from the likelihood of language being the main connection between the concepts of colour and musical key (or pitch) - there is at least a small amount of consensus between musicians' use of language to describe pitches. Furthermore AP may be preconscious and unlearned at an early age.

It is therefore likely that a musician who associates the key of E major with the colour orange would describe each of these as having similar degrees of happiness, tenseness, stability or any other such affective adjectives. To test this, a survey was circulated to question musicians on how they rate keys and colours on scales between semantic opposites. This is now quite a standard procedure in psychology and is called the semantic differential (Osgood 1971). The experiment is the topic of Chapter 11.

7. Key/Colour Experiment.

It is well documented that many synaesthetes see colours in connection with music, other sounds or other sensory input. Many non-synaesthetes, however, while not 'seeing' sounds, tastes or smells as colours in the way that synaesthetes do, tend to imagine them in certain contexts (e.g. Allott 1994). For many non-synaesthetic people (musicians for example) different keys are imagined to possess their own distinctive colours. This is exemplified by the colour associations of 32 musicians which were compiled by Sabeenev (1929) which included the composer Skryabin who made use of these 'colours' in some of his later works. Skryabin's associations for all twelve keys, as shown, for example, in the front of the score of 'Prometheus', seem to be an extension of just three early colour associations - C Major/ red, D/ yellow and F#/ violet, and from these he suspected that the colour wheel and the cycle of fifths were interrelated. As a result of that suspicion he allocated G to orange, A to green, E and B to blues, and the flat keys to purples and unsaturated colours. It is possible that the composer thereafter saw all twelve keys as colours as a result of self suggestion, convincing himself that there must be a cycle of fifths pattern to the colour allocations until, for him it became a reality (Sabeenev 1929). The colour associations of all 32 participants for some of the keys are shown overleaf.

TABLE 6

THE COLOURED ASSOCIATIONS FOUND BY SABEENEV FOR 32 PARTICIPANTS AND FOR SELECTED KEYS.

Participant	C	D	A	F#	Ab	F
Skryabin	RED	YELLOW	GREEN	BT.BLUE	VIOLET	RED
Rimsky-K	WHITE	YELLOW	ROSE	P.GREEN	V/GY	GRN
Sabeenev	WHITE	YELLOW	ROSE	RD/PPL	D VIOLET	RED
4	WHITE	BLUE	RS/VIOLET	LC/RED	BL/LLC	------
5	RSE/GRN!	YELLOW	ORANGE	RD/PPL	BL/PPL	GRN
6	P.YELLOW	ROSE	O/YEL	ORANGE	SILVER	GRY
7	WHITE	YELLOW	ROSE	D LILAC	MOON	RED
8	WHITE	YELLOW	GREEN	LILAC	BROWN	GRN
9	RED	YELLOW	GREEN	--------	METAL	RED
10	WHITE	YELLOW	PINK	D BLUE	VIOLET	RED
11	WHITE	YELLOW	ROSE	LILAC	BRN/VT	GRN
12	WHITE	BLUE	ROSE	D VIOLET	BROWN	GRN
13	RED	BLUE	GREEN	D RED	VIOLET	RED
14	WHITE	YELLOW	RSE/GRN!	D BL/PPL	---------	WH
15	WHITE	YELLOW	P ROSE	RED	D LILAC	YW
16	WHITE	YELLOW	ROSE	D RED	LILAC	RED
17	P YELLOW	YELLOW	RED	D VIOLET	---------	PINK
18	YELLOW	YELLOW	ROSE	MOON-	RD/GN!	-----
19	GREEN	BLUE	LILAC	BLACK	GREY	RED
20	P YELLOW	YELLOW	---------	D RED	---------	O/Y
21	WHITE	YELLOW	GREEN	BLACK	VIOLET	-----
22	WHITE	BLUE	---------	BLACK	BROWN	WH
23	WHITE	YELLOW	ROSE	D LILAC	---------	RED
24	WHITE	GOLD	GREEN	D RED	VT/BRN	GRSS
25	P YELLOW	FIRE	PINK	D ROSE	S VIOLET	RED
26	RED	ORANGE	YELLOW	LILAC	FIRE	GRSS
27	WHITE	YELLOW	RED	D GREEN	D FIRE	-----
28	WHITE	WHITE	---------	BLACK	VIOLET	RED
29	WHITE	YELLOW	---------	---------	SVR/VLT	RED
30	WHITE	BLUE	RED	D GREEN	----------	RED
31	RED	BLUE	---------	BLACK	-----------	RED
32	WHITE	YELLOW	ORANGE	RED/PPL	RED	GRSS

Specific pitch class discrimination, that is without a reference point (i.e. Absolute Pitch (AP)) and coloured hearing are similar phenomena in one important respect, namely that their presence has been found to involve connections in the brain that are believed to be normally severed in adults or in older children. This suggests that synaesthetic links are usually eradicated when a child is young as part of the adaptation process to an environment where perceiving reality is necessary and where perceiving trans-modal equivalents is not only unnecessary but may also be a hindrance (Harrison 2001). Regarding AP, Bachem states that we live in a predominantly relative pitch world where the former system of pitch processing is unlearned in favour of the relevant suitable relative system (Bachem 1955).

Lockhead & Byrd defined AP as 'the ability of some people to identify any note of the musical scale' (Lockhead & Byrd 1981). They point out that in practice AP is often studied by focusing on the tones of one or many instruments (Ward 1963) or the ability to produce a specified pitch unaided (Bachem 1955). This type of study of AP has a concrete focus, whereas Lockhead & Byrd define it as something less palpable. Therein lays an important difference between the two investigator's approaches, in that while Bachem talks of the sense of pitch being identified generally, Lockhead & Byrd's definition includes the specific mention of the musical scale. This does not, presumably refer only to diatonic notes in a scale, but rather it places an emphasis on pitch class. Pitch class was distinguished from pitch height by Revesz who represented pitch as a spiral where an increase of pitch of a semitone corresponds to a turn of 30 degrees round to a point which is also slightly higher than the original pitch. The pitch an octave higher is, therefore, twelve times as far above the original pitch but is directly above it in the pitch height dimension (Revesz 1953, p59).

The two-dimensional pitch theory can be seen in our musical convention of locating pitches in the pitch class dimension - we speak of pitch class 'A' to denote not only A440 but all octave equivalents below and above that pitch. It is also the case that most people find that notes an octave apart have something in common which notes of different pitch classes do not.

Balzano (1984) tested himself and a university student with an absolute pitch task. Both subjects had near AP and correctly identified most of the pitches. What is significant from the point of view of the two dimensional pitch model, however, is that the majority of the errors were of an octave (in some instances two octaves and in one even three octaves): that is, pitch name was correctly identified but the pitch height was sometimes incorrectly placed (Balzano 1984).

Generalisation of octaves and the preservation of pitch class was observed by Demany & Armand and tested by a conditioning exercise to test for pitch discrimination with six month old infants (Demany & Armand 1984). The subjects were presented with a conditioning stimulus consisting of a short sequence of tones, and then tested for conditioned responses at the original pitch, and also a major seventh, octave and ninth higher and lower. Although the original pitch produced the strongest response they generalised significantly more to the octave transpositions than they did to the seventh or ninth transpositions. Presumably this indicates that the young subjects perceive in pitch class terms or something related to it. This suggests that they not only process pitch class information but that this may preside more over their judgements of difference than pitch height does. This study, while demonstrating that an octave is in some sense a smaller interval than a minor seventh, does not address the issue of absolute pitch class, since the stimuli were never transposed and never depended on absolute pitch differences. More recently, interference tasks have been used to measure how pitch is processed. Semal & Demany (1991 & 1996) have used these techniques to demonstrate that pitch is processed separately from other aspects of sound such as timbre, loudness, and temporal structure.

In a recent study (Beaumont 1997) 50 participants were played the same sequence transposed into all twelve major keys and then asked to select colours from a large selection to suit each playing. On the surface, at least, some consistency was found between participants who included *higher pitches* having more light colours, which tended to have more yellow, associated with them than lower ones which showed tendencies towards blue or purple. The study here reproduces the procedure, this time with minor keys. It sets out to provide support for the notion that both coloured hearing and absolute pitch reference faculties might be present in people conventionally regarded as being without either, at preconscious level, and that this may cause specific associations between the two. This possibility was tested by asking 53 participants to associate colours from a selection of 280 with a harmonised melody played in all twelve minor keys.

Individual consistency between keys (or pitches) and colours is fairly common in chromaesthetes and musicians with AP, the two often going together. An example of a synaesthete with this level of consistency is Myers' subject, who was tested once in 1905 and three times in 1912 for coloured hearing and was found to be quite consistent across the four occasions (Langfield 1914). Regarding consistency of associations, Ostwald's patient is also of interest. Her consistency between sound and colour were tested thoroughly by an audiologist. The subject reported 'Every sound I hear registers a colour' (Ostwald 1964). The patient came for help not because of the synaesthesia itself, but because of her obsession with cross modal correlations, (Ostwald 1964). This obsession is an exaggeration of the interest which, to a lesser extent, applies to most people who have made synaesthetic connections, including many of those mentioned in this thesis.

Masson, a linguist, also had detailed colour images for sounds although his self-reported images were less spontaneous than those described above since he searched for and found systematic patterns to his colour relations. For example, he pointed out that his rounded vowel associations were similar in colour to their less rounded counterparts 'except for the addition of blue'.

It seems, therefore, that Masson's associations were a conscious manifestation of preconscious representation of the pitches of the first and second formants of vowels (Masson 1952). The stronger of the two influences for people in general is that of the second formant, the higher its pitch, the lighter the associated colour will be (Marks 1974).

It has already been mentioned that pitch class is sometimes referred to as chroma, reflecting an analogy between colours and pitches. This has prompted much research into colour, musical pitch, and their correlation. Baggelly's study (Baggelly 1972) includes an analysis of the associations of Sabeneev's aforementioned collection of 32 subjects (see Table 6 above). This is analysed in a similar fashion to one which Marks (1974) used for vowel sounds (see Chapter 9).

Baggelly discovered certain colour associations for certain keys which when arranged in a circle representing the cycle of fifths forms a fairly consistent pattern of association with only a small number of deviations. 'Home' keys tend to be greenest, middle sharp keys yellowest, 'remote' keys reddest and middle flat keys bluest (Baggelly 1972). Although Baggelly found these associations, it must be remembered that the study is based on anecdotal data and that it is quite possible that Skryabin was no exception among the contributors with others in the study also forcing associations in accordance with their own rationales. Baggelly's research is, to date, the most comprehensive study demonstrating that hue and pitch class are related. Nonetheless, on a smaller scale there have been other studies. Cuddy believes there to be a strong link between hues and pitch classes for any individual yet a complete lack of consistency between people. Block's (1983) observation that AP possessors were more consistent in their choice of colours for pitches was explained by Cuddy in terms of them being more sure about pitch and therefore being more likely to pick the same colour every time (Cuddy 1985).

Since AP and cross modal connections are both probably preconscious, it is suggested here that there is an association between key and colour that is, to some extent consistent between participants as a result of this preconscious activity. The experimental hypothesis, therefore, is that different keys will have different associated and avoided colours to a degree which is unlikely to have occurred by chance. The null hypothesis was that no such relationship would be found and chance variations alone would determine the distribution.

METHOD

PARTICIPANTS

53 participants (29 male, 24 female, ages 18-81) were used for the experiment on key and colour. None were studying music at the time of the experiment and while eleven had a reasonable musical training, only two had AP. None had synaesthesia and none were colour blind or colour defective. All were from Northampton, Blackpool and Manchester areas.

MATERIALS

A four part extract in the minor key was composed by the experimenter and was played to the participants in all twelve keys (the order was the same each time, F#m, Bbm, C#m, Am, D#m, Bm, Gm, Em, Cm, G#m, Fm and Dm. The number of possible orders that provided reasonable contrast of keys was limited, but in retrospect it could have been reversed (Dm, Fm, G#m &c.) so that order effects made less of a contribution to the outcome. This was considered to be suitable because it has a strong and simple sense of tonality and does not modulate, so that when it starts in a given key (F#m for the first playing, Bbm for the second etc.) it stays in that key for all of its eight bars. The music is shown in E minor overleaf.

This order was chosen as one of many possible orders, because it was one which ensured contrast of adjacent keys in terms of pitch classes (cycle of fifths) and pitch height (e.g. C minor did not follow G minor and G# minor did not follow A minor). E minor was the lowest key with the soprano line starting on G 392 and D# minor was the highest key with the soprano line starting on F# 698. The chorale was presented on an upright piano tuned to equal temperament and A440 and was played by the experimenter at approximately 75 crotchets a minute.

A colour chart was used in the experiment consisting of 280 colour patches all of which were numbered. These colours were selected from a paint colour chart by the experimenter to effectively represent colour space.

PROCEDURE

Participants were tested individually in a room in north light conditions and sat down at the colour panels with the instructions overleaf:-

> I will play you a harmonised melody in all twelve possible transpositions. For each playing you are required to select a colour that you think is appropriate for it and read out to me the corresponding number which I will write down. You may have any presentation repeated as often as you like and when you have selected a colour we can continue with the next playing. Try and think of a colour to suit each playing, however arbitrary, but if it proves totally impossible in any instance then we can move on.

The sequence was then played in the way described above. Each participant faced away from the piano so that they could not see the notes being played. For each trial the colour selections were written down under the respective key and participant number for the specific colour numbers of all 53 participants for the twelve keys. After the colour selection had been made for the twelfth playing, participants were thanked for their time and informed of any details of the study that interested them. The participants generally found the task fairly straightforward, enjoyable and enlightening. In about half the cases repetitions were requested for one or more performances of the sequence. The experimenter wrote down the associated colour numbers of each participant. For expediency the colours were allocated six categories ('Red', 'Yellow', 'Green', 'Blue', 'Purple', and 'Low Saturation') by the experimenter. This allocation of categories was necessary since there were far too many possible colour choices to get any meaningful results without a clustering process of some kind and this splitting into six tends to group colours in a way that is akin to the way which most people think of colour space. This task was performed without reference to the choices made in order to prevent any risk of observer bias and like the experiment itself it was performed in daylight. Counting only the first five categories a contingency table was drawn up of the associations made for each key. This is shown as Table 7 overleaf.

TABLE 7

OBSERVED VALUES (OUTSIDE BRACKETS), EXPECTED VALUES (INSIDE BRACKETS) AND CELL VALUE OF CHI SQUARED (ITALICS) FOR EACH KEY AND EACH COLOUR CATEGORY.

	Red	Yellow	Green	Blue	Purple
1 A minor (4th)	13 (10.0)	11 (10.9)	9 (10.1)	7 (8.8)	7 (7.2)
	0.9 (+)	*0*	*0.1 (-)*	*0.4 (-)*	*0*
2. E minor (8th)	12 (9.4)	6 (10.2)	8 (9.5)	9 (8.2)	9 (6.7)
	0.7 (+)	*1.7 (-)*	*0.2 (-)*	*0.1 (+)*	*0.8 (+)*
3. B minor 6th)	11 (10.0)	11 (10.9)	12 (10.1)	12 (8.7)	2 (7.2)
	0.1 (+)	*0*	*0.4 (+)*	*1.1 (+)*	*3.8 (-)*
4. F# minor (1st)	5 (9.4)	5 (10.2)	13 (9.5)	12 (8.2)	9 (6.7)
	2.0 (-)	*2.6 (-)*	*1.3 (+)*	*1.7 (+)*	*0.8 (+)*
5. C# minor (9th)	8 (9.6)	14 (10.4)	11 (9.7)	6 (8.4)	6 (6.9)
	0.3 (-)	*1.2 (+)*	*0.2 (+)*	*0.7 (-)*	*0.1 (-)*
6. G# minor (10th)	13 (8.9)	4 (9.7)	12 (9.0)	7 (7.8)	6 (6.4)
	1.8 (+)	*3.4 (-)*	*1.0 (+)*	*0.1 (-)*	*0*
7. D# minor (5th)	8 (10.2)	16 (11.1)	9 (10.3)	10 (9.0)	5 (7.3)
	0.5 (-)	*2.1 (+)*	*0.2 (-)*	*0.1 (+)*	*0.8 (-)*
8. Bb minor (2nd)	2 (10.4)	15 (11.4)	11 (10.5)	9 (9.2)	12 (7.5)
	6.8 (-)	*1.2 (+)*	*0*	*0*	*2.7 (+)*
9. F minor (11th)	9 (7.7)	7 (8.3)	7 (7.7)	7 (6.7)	6 (5.5)
	0.2 (+)	*0.2 (-)*	*0.1 (-)*	*0.1 (+)*	*0.1 (+)*
10. C minor (3rd)	12 (9.8)	19 (10.7)	10 (9.9)	3 (8.6)	2 (7.1)
	0.5 (+)	*6.5 (+)*	*0*	*3.6 (-)*	*3.6 (-)*
11. G minor (7th)	8 (8.7)	4 (9.5)	9 (8.8)	9 (7.7)	11 (6.3)
	0.1 (-)	*3.2 (-)*	*0*	*0.2 (+)*	*1.5 (+)*
12. D minor (12th)	13 (9.8)	12 (10.7)	4 (9.9)	10 (8.6)	7 (7.1)
	1.0 (+)	*0.2 (+)*	*3.5 (-)*	*0.2 (+)*	*0*

A repeated measures design was used in this study, i.e. each participant experienced all twelve transpositions of the harmonisation.

RESULTS

A chi squared test showed a significant association of colour with key (chi squared= 65.7; df. = 44 $p<0.02$). The experiment was also ran 100000 times with replacement data, however, and that showed a greater level of significance of $p=0.005$. (see overleaf) This demonstrates that there is a non-random association between the key and colour, thereby supporting the experimental hypothesis.

DISCUSSION

That there is this non-random association between the key and colour suggests that the preconscious faculties of both AP and chromaesthesia might have manifested themselves since consistent colours were selected for keys even though the keys were consciously unknown to all but two of the participants (those who were aware of possessing AP). Certain colours were selected significantly more often than others for certain keys. These associations could be the result of chroma differences, pitch height, or a combination of both. While the overall result was significant, certain keys (notably C minor, Bb minor and F# minor) and 'Yellow' contributed highly to the overall value, while F minor, A minor, 'Green', and 'Blue' contributed much less. Of the specific cells, twelve of the 60 were at $p<0.05$, three of which were more significant than $p<0.005$. Using the results of the multiple testing method; the most significant cell was for the positive selection of unsaturated colours for F minor. The second most significant cell was also positive (C minor and 'Yellow'), but the third and many of the others are. The 20 most significant cells are shown in Table 8 below:-

TABLE 8
The Significant ($p<=0.05$) Positive and Negative Key/Colour Associations in Rank Order with the Probabilities of Random Occurrence for the Respective Cell.

+ 1	F minor Unsaturated	0.00	- 11	C minor Blue	0.04
+ 2	C minor Yellow	0.00	- 12	F# minor Yellow	0.05
- 3	Bb minor Red	0.00	+ 13	G minor Purple	0.06
+ 4	Bb minor Purple	0.02	- 14	F# minor Red	0.07
- 5	G minor Yellow	0.02	+ 15	Bb minor Yellow	0.08
- 6	G# minor Yellow	0.02	- 16	Bb minor Low Saturation	0.08
- 7	D minor Green	0.03	- 17	E minor Yellow	0.11
+ 8	D# minor Yellow	0.03	+ 18	G minor Low Saturation	0.12
- 9	B minor Purple	0.04	+ 19	F# minor Blue	0.13
- 10	C minor Purple	0.04	+ 20	B minor Blue	0.13

In the 1997 study the most significant cell is positive ('Yellow' and A major for half the participants), while the second is negative ('Yellow' and Eb), and the next five associations are positive ('Violet' Eb, 'Yellow' Ab, 'Yellow' B and 'Green' F). Here, in contrast, there is a slightly tendency towards more negative cells being significant than positive ones. The causes of the difference in distribution between the 1997 study and this one are unclear, although one possibility is that in the earlier study a much larger proportion of the significance of the results concerned the colour yellow (52% of the chi squared value compared to 33% here). The earlier study found Yellow to be strongly influenced by pitch height as measured by the number of significant results. Since yellow is the lightest colour and it accounted for a much greater proportion of the significance, i.e. the value of chi squared, in 1997 than it does here, it can be concluded that pitch height and colour brightness played a greater role.

It is possible that this is caused by the more remote intervals that tend to prevail in the minor key compared to the major, since minor keys containing more augmented and diminished intervals do not reinforce the fundamental pitch with higher harmonics at the same magnitude. Different pitch heights would therefore have been more likely to produce specific choices in the earlier study, whereas in the present study chroma factors may be more apparent and operate in a way which is more likely to exclude single categories for a given key (i.e. negative associations) than to include them (positive associations).

As with the earlier study's results, there seems to be little correspondence between the cycle of fifths and the colour circle in the way in which Skryabin's major colour keys were found. For example, C minor is predominantly yellow while G minor is predominantly purple and has very few yellow associations. D minor is predominantly red, chromatically being between the yellow of C and the purple of G, as opposed to continuing in the same direction. When the keys are arranged in the order of the cycle of fifths yellow associations are be alternately high and low, with the exception of D# minor and Bb minor, where yellow is high in each case.

The 'inconsistencies' continue, whereas with a cycle of fifths relationship adjacent keys on the cycle had similar colour associations and the next key adjacent showed a continuation of any change between the initial two, so that if A minor is mainly red and slightly yellow, as it is here, E minor could be half red and half yellow and B minor could be mainly yellow with a little red and a little green.

Of the individual participants, only eleven of the 53 showed any notable degree of cycle of fifths patterns, and none of these continue consistently for all twelve keys. The closest fit in the study is probably Participant 49, whose associations were as follows, A minor pink, E minor light caramel, B minor dark emerald, F# minor amulet (a very dark green), C# minor emerald green, G# minor dull lime, D# minor pale, soft blue, Bb minor misty indigo, F minor greenish sand, C minor *dusk pink*, G *minor* aquamarine, D minor lavender. This shows a general shift from pink (in the red part of the colour circle) at A minor, to light caramel (yellow part of the colour circle, moving through greens and blues, arriving at 'lavender' for D minor and leading back to the pink at the start. G# minor and C minor show slight deviations from this but still conform to the general colour area, while F and G minor show greater deviation. Each transition between colours for associated keys, with C minor excluded since it is a contrasting colour to F and G minor, is no more than one quarter of the way round the circle, as mapped by the International Colour Standard (Kornerup & Wanscher 1967, pp 241-243) than the previous one (for example C# minor, emerald green to G# minor; dull lime is about one sixth of the way round the circle). This means that each of these colours is in the same quarter of the colour circle as those of adjacent keys. The chances of this happening is 0.5 (for the two tailed hypothesis of E minor being a quarter or less away from A minor in either direction) multiplied by 0.25 (predicting that they all continue in the same direction) to the power of ten. This gives a significance of 0.0000048 to two significant figures, hardly indicating coincidence.

The associations of participants 40 and 51 are of special interest because of their similarity: for G minor both selected exactly the same colour - pale violet, and their F# minor selections are also very close. Their selections were made as indicated in Table 9 below.

TABLE 9

	Participant 40	Participant 51
A minor	Emerald	Brownish Red
E minor	Dusk Pink	Chocolate
B minor	Paste Green	Misty Blue
F# minor	Dark Brown	Reddish Brown
C# minor	Smoked Amber	Pale Gold
G# minor	Brownish Red	Bluish Grey
D# minor	Flesh Orange	Bright Yellow
Bb minor	Sand/Topaz	Pale Tangerine
F minor	Bluish Grey	Brownish Red
C minor	Bright Tree Green	Apricot
G minor	Pale Violet	Pale Violet
D minor	Flesh Pink	Flesh Orange

In these cases there is a unanimous violet at G minor. This colour modulates round the colour circle in accordance with the cycle of fifths to produce other hues (although there are a few inconsistencies), so that the colours are dark reds between A minor and F# minor, within the orange and yellow area at the extreme keys, while B minor is green for participant 40 and blue for participant 51. Both participants have four associations which violate this pattern to varying degrees. Concerning cycle of fifths relationships and the colour wheel, a difference between this study and the earlier one is that here, where cycle of fifths patterns are to be found, the participants concerned do not have particular musical abilities or tendencies towards AP. A further difference in the results is that yellow did not work in opposition to blue or purple (i.e. yellow did not have opposite associations with keys to those of blue or purple; the former study used the category 'Violet' rather than 'Purple').

Of the keys that produced significant results (F#m, G#m, Bbm, Cm, Gm and Dm) three of the ten possible combinations of most and least selected categories do not occur, these being green in opposition to blue, green in opposition to purple, and blue in opposition to purple. The other seven possible combinations occur in more or less equal proportions. The implication is that that the colours in the blue area of the colour wheel are in positive association with each other together while the reds, oranges, and yellows operate less unanimously.

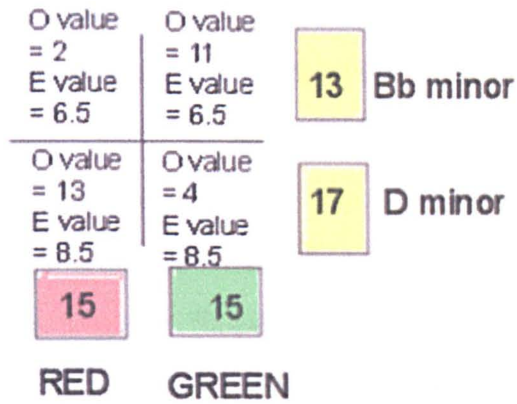
While the results are very unlikely to have occurred by chance variations alone, it is necessary to address factors that they could be measuring apart from a definite link between colour and pitch class. The differences in choice of colour could, for example, be a product of how many times participants had heard the extract. This would mean that Bb minor was usually yellow or purple, and hardly ever red simply by virtue of its being the second presentation, and that if another key had taken its place it would have been associated with the same colours). If this is the case it is hard to detect since few order effects are apparent

What is evident regarding brightness and pitch height influence may be summarised as follows. Firstly, 'Yellow' is responsible for a smaller proportion of the overall result than in 1997. Secondly the most significant cell is negative for 'Red' (neither a dark or nor a light category). Thirdly the most significant cell in the chi squared matrix concerns an intermediate pitch (C minor transposition) rather than one where pitch height is at one extreme or the other. Fourthly, the three highest pitches favour yellow less, with the D minor transposition not favouring the colour at all. Lastly, the lack of pitch height/lightness is further emphasised by the 'Blue' category contributing the least to the overall statistical significance of the results. Rank correlations between yellow and pitch height (where we are testing for a positive correlation) and purple and pitch height (where we are testing for a negative association) give results that show that pitch height is a significant factor. The results of these correlations are shown in Table 10 overleaf.

TABLE 10

Key	Yellow Rank	Purple Rank
D#m (1)	2	10
Dm(2)	5	5.5
C#m(3)	4	8
Cm(4)	1	11.5
Bm(5)	6.5	11.5
Bbm(6)	3	6
Am(7)	6.5	5.5
G#m(8)	11.5	8
Gm(9)	11.5	2
F#m(10)	10	3.5
Fm(11)	8	8
Em(12)	9	3.5
Correlations with key pitch ranking (-1 - +1)	+.757	-.538
Statistical significance for one Tailed test.	p<0.0000002	p<0.05

Although we can be almost certain that yellow is connected with pitch height, the connection of purple and pitch height is only just statistically significant. This is probably because there are light purples as well as dark purples whereas most purples are light. On a re-run pitch height differences could be reassessed by making the range of the transpositions different, for example making C minor the lowest pitch and B minor the highest. Nonetheless, as with the 1997 study there are still significant consistencies of choices that concern just red and green, two colours whose lightness tends, on average, to be approximately the same. Using a chi squared test for association of 'Red' and 'Green' with D minor and Bb minor, it is found that shows that the former key Red and the latter key is Green, (chi squared = 11), (d.f.=1), (p< 0.002) as shown overleaf.



This test shows that although pitch height and colour brightness are very closely related, differences between red and green associations such as the one shown above indicate that there are other factors at work as well. It is necessary to attribute these to a consensus of association between people of certain hues and with certain keys. Quite how these arise and operate is not clear. The semantic differential experiment with keys and colours (Chapter 11) clarifies this further.

The significance of the results of the study shows that within the experimental context certain keys tend to be associated with certain colours. Consequently the study is supportive of the proposal that certain keys have a connection with certain colours. This shows the existence of colour's connections with musical key, and raises the issue of whether coloured hearing is of a similar origin to AP. The study implies preconscious awareness of absolute pitch class in many individuals without AP. This manifests itself here, also, in a preconscious presence of coloured hearing which shows some consistency between participants. This suggests that AP is, in non-synaesthetes, present at the same pre-processed level as chromaesthesia. In the same way that this and the 1997 study have found synaesthesia, or something akin to synaesthesia, in those generally supposed not to possess it, it has found AP in those who would not normally be said to possess it. Levitin has found by examining the keys of reproduction of well known melodies that many more people do have AP than are aware of it (Levitin 1994).

Working on the prevalent but somewhat controversial basis that both synaesthesia and AP are said to be unlearned during a child's early years (Bachem 1953, Harrison 2001), there is increased support for the notion that AP, like chromaesthesia, is a manifestation of preconscious workings.

It would have been rewarding to have found a cycle of fifths related patterns with key and musical pitch as given by Skryabin but which here and in 1997 only a small minority of the total of 103 participants that I had; besides which how consistent would Participants 40 and 51 have been over time. Even in those cases we cannot say that an innate system of association exists since rationalisation, convention and learning are equally plausible explanations both for Skryabin and the current participants. Being aware of the differences between spontaneous and pre-planned associations helps us to avoid the risk of using the term 'chromaesthesia' to refer to the perceptions of people who report seeing colours but who in reality fall into the latter category.

There is both scope and value in conducting future investigations into the proportion of the population that have both preconscious synaesthesia and AP. It is still likely that some people are not born with AP. Other empirical research in this thesis on synaesthesia, on synaesthetes, on non-synaesthetes, and concerning the role of language in cross modal image formation, helps to shed light on some of these questions, but this experiment was specifically geared towards the issue of colour and absolute musical tonality. Similar and replica studies are probably the best ways in which support for these speculations may be strengthened, an important part of which would be any evidence for cross-cultural cross-modality.

8. The Quality of Compound Sounds and its Relation to Colour: Are Synaesthetic Perceptions of Complex Sounds Based on Frequency Analysis?

INTRODUCTION

For the purposes of this thesis, I have obtained feedback from various synaesthetes, through a questionnaire consisting of 20 questions including some about the types of sounds that are coloured for them and also more generally. I have also analysed other reported cases listed in sources such as Cytowic's 'A Union of the Senses' (1988). The evidence is that the colours of sounds seen by these different cases, whether the sounds are harmonic or inharmonic, are influenced by a wide range of parameters. The parameters that are especially important are absolute and/or relative pitch, and timbre. According to Cytowic, one of the characteristics of synaesthetes' trans-modal perceptions is that they are durable - that is to say that they are consistent over time (Cytowic 1994, pp 76-77), so that if a C523 played fortissimo on a horn is red for a particular synaesthete it will always be that colour. What Cytowic does not establish, however, is whether the same colour connection is arbitrary and or whether each secondary sensation relates to the frequency components in the sound. The significance of this question for the biological basis of synaesthesia is whether the auditory information is still recorded as a set of separate components or whether it becomes a pitch with a given timbre during the preconscious process in which the secondary image is 'generated'. If the secondary sensation relates directly to those produced by the frequency components present on their own, then it means that the sound retains its Fourier analysis at the point when the secondary sensations are generated. If there is no direct link between frequency components and secondary sensations then there are two possibilities regarding what the secondary sensations are responding to.

A possibility is that the secondary sensations could arise even before the recipe is established, i.e. from the raw waveform, prior to component analysis. This is quite unlikely, however, since the basilar membrane in the cochlea has already began to convert sound energy into separate sinusoids, and therefore such a hypothesis requires some connection between preconscious operations and the outer (i.e. pre-cochlean) ear. It is much more likely that secondary sensations are triggered at a more advanced stage in the process and that they are responses to more complex textural or aesthetic attributes which constitute later processing than that of Fourier analysis or of the initial time domain pattern. In other words if the secondary sensations within a complex tone cannot be determined by the tone's recipe then the alternative possibilities concern their generation either before (in the first case) or after (in the second) the frequency analysis. Both timbre and pitch are predominantly determined by the same parameter of sound, namely frequency: if either the pitch or the timbre of the sound or sound complex changes, then so also does the presence, absence, and/or intensity of some or all of the frequency components. This suggests that the colours may be determined by the presence of these components regardless of context.

To test the hypothesis an experiment was devised to be run on chromaesthetes which uses certain components in different contexts, with varying additional components. More specifically, 49 different components were used and these are shown in Table 11 under 'Materials'. Using only these components, 98 sound complexes were made. Each sound complex consisted of a selection of five of the 49 components.

The idea of this arrangement was that it made it possible to observe the effect that each component had on the colours that are sensed by the chromaesthetic participants. For example, if the only sound complexes producing the colour orange are 2, 13, 15, 22, 38, 48, 53, 65, 73 and 89, for a given participant, and these and only these sound complexes contain a 1432Hz component, then a connection can be made between 1432Hz and orange.

As there are 98 complexes containing five components each, there are 490 sinusoids used if duplicates are included (98*5). In order to distribute the 49 components evenly these must all appear exactly ten times (490/49). This means that each component is absent in the other 88, presentations.

The experimental hypothesis is that choice of colour for the synaesthetic participants will, in part, be determined by whether a frequency is present of absent. The null hypothesis is that such a relationship will not exist as each compound sound, although consistently coloured will in no way reflect the components out of which it is composed.

METHOD

PARTICIPANTS

Four participants (all male, age range 32-49) took part in the study. They all had coloured hearing synaesthesia and were selected for that reason. One was in Sheffield and the other three were in Northampton. All had studied music as adults to some level.

DESIGN

A repeated measures design was used, in which all four participants experienced the same experimental stimulus in exactly the same order - this being a series of 98 tone compounds.

MATERIALS

A compact disc was prepared 98 containing combinations of 49 frequency components. The 49 components were selected to correspond to partials belonging to one of seven pitches (103Hz, 127Hz, 137Hz, 149Hz, 157Hz, 181Hz and 193Hz):- there being seven components belonging to each of those seven sets. In order to make them sound more like natural sounds in combination where mechanical resistance and, to a lesser extent, changing air pressure makes waveforms alter slightly over time, some of the harmonics were altered slightly so as not to be exact multiples of the fundamental. Sounds were further made to imitate the real sound world by making the middle frequencies have more power than the outer frequencies.

The amplitude of the components was given a normal distribution curve function centred on 800Hz and with one standard deviation corresponding to two octaves (i.e. 200Hz and 3200Hz were one standard deviation away from the centre). This function determined linear power as opposed to decibels.

49 of the complexes were allocated as 'pitch', for these five tone components were taken from the same set (seven of each) and the other 49 were allocated to be 'noise', and for these the five components were taken from different sets. The components were arranged on a compact disc so that each component was present in ten presentations and absent in the other 88 (the arrangement of the tones is shown in the Appendix). Each tone lasted five seconds, followed by a one second gap. The frequency components used are shown in Table 11 below.

TABLE 11

103	127	137	149	157	181	193
103Hz	127Hz	137Hz	298Hz	157Hz	1267Hz	193Hz
206HZ	381Hz	411Hz	447Hz	314Hz	1448Hz	965Hz
309Hz	887Hz	685Hz	596Hz	785Hz	1629Hz	1351Hz
721Hz	1143Hz	959Hz	745Hz	1099Hz	1810Hz	2509Hz
824Hz	1387Hz	2055Hz	894Hz	2699Hz	1991Hz	3367Hz
927Hz	1641Hz	2593Hz	1043Hz	3611Hz	2172Hz	4439Hz
1133Hz	2149Hz	2867Hz	1192Hz	4673Hz	2353Hz	5983Hz

PROCEDURE

As each of the chromaesthetic participants had the compact disc played to them, they were required to indicate any colour or colours that they saw as secondary sensations while each of the 98 tones were playing. These were noted on response sheets which had the sound numbers (1-98) listed as the rows with the columns consisting of the eleven basic colour terms (Berlin & Kay 1969) to the right of them. Participants ringed the colours that they perceived as secondary sensations (It was thought that as synaesthetic responses are constant over time that there would be no danger of order effects interfering with the outcome of the experiment). Participants were given instructions as shown below.

> In a minute you will hear 98 sounds, lasting five seconds each played through headphones. In front of you is a list of numbers, 1-49 on one, side 50-98 on the other, with colour names by the side of them. For each of these you are required to ring any colours that you see in association with the tones. If you lose track at any point then let me know and tones can be repeated. When you are ready, we can begin.

As mentioned in the introduction, every one of the 49 frequency components was used in ten of the tone compounds and only ten, it being absent in the remaining 88, it was therefore possible to analyse how each component influenced the colour selections made by each participant. This was done by comparing selections in the ten presentations with a given component to the 88 without it. This was carried out for each of the 49 components.

To process the data in this way chi squared tests were used. In each case the contingency table was 2x2, one dimension being component present / component absent, the other dimension being colour 'seen' / colour not 'seen'. These statistical tests could involve any colour or combination of colours.

Sometimes two or more colours were used on a test, in which case all of the colours were treated as one entity. For example, if brown, yellow and green were tested with respect to the 927Hz component, and sound complex No. 10 (which contains it) had been marked for one, two, or all three of these colours, then it would count as a single case for component present and colour present.

It must be emphasised that synaesthesia is different for each synaesthete and that it cannot be expected that the colour of the 447Hz component, for example, will be the same for every synaesthete. It may only be expected that if it is red for one chromaesthete it will always be red for that individual. Accordingly, all analyses are specific to each of the four individuals.

RESULTS

The results for the two participants with significant results are listed in order of significance below:-

TABLE 12
THE RESULTS OF THE TONE COMPONENT EXPERIMENT IN ORDER OF SIGNIFICANCE FOR TWO PARTICIPANTS.

TONY

	Freq.	Colour(s)	Chi sq		Freq.	Colour(s)	Chi sq		Freq.	Colour(s)	Chi sq
1	4439Hz	Y,O,Pk	11.14	31	1387Hz	Blue	06.21	60	1810Hz	W,G	04.60
2	1351Hz	Blue	10.15	31	3367Hz	G,P,O,Pk	06.21	64	1351Hz	Bk,G,O	04.41
3	1351Hz	Bk,R,G,O	09.91	34	447Hz	G,Br	05.72	65	824Hz	Bk,G	04.24
4	745Hz	Br,Pk	09.85	34	4439Hz	G,Br	05.62	65	1641Hz	Bk,R	04.24
5	4673Hz	Bk,G,P	09.66	34	2172Hz	G,Br	05.72	65	4673Hz	Bk,G	04.24
6	411Hz	G,B,P,Pk	09.18	37	4439Hz	Y,O	05.69	65	1991Hz	G,P,O,Pk	04.24
7	596Hz	Y,O	09.05	37	4439Hz	Y,Pk	05.69	65	206Hz	R,W	04.24
8	2172Hz	Br,Pk	08.95	39	411Hz	Bk,Y	05.49	65	2509Hz	R,P,Bk	04.24
9	4439Hz	G,Y,Pk	08.71	39	1089Hz	B,P	05.49	71	1143Hz	Y,Br	04.15
10	685Hz	B,Pk	08.24	39	3611Hz	B,O,Pk	05.49	72	5983Hz	R,G,Pk	04.04
10	1387Hz	B,Pk	08.24	42	1043Hz	W,G	05.47	73	927Hz	Bk,Br	04.03
12	447Hz	Br,O	08.01	42	1192Hz	G,P	05.47	73	1641Hz	W,Pk	04.03
12	596Hz	Br,O	08.01	42	1351Hz	Bk,R,G	05.47	73	157Hz	W,Pk	04.03
12	2509Hz	R,G,P,Pk	08.01	45	1133Hz	R,Br	05.32	73	2699Hz	BkG,P,Pk	04.03
15	824Hz	Bk,Br	07.77	45	745Hz	R,Br	05.32	77	103Hz	Y,P	04.01
15	2699Hz	W,Pk	07.77	45	5983Hz	RG,P,Pk	05.32	77	596Hz	Y,P	04.01
15	2509Hz	BkG,P,Pk	07.77	48	3611Hz	Bk,B,Pk	05.27	77	2509Hz	R,G,P	04.01
15	3367Hz	B,Pk	07.77	49	1387Hz	G,B	05.04	77	5983Hz	R,G,P	04.01
15	4439Hz	Y,O,Pk	07.77	49	411Hz	W,P	05.04	77	5983Hz	R,G,O,Pk	04.01
20	2509Hz	BkR,P,Pk	07.36	49	157Hz	W,P	05.04	82	3611Hz	B,P,Pk	03.93
21	2149Hz	B,O	07.31	49	1089Hz	W,P	05.04	83	314Hz	R,G,Pk	03.84
22	2509Hz	BkG,B,Pk	06.90	49	4673Hz	W,P	05.04	83	2509Hz	R,G,Pk	03.84
23	1641Hz	W,O	06.85	49	1810Hz	W,P	05.04	85	447Hz	Brn	03.81
23	3367Hz	B,O	06.85	55	1351Hz	Bk,R,O	04.86	85	745Hz	Brn	03.81
25	103Hz	G,Y	06.66	56	1810Hz	Bk,Pk	04.79	85	1043Hz	Brn	03.81
25	411Hz	G,Y	06.66	57	2149Hz	R,B	04.67	88	596Hz	G,Y	03.62
25	298Hz	G,Y	06.66	57	3611Hz	R,B	04.67	88	4439Hz	G,Y	03.62
25	1448Hz	Bk,W	06.66	57	193Hz	R,B	04.67	90	795Hz	,O	03.61
29	3611Hz	R,B,Pk	06.62	60	381Hz	W,G	04.60	90	1089Hz	B,O	03.61
30	5983Hz	RG,P,OPk	06.40	60	157Hz	W,G	04.60	90	3611Hz	B,O	03.61
31	889Hz	Blue	06.21	60	2699Hz	W,G	04.60	93	2055Hz	R,G	03.51

AIDEN

	Chi sq	freq.	Colour(s)
1.	10.63	381Hz	BkWYGy
2.	9.83	1267Hz	BkRGy
3.	8.22	1387Hz	BkW
4.	7.81	381Hz	BkWGy
5.	6.17	309Hz	RGYB
6.	6.00	381Hz	WYGy
7.	5.98	894Hz	BkRYBrn
8.	5.91	824Hz	RW
8.	5.91	1641Hz	BkRBrn
8.	5.91	1810Hz	RW
11.	5.76	381Hz	BkWY
12.	5.30	1267Hz	RGy
13.	5.08	103Hz	BkR
13.	5.08	1267Hz	BkR
15.	4.65	1133Hz	RG
15.	4.65	894Hz	BkRBrn
17.	4.44	894Hz	BkRY
18.	4.33	1641Hz	BkWRBr
19.	4.24	1043Hz	RGBrn
20.	4.11	381Hz	WGy
20.	4.11	4439Hz	WGy
22.	4.03	309Hz	RGY
23.	3.81	721Hz	WhRG
24.	3.70	2509Hz	GGy
25.	3.65	309Hz	GYB

Tony had the most associations that were significant, followed by Aiden. This demonstrates that for them there was an association between coloured secondary sensations and the presence or absence of certain frequency components in the stimulus. In those two cases, where there are a large number of significant results, it is possible to plot the association colours on an audio frequency axis, showing where the red frequencies are relative to the blue ones, for example. The results of this, for the most significant of Aiden's and Tony's associations are shown in Table 13.

TABLE 13

The range of colours selected with high consistency in connection with the frequency components on the tape for Tony and Aiden.

Component	TONY	AIDEN
5983 Hz	R*,G*,P,O,Pk	
4673Hz	W,Bk,G,P	
4439Hz	G,Y,B,P,O,Pk	
3611Hz	Bk,R*,G,B*,P,O,Pk	
3367Hz	B,O,Pk	
2699Hz	W,G,Pk	
2509Hz	Bk,R,G,B,P,Pk	
2172Hz	G,Brn*,Pk	
2149Hz	R,B*,O	
1810Hz	Bk,W*,G,P,Pk	W,R
1641Hz	W,O	Bk,R,Brn
1448Hz	Bk,W	
1387Hz	G,B**,Pk	Bk,W
1351Hz	Bk,R,G,B**,O	
1267Hz		Bk,R*,Gy
1192Hz	G,P	
1133Hz	R,Br	R,G
1089Hz	W,B,P	
1043Hz	W,G	
894Hz		Bk,R,Y,Brn
889Hz	B**	
824Hz	Bk,Br	W,R
795Hz	O*	
745Hz	R,Brn*,Pk	
685Hz	B,Pk	
596Hz	Y,Brn,O	
447Hz	G,Brn*,O	
411Hz	G*,B,P,Pk	
381Hz	W,G	Bk,W*,G,Y,Gy
309Hz		R,G*,Y,B
298Hz	W*,G,Y,P*	
193Hz	R,B	
157Hz	W*,P,G	
103Hz	G,Y	Bk,R

** = Colour/frequency association is significant for single colour, * Most significant colour(s) for a particular frequency.

There is little large clustering of any colour in any frequency band, in either Tony's or Aiden's case, but with respect to what clustering there it may be observed that Tony has three main colours that correspond to frequency areas. Above 2000Hz pink predominates

(Tony subsequently said that the colour that he saw was more of a 'flesh-coloured-going-on-fawn' colour that he sees regularly as a secondary sensation), meaning that musical sounds are more likely to be 'seen' as that colour if the harmonic content is high. Use of chi squared for frequency components with and without pink and frequency associations above and below 2000Hz showed a high level of statistical significance ($p<0.01$).

DISCUSSION

Tony seems to have a moderate degree of yellow and brown clustering at frequencies below 800Hz which the chi squared test showed as not significant ($p=$ c.a. 0.09), but the test showed it to be much more likely that low frequencies produce these colours for Tony than that the results occurred by chance alone. An assessment of more frequency components may have produced a $p<0.05$ result.

Brown and low frequencies tend to go together in non-synaesthetes owing to the former's darkness. Dark colours and low frequencies were found to correspond in non-synaesthetes, as were light colours and frequencies, according to 'The Law of Universal Brightness' (Marks 1974, see Chapter 9). For Tony, however, yellow also connects to these frequencies. This combination is unlikely to be found in non-synaesthetes.

This is highlighted by the optical complementary colour to yellow, blue contrasting it by being statistically significant ($p<0.01$) in higher frequencies (above 1300Hz), but especially in the first two above and in frequencies between 3500Hz and 4500Hz, that latter frequency band accounts for the bright hard edge of sounds. It is likely that blue's being complementary to yellow is of some consequence as it means that contrasting sound colours produce contrasting visual colours. Given that colour is conceptually coded in red/green and blue/yellow, it could be that in Tony's case the latter is more closely connected to his synaesthetic faculty than the former, although the significance of the pink cluster with the higher components suggests that there is some association in the red/green dimension as well.

A less comprehensive stratification of colours can be found for Aiden. The range of associations is also smaller. There are for example very few significant associations for frequencies above 2000Hz, green and grey are just significant ($p<0.05$) for 2509Hz:. For $p<0.01$, the threshold on the table, the highest frequency is 1810Hz producing red and white. For Aiden all middle frequencies have red associated with them except 1387Hz which is just black and white. Since red predominates generally, only a small level of significance can be established for this ($p<0.025$).

. Aiden has few low associations but those that do exist include all colours with no significant clusters being established. For two low frequency components yellow is significant at $p<0.01$ and in one case blue is. Yellow is significant at this level for only one middle frequency component.

Apart from these exceptions all the colours consistently connected with given frequency components are red, green, black, white and grey. All clustering, is restricted to these colours, implying that the stratified colour/sound connections are only 'finely tuned' for the red/green and black/white dimensions. A combination is also found in Downey's study of a case of coloured gestation (Downey 1911) (see Chapter 14).

As with Tony, red seems to have more connection to the sounds than green. The predominance of red coding over green coding was found by Marks in non-synaesthetes in connection with coloured vowels. The range of frequencies where Andy's associations are most consistent is in the band where the first and second formants of vowel sounds are (Marks 1974, see next chapter). This is evidence for the coloured vowel type of association being more common than is generally thought.

It is generally the case, especially in the imaginations of non-synaesthetes, that different octaves of the same pitch class are 'seen' as different brightnesses of the same colour as shown in the colours of Castel's ocular harpsichord described in Chapter 5. In this study, however, there is no similarity between the colours of the same pitch classes in different octaves in either case. This is inclusive of the possibility that Tony's and Aiden's synaesthesias are organic, insofar as their secondary sensations are beyond conscious control. Intellectualised approaches, by contrast, often adopt the octave similarity scheme, presumably because different octaves of the same pitch class seem to be similar in a very special way, to the musically developed ear.

While a stronger cross-spectral pattern might have been expected than was actually present, what our tests indicate remains supportive of the notion that the colours 'seen' by coloured hearing synaesthetes for a given sound complex are directly related to the colours 'seen' for the components present in the sound. It must be emphasised that only claim made by the experimental hypothesis is that cross modal connections would be consistent and not that there would be similarity between proximate frequencies. It is, after all, probably not in the nature of synaesthetic perceptions that there should be any such recognisable patterns, since primitive responses to sensations, which are trans-modally unified, seem not to exist in forms that the linguistic cortex calls 'rational'. The fact that there was a high level individual consistency observed is particularly significant in the light of how difficult it is for the rest of us to consciously identify the various frequency components within a complex sound.

In connection with the above point on the nature of synaesthesia, as clinically defined, any secondary sensations that are perceived by a synaesthete must be regarded as real irrespective of the extent to which this can be scientifically measured. The statistical testing of sound to colour linkage only served to test a hypothesis of how synaesthesia might work and this hypothesis is supported by the findings of the experiment. This association, which is demonstrative of the colours produced being a direct result of the respective frequency response being present in certain tone complexes, would not have been expected, but for the experiment's hypothesis and its underlying theory. What this indicates is that the place where auditory stimulus registers as colours as well as sounds, in chromaesthetes represents the latter in the relatively raw form of a spectrum of frequency components. This is support for the widely held notion that synaesthesia is a pre-conscious faculty which is derived from unprocessed sensation selections being made.

A minor concern with this interpretation is that in order to find out which connections existed it was necessary to carry out numerous tests; enough, in fact, to make an occasional $p<0.05$, or even $p<0.01$ results almost inevitable. The likelihood of such results occurring by chance was tested with random colours being given for 50 imaginary participants. This produced between two and seven (mean 3.42) $p<0.05$ associations per 'participant', less than a third of Aiden's and less than a tenth of Tony's even in the least chance-like of the 50 cases. This shows two things; firstly that the vast majority of results are unlikely to mean very much, but secondly that the overall result is probably meaningful. What we can say, and all that we can really say for certain, is that the issue of consistency over connections made by the four participants (as opposed to the connections themselves) for the different frequency components in the experiment can legitimately be extrapolated to the general experience of synaesthetes and that the experiment has proved to be a valuable contribution to this thesis. In the next investigation these random generated choices could be substituted by real participants without synaesthesia. This will involve non-synaesthetes taking part in the experiment and applying to their responses the same statistical procedures as the synaesthetes and seeing if the significance of these results matches those of the synaesthetes. The only perceivable difficulty with this is the likely feeling of the non-synaesthetic participants that the exercise of naming colours is, for them futile. This is probably, however, a minor hurdle and non-synaesthetes in addition to synaesthetes may be used in a future investigation.

9. Colour and Non-Visual Stimuli.

Up to this point colour has been addressed as part of visual experience. This chapter looks at colour from the perspective of its relating to sensations from other channels, and how sensations normally associated with these channels such as touch or hearing relate to colour. The relationship between the senses is borne witness to by phrases like 'cold colour' and 'warm colour' and the acoustic term 'timbre' meaning tone colour. A question raised by the above observations on language is 'Are these terms merely convention or is there some underlying unity of the senses'? It is quite possible that while most people use cross-sensory language unconsciously, it first arose as a consequence of analogies between qualities of different modes of sensation. They could have been transmitted verbally between generations which would mean that the terms would be expected to agree with the experience of most people. That we generally agree on some analogies, such as red and hot can be demonstrated by their similar effect on the body. The body reacts to a hot object by producing adrenaline which facilitates a faster escape from the object; this same reaction occurs (to a much smaller extent in well adjusted people) when confronted by a bright warm colour (Steiner 1992, p 35). Similarly a loud noise or strong smell is analogous to the above perceptions in terms of their effect. These four sensations although in different modes are united by their intensity (Marks 1978, pp. 187-188).

The idea of an intensity scale for each of the sensory channels was suggested by Weber (1795-1878) and Fechner (1801-1887). The Weber-Fechner law proposes that we perceive stimulus intensity for all of the senses on a logarithmic scale of just noticeable differences (Padgam & Saundey 1975 p. 55). For example, to detect one coffee sample to be more bitter than another, the difference in bitterness between them would have to exceed a minimum ratio, in this case about 6:5 (Briggs, Hough, Stevens & Young 1981).

The implication of the Weber-Fechner law is that all of the senses work according to the same laws. In the 1950s, Stevens developed this implication of a unity between the senses into the Stevens Power Law. He stated that people could quantify a stimulus from any sense numerically (Marks 1978, p 193). Steven's Power Law has been developed by many researchers but, most notably, by Marks. Marks elaborated on the notion that all sensation has much in common. He points out that in Stevens' experiments, where people were at times required to match stimulus intensities between senses (e.g. 'which noise matches the intensity of this smell') or produce an intensity to match a stimulus (e.g. 'clasp my hand according to the intensity of the sound'), that they were surprised how easy they found this to do (Ibid.).

A second way in which Marks expanded on the Weber-Fechner principle was by supplementing the notion of universal intensity with that of universal brightness. For an isolated light, its brightness constitutes intensity, therefore having an analogy with the loudness of a sound. The situation is slightly different, however, regarding a selection of objects (cards for example) of varying brightness viewed in a fixed light. The extent by which a darker and lighter grey differ from each other has an analogy with sounds having different pitches, higher sounds corresponding to lighter colours. Marks called this the Doctrine of Universal Brightness. Examining the sound spectra of vowels, and treating the lower frequencies as dark and the higher frequencies as light, Marks applied this doctrine to vowel sounds in order to allocate them colours in somewhat more systematic way than French symbolist did (see Chapter 4).

The most fundamental feature of the sound spectra of vowels is the lowest and strongest two of a number of amplitude peaks called formants, the first of which is labelled *f1* and depending on the vowel sounds is between 250Hz and 700Hz and the second of which is labelled *f2* and is between 800Hz and about 2400 Hz. It is the second of these formants that determines the perceived brightness When *f2* is towards the 800Hz end of its range, a vowel is perceived as being low and therefore dark, whereas when *f2* is towards the 2400Hz end of the range, a vowel is perceived as being high and light (Marks 1974).

It seems that 'dark' and 'light' vowel sounds are perceived as such almost universally throughout the population, although the functional value of vowels in language means that they are ignored in the conscious mind of the practical adult. However this is different in young children, Marks reports

> A five year old girls says 'My father talks like Santa Claus 'boom boom boom', but we talk like the daytime 'bim bim bim''.
>
> (Marks 1978, p 207)

Marks gives a quotation from the French Symbolist poet and writer Mallarme (1842-1898) about his own poetic sense lamenting the fact that some (French) words had vowel sounds whose brightness contradicted their meaning, *jour* for example is a dark tone and *nuit* a light tone (Marks 1978, p 209).

In analysing vowel colours, Marks found, what seemed to be, a second, red-green dimension corresponding to the proximity of the two formants in terms of frequency. In general vowels are found to 'produce' reddish colours more often than greenish colours but where *f1* is low and *f2* is high, as for example in *ee* as in 'heel', then the tendency is towards a greenish colour, whereas if *f1* is high and f2 low (e.g. *aw* as in horn) then the tendency is towards red. There is, however a slight bias towards red in vowels generally so that the neutral vowel produces more red than green, *aw* is nearly always red, and *ee* only slightly more often green than red (Marks 1974).

While actually seeing colours in the presence of certain sounds is rare, it was established in the nineteenth century that the hearing of vowels as colours was relatively frequent. The majority of research on coloured hearing also relates to conceptualisation of vowels in colour, for example Sachs in 1812, Perroud in 1863 and Laurette in 1885 (Suarez de Mendoza 1890). Poets and musicians were also at that time describing their experiences of coloured vowels, especially those which were drug induced. In 'An Inquiry into the Human Faculty' Galton collected people's reports of coloured vowels and coloured forms and illustrated that in many cases, the written form of vowels and other letters are coloured and that coloured words often conform to the letter associations of the person so that if the letter 'A' is red when written down then the sound 'A' (rake) will also be red. Galton's observations on visual imagery in children, especially number, letter and time forms are discussed in relation to what used to be called 'psychochromaesthesia' (see end of /this chapter). Galton was among the first to seriously examine colours perceived or imagined for the written forms of letters as opposed to and in addition to the heard forms. He also implied that coloured hearing had an associative basis (Galton 1883, pp 250-259).

Associative Theory became the prevalent school of thought between about 1890 and 1930 (Cytowic 1994, p 83). It stated that if something was conceptualised as being a certain colour, then related concepts would also be that colour. The sound 'O' (post), for example, is associated with the letter 'O'. 'O' is the shape of an orange and it is the first letter of the word 'orange'. This provides two explanations of the relatively common association of the letter 'O' sound with the colour orange. Many people however associate the sound 'O' with white, again probably relating first to the written form basing their colouring on the physical aspects of the letter written on white paper, where it is white inside. From the audiological point of view, however, it seems that 'o' would not be associated with white as it is a slightly 'dark tone', *f2* being slightly lower than the unaccented vowel ('the') at about 950Hz and indeed for some people dark tones are reported for that sound.

A combination of appearance, associative and audiological factors was found in a 1998 survey that I conducted. The results of this survey are shown below:-

	Black	White	Red	Green	Yellw	Blue	Brown	Pink	Purple	Ornge	Grey
aye	8	10.75	51.75+	31.75	26.25	26	3	0	3.25	9.25	7
ee	1.25-	9.5	23.75	42.5+	37	34	5	1	3	12.5	8.5
eye	13.75	20.5	8.5	25.5	19.5	48.5+	4	6	19.75	6.25-	3
oh	14.75	23.25	14	8-	16.25	15	7.5	3	4.25	64+*	5
you	19	10	10	18.25	25.5	23.75	11.5	7	29+	8	9

* A frequency of 64 for Orange associated with 'oh' is the most significant result (chi =97)

A significant result at the $p<0.05$ level involves at least an average significance of 1 per square and the total chi squared in this case should be at least 55 in order to be significant. Chi squared is here slightly more than 340 and is significant beyond one in 100,000. (Rows do not add up to 180 (or the total 900) since participants were allowed the 'no colour' option. Non-integer numbers arise from split allocation of colour categories for non basic colours e.g. crimson was allocated .75 Red and .25 Purple. Plus and minus signs denote extremely significant (chi value >=9) results).

Associative Theory does not completely exclude the possibility of an audiological basis for coloured vowels. In fact some properties of association as a result of common experience even support it. For example, there tend to be more low sounds heard below our physical plane, where it is usually darker, and more high sounds above our physical plane, where it is lighter (Marks 1978, p327). This tends to have the effect of making low pitch sounds become associated with dark and high pitched sounds with light. These high-low/light-dark associations consequently influence the tones of the written letters, the higher the pitch the lighter the associated tone. Associative theory can be summarised as a theory that suggests that colour associations form as a result of associative links (Harrison 2001).

The end of the nineteenth century was an age of combining different concepts, ideas and sensations which Ostwald called 'an age of synaesthesia': 'Synaesthesia' has a somewhat particular meaning which may apply to parts but by no means the whole of the cross-modal concepts of the time. It was, of course, the generation when Wagner, influenced by early German Romantic writers and philosophers, conceptualised a complete and superior art form that combined music, drama, colour, Ancient Greek legend, poetry and anything else that would unite the arts into one work. It is therefore not surprising therefore that among musicians and theorists alike attempts were made to relate colour to music and one such set of associations that took root was between was colour and musical pitch. The first notion of musical pitches having different colours goes back at least as far as Pythagoras' Music of the Spheres in the sixth century BCE. Newton, on discovering the components of the spectrum gave each of the seven arbitrary bands (red, orange, yellow, green, turquoise (or blue), blue (or indigo) and violet) one of the seven diatonic scales degrees, and, as has already been discussed, colour keyboards have also been designed and occasionally made (e.g. Arcimboldo 1582 and Castel 1725). Following the development of Western tonality, certain musicians in the nineteenth century had ideas regarding colours and musical keys often *involving the idea is that the writer* and the listener should perceive one key as distinctly different from another key even if it has a similar pitch, for example Bb major and B major.

The first known notion of keys having colours was that of Hoffmann in a set of piano pieces, *Fantasiestucke*, published in 1815/6. This collection includes called an 'essay' actually written in 1810, *Johannes Kreslers der Kappelmeister, Musik Alische Lieden*, where he depicts Kreslers as having a C# minor coat and an E major collar (Scholes 1983). At about that time Beethoven described B minor as black (Scholes 1983).

The use of different keys in the operas of Weber for different moods, and colours seems inseparable some of the prevalent concepts of early German Romanticism. The music theorist, Reitmann in writing about Bach's 48 Preludes and Fugues described the key of A as green (Scholes 1983). That at least some composers thought in terms of colours is exemplified by reports of Liszt when conducting making comments such as 'more blue if you please' (Scholes 1983). At the end of the nineteenth century, Rimsky Korsakov (1844-1908) left us his very elaborate and apparently fixed key and colour associations which he provides for ten out of the twelve major keys. Whether or not the composer had Absolute Pitch (AP) is uncertain but he obviously had an interest in the absolute key of music. As referred to previously, Skryabin established his own key and colour associations. While Skryabin's associations are given in earlier documents they are nowhere better documented than in the composers introduction to his orchestral poem *Prometheus* (1911). This work is for orchestra and colour organ, but unlike many of the earlier colour instruments, the instrument does not make any sound, but only follows the chord and key structure converting the pitches into a display of lights of various colours. The colours correspond to Skryabin's association of the twelve keys and each has its own mood or concept as shown in Table 14.

TABLE 14

Key	Colour	Concept
C	Intense Red	Human Will
G	Orange	Creative Play
D	Yellow	Joy
A	Green	Matter
E	Sky Blue	Dreams
B	Blue	Contemplation
F#	Bright Blue	Creativity
Db	Violet-Purple	Will-of-Spirit
Ab	Lilac	Sprit-to-Matter
Eb	Flesh-Steel	Humanity
Bb	Rose-Steel	Lust
F	Deep Red	Diversification of-Will

(Skryabin 1980, p IX)

Some observations can be made about these associations. Firstly, related keys correspond to related colours; that is keys a fifth apart that share six notes in their basic pitch sets have colours that are adjacent on the colour circle. Secondly, the sharp side of the cycle of fifths contains a nearly full range of saturated colours while the flat keys have a smaller range of unsaturated colours with the colours for Eb and Bb least saturated. The most rapid transformation of colours occurs between the key of C and A with each of these four keys occupying the whole of one 'basic' colour area each in the spectrum. That related keys have related colours should be no surprise, but for Skryabin the tonic pitches of the keys also possessed the colours of the keys, with the exception of Bb (Scholes 1983).

The pitch classes on their own following the relationships of the cycle of fifths can be explained in one of two rational ways. It can be explained in terms of the Associative Theory described above. According to this theory, the pitches B and F#, for Skryabin, are both blue since they are associated with keys that are classed as blue as a result of an association with the six notes that the two keys have in common (B, F#, C#, G#, D#, A#). A second theory for two pitches a fifth apart being associated with similar colours is to do with the harmonic overtones of a sound. The third partial of a harmonic tone sounds at the same pitch class as the note one degree in a sharp direction on the cycle of fifths. The B a semitone below middle C, for example has F# on the top line of the treble clef as its third harmonic. This gives it a certain unity to F# tones where F# is the fundamental. The ninth harmonic, C# in this example, also sounds, since it is the third partial of the pitch a fifth in a sharp direction (here F#) and this is the fundamental of C# tones. B is therefore also connected to C# by its ninth partial.

Chapter 7 referred to how Skryabin's biographer, Sabeenev, compiled the colour and tonality associations of 32 subjects (Sabeenev 1929, see Chapter 7), one of whom was Skryabin, another himself and a third Rimsky Korsakov. It notes how he seemed initially to have just had three pitch/colour associations later developing some the others, and eventually relating the whole colour circle to the cycle of fifths.

For the 32 subjects, Sabeenev concluded that some keys produced more consistent responses between subjects than others. D had the most agreement with one colour, yellow (Skryabin's D Major Colour) and was given in 21 of the 32 cases. C Major had 25 associations that were either red or white; F major also had a majority of associations with two colours, this time opposites, red and green, while G major showed little consistency, the 32 people allotting it between them to any of the basic colour classes except blue. Sabeenev's investigation also included a larger survey on people's experience of colour in connection with music and found that out of 250 subjects, 226 had visual association of some kind. The largest number of associations was between pitch height and light and dark, in a way that is supportive of Marks' law of universal brightness discussed earlier. 176 however reported definite colours and by far the majority of these (170) were related to tonalities.

Sabeenev's study relates to tonalities rather than single to notes but, as I pointed out, Skryabin claimed that his colour associations applied not only to tonal pitch sets, but to the respective key note as well. Musical pitch can be classified in two ways: according to pitch height and according to pitch chroma or class (Revesz 1953, p 59). As stated in Chapter 7, pitch height is the model's one dimensional ladder from a low pitch to a high pitch whereas pitch class is what gives a pitch its note name regardless of octave. I can clarify the distinction between pitch class and pitch height as overleaf-

> The pitches 110Hz and 1760 Hz 'possess' the same pitch class (in modern concert standard, A=440) and in this respect they are alike. In terms of pitch height, however they are very different, as they are 48 semitones apart. On the other hand, the pitches 440Hz and 484 Hz, the first being A and the second being Bb, are in different pitch classes, but in terms of pitch height the difference is very small, only one semitone. Those without AP would certainly detect 110Hz and 1760Hz as different pitches but would not detect 440Hz and 484Hz as different if presented on separate occasions. AP possessors generally focus on the chroma classification at the relative expense of the pitch height classification, so that when tested they generally make more octave errors than musicians without AP.

Where pitch height can be visualised as a progressive change from darkness to lightness with the fundamental frequency of a tone, pitch class is the musical equivalent of the colour circle, as exemplified by the aforementioned colours of colour organs (e.g. Rimington 1863). For someone who associates colours with pitch classes each pitch class also has its own colour. The correspondences between the pitch and the colour vary from individual to individual but associating pitches adjacent in the cycle of fifths (G, D, A) to colours adjacent in colour wheel position (orange, yellow, green) is fairly common in those with coloured pitch classes. Many of the people who claim such pitch colour relationships have AP, but they often possess AP in a more partial and in a qualitatively different way to those without pitch to colour associations.

One amusing, if somewhat speculative, case of someone using associated or perceived colour to determine pitch was reported by Albertoni (1889). Albertoni's case was able to locate most notes by their colour and according to a scheme that he believed was inherent in the notes themselves. According to the system, the colours of the white keys were more vivid than the colours of the black keys and the notes associated with the basic colours according to what Albertoni speculated were blue for C, green for D, yellow for F and red for G. The subject however was reportedly unable to name the note G, which was attributed to his inability to associate the note with the colour. Albertoni called this 'Auditory Daltonism' in reference to the inability of the eighteenth century Quaker chemist to see red (Albertoni 1889).

Langfield reports a study by C S Myres who investigated the colour associations of a subject, once in 1905 and three times in 1912. The report emphasises the consistency of the subject's associations on the four occasions: while there might have been very subtle variations in most areas of colour association, there seemed to be few regarding musical pitch. The colours seemed additionally to obey the rules of colour mixing, for her G was blue and A was yellow but if both pitches sounded together the green which would result from the visual mixture (Langfield 1914). This case constitutes Case 11 of Chapter 14.

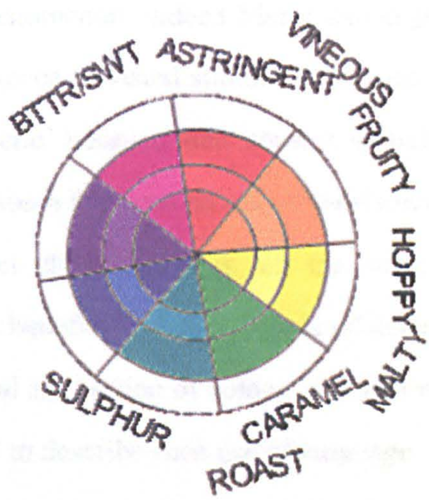
Such consistency has also been found in more recent studies such as Ostwald's patient (Ostwald 1964). Every sound that she heard registered a colour with musical pitch producing the greatest variety of colours. The consistency of these colours was tested for by an audiologist who found that the same words were consistently matched by the same colours. There is no reason to doubt that the same did not hold for her musical pitch associations especially as she also had AP (This is Case 7 of Chapter 14).

In the early 1980s there was some research focusing on the connection between AP and coloured hearing. Radocy & Haack studied one subject who possessed both (Radocy & Haack 1981), 'D', and Rogers studies four such subjects (Cases 3-6 in Chapter 14) and all of these five cases exhibited the same level of congruity as described above and furthermore most claimed, again, that but for the colours they would not attain behavioural AP (Rogers 1987). The aforementioned study by Block presented tones from an 8 foot flute, organ stop within the range of one octave (C262 - B492) to 22 subjects, ten with AP and twelve without, and then asked them to pick a colour from a range of 51 discrete colours arranged in a colour circle. She found more consistency for the colour selections of those with AP than those without, although each subject's associations were different from those of the other subjects (Block 1983).

COLOUR AND THE OTHER SENSES

So far this study's encounters with colour have mainly consisted of exploring the relationship of colour to sound and, more especially, to music. This is partly because of colour and music's long documented history and partly because music has become a well developed area with its own syntax, grammar and other features which has generally had much conscious attention paid to it. The relevance of referring to the other senses in this discussion is documented, however, by the fact that synaesthetes may have cross modal transfer between any combination of the senses (e.g. Downey 1911, Cytowic 1994), and yet visual aspects, usually including colour tend to play a part in most cases. Unlike sight and hearing, we are not so conscious of touch and taste-smell. In the case of taste-smell, we have a particular lack of relevant language to describe sensations. Smell appears to be connected to the brain in a way that bypasses language and sensations therefore have to be modified by consciousness before any descriptive words can be found (Cytowic 1994, pp9-11).

Tasters are somewhat limited in language to describe flavours. It seems that flavour perception, especially its olfactory element, is a preconscious function (Cytowic 1994, pp 151-152) and is likely to be far removed in quality from the scope of consciousness. Since language is generated in consciousness, this would mean that the initial experience is far removed from the faculty of language to describe it. Consequently it is necessary for coffee, and wine, to give two examples, to develop their own conventional, ad-hoc tasting languages. Marks relates the cross modal unity of olfaction and colour to the Fechner-Stevens pitch height analogy described above (Marks 1978, pp195-201) and also attempts to allocate the four basic colours to the four basic tastes. A complete flavour model needs to encompass aroma, taste and mouth-feel (Briggs, Hough & Stevens 1981). I have attempted to set this wheel alongside a chromatic colour wheel in a way that maximises the analogy, as shown below.



The body of work relating colour to touch is smaller but Marks demonstrated a relationship between a strong handclasp, a loud noise, and a bright light. A common manifestation of cross modal transfer used to be called 'psychochromaesthesia' - association made between 'psychosms' (meaning concepts). Examples of such 'psychosms' are numbers, colours and the names of days of the week. This is often referred to as 'pseudochromaesthesia' since it is difficult to determine whether it is a form of synaesthesia or not. Psychochromaesthesia may be an example of one of the ways in which people provide colour with context.

This systemisation and plotting of our concept of colour is further assisted by the ways in which colour terms are used in language in contexts other than those which refer to the visual presence of colour itself. 'blue cold', 'red hot', 'green freshness' and 'red alert' are just a few terms in current usage that supply our understanding of colour with auxiliary connotations. As with psychochromaesthesia, this has often been regarded as a synaesthetic phenomenon, indeed Marks called phrases that refer to colour or brightness terms in the absence of visual stimulus reference 'synaesthetic metaphor' (Marks 1978, p 215): 'synaesthetic' because their content is multi-sensory and 'metaphor' because they are figures of speech that bear no relevance if interpreted in a literal fashion.

The next chapter focuses on the ways in which metaphor works. Such an investigation is beneficial to the process of determining the extent by which such terms affect our mental abstraction of colour, and also whether the term 'synaesthetic metaphor' is truly justified to describe such use of language.

10. The Nature of Metaphor.

. This chapter looks at how the language that we use is often, even more so in aesthetic writing, cross modal in character, that is that it describes colour in terms of sound, odour in terms of colour, or other uses combinations which transfer between our different channels of perception. Since such use of language is metaphorical, or, at least, metaphorically related, a summary of the properties of metaphor in general is required in order to address the issue.

Aristotle believed that metaphor showed superior intellect and that it was creative and constructive in general. He believed, however, that because of its ambiguity its use should be restricted to 'poets and politicians' and that it was misleading when facts are being dealt with (Ortony 1998). Compared to our modern ideas of metaphor, Aristotle's ideas seem narrow in suggesting that metaphor has only artistic and aesthetic use. It is now, on the contrary, widely realised that metaphor is a very useful tool for making familiar what is currently unfamiliar to a person, and that it thereby has informative and explanatory value. It is metaphor in its wider sense which is of concern to this thesis since when most non-synaesthetic people talk about colour and music they are using a type of metaphorical language.

Later in this chapter there is discussion of the use of synaesthetic metaphor in poetry, which seems to be different in quality to the clarifying type of metaphor referred to above which Aristotle seemed to overlook. If, however, the effect of having such metaphor in poetry is to make conjured up colours or scents more apparent in the mind of its readership, then it is, nonetheless fulfilling the function of familiarisation. It is unlikely that Aristotle was receptive to the, now realised, link between metaphor and simile, this being that both involve comparison and therefore both involve associating one thing to another, in the case of synaesthetic metaphor sensations normally related to different sensory channels.

Since we shall be dealing with implied activation of different sensory channels when the actual stimulation is within a particular mode, such as music (where it is auditory) or (as in the next section) poetry, simile is the principal mode of expression that we are concerned with here.

Simile and metaphor both involve the relationship between two entities, be they objects or abstract notions, which are in some respects dissimilar, but have enough in common to be related to one another. To say 'money is the drug of the affluent' (because of its addictive properties) is to use a metaphor. The metaphor uses two concepts 'money' and 'drug' which Richards termed *tenor* (often interpreted as 'topic') and *vehicle*, respectively. He states that for metaphor to work, the *tenor* and the *vehicle* must have a fairly intermediate distance between them in their conventional semantic meanings (Ortony 1988). The contrast between the two entities, *tenor* and *vehicle*, is called a tension. The *tension* of a potential metaphor can fail to become a metaphor by being too strong (disparate), and therefore inappropriate, e.g. 'We are lost in the space of Shakespeare', or too weak (the two entities too closely connected), and therefore not metaphorical, 'The science of Chaos'. This requirement of metaphor is supported by its Oxford English Dictionary definition which says that it is -

> The figure of speech in which a name or descriptive term is transferred from some object different from, but analogous to, that which is properly (i.e. conventionally) applicable. An instance of metaphor is a metaphorical expression.
>
> (Simpson & Weiner 1989).

In other words the 'different from' stresses the importance of the strength of the tension, while the 'analogous to' expresses the need for the *tenor* and the *vehicle* to be close enough, in some way, to be relatable if the metaphor is to be successful. This tension model of metaphor is relevant to the phenomenon of cross modality in non-synaesthetes, since trans-modal references involve a degree of contrast and a degree of similarity or unity. This explains why soft, delicate sounds are usually associated with colours like green or blue, that we refer to as gentle colours, while red is often attached to the sound of a trumpet by non-synaesthetes.

Recent reactions have been made to the proposal that metaphor works through the interaction of a *tenor* and *vehicle* the most influential of these being that of Lakoff & Johnson. They do not see the need for the tension model since they attribute metaphor primarily to convention rather than seeing it as being constructed afresh every time. A major body of support for this is large and complex networks of non-poetic clichés which overspread everyday language (Lakoff 1980, pp 97-98).

That the conventional network model of metaphor is relevant to the development of cross modal relationships in non-synaesthetes is evidenced by the increase in the number of 'synaesthetic' artworks during the nineteenth and early twentieth centuries. It can be argued in this way that during that time a conventional cross modal language was being developed. However, this does not seem to explain as adequately as the Richards model why sounds, colours and odours that are related to each other most often share dynamic or affective attributes. Nonetheless, the Lakoff & Johnson model seems better equipped to deal with the elaborate complexity of much cross modal reference.

It is true that the complexity of many metaphors can be accounted for by either model but the later model does so much more economically, since it can offer a single explanation for the way in which quite often a *vehicle* penetrates further than just a single isolated *tenor.* Many examples of this occurrence are exemplified by instances in our everyday use of language. 'Time flies' (or has flown) is appropriate, for example because we have the 'bird of time' metaphor. Time can also be treated as a physical resource, which can run out, run short, be saved or be wasted. The metaphorical treatment of time as a physical entity can, therefore, be extended to several terms. A striking example of a metaphor being carried through many aspects is the 'Water Model of Finance' - by talking of money as if it is water we have developed many phrases to do with money that we are usually unaware of. These include 'bank', 'flooding' (the market), 'solvency' (or 'insolvency'), 'currency' and 'cash flow'.

Lakoff & Johnson suggest that metaphor develops in the same kind of way as other types of language; thus Aristotle observed that it is often regarded as the most complex and sophisticated form of language. For that reason, it is considered to be especially important to philosophy and raises puzzling questions about the limits of language and knowledge such as 'is meaning essentially untranslatable' (Lakoff 1980, p11). Many theorists claim that metaphor bypasses logic by its being able to transpose the meanings of words.

Figures of speech in poetry can be from any part of the metaphoric spectrum, from a simple metaphor that is used once only, to complex metaphor that is carried through. Elaborate examples of complexity in poetry include the poem 'The Windows' by George Herbert (1593-1633). This poem uses the transposition of 'transcendence from God to us', the *tenor*, and 'light', the *vehicle*: the poem is given overleaf.

Lord, how can man preach thy eternal word?
He is a brittle crazie glasse
Yet in this temple Thou dost him afford
This glorious transcendent place,
To be a window through his grace.

But when Thou dost anneal thy glasse Thy storie,
Making Thy life to shine within
Thy holy preachers, then the light and glorie
More rev'rend grows, and more doth win;
Which else shows watrish, bleak, and thin.

Doctrine and life, colours and light, in one
When they combine and mingle, bring
A strong regard and aw; but speech alone
Doth vanish like a flarring thing,
And in the eare, not conscience ring

The exposition of the metaphor is little more than an explicit simile '(Man) is a brittle crazie glasse' and 'This glorious and transcendent place, To be a window of thy grace', and yet the second and final verses comprise an extension of this which is metaphoric. The equivalents within the framework include: verse two, scripture *tenor* to glass *vehicle* and glorified (life) *tenor* to shining (life) *vehicle*, and verse three doctrine and life *tenors* to colours and light *vehicles*.

Epiphoria, a Greek word that Richards applied to the issue of metaphor, is applicable to a whole group of metaphor related devices and not just to metaphor and simile; the name given to the manipulation of, or reason for using, either of the above. The literal meaning of the Greek word is 'The transposition from one pole to another' or 'a bringing upon'. This 'family' includes the use of synaesthetic references by those without synaesthesia and the use of the word *epiphoria* in a specialist sense can refer to the basis of synaesthetic phenomena in visual art, music or poetry. It seems that the English language has modified the meaning of the word to focus upon the structural aspects of metaphor (how the two entities interact within the sentence structure) rather than the semantic aspects of *epiphoria*. While the English definition applies almost exclusively to metaphor and simile, the Greek word's emphasis on transposition widens its meaning to apply to other uses of language. Forms of language that involve the wider, Greek *Epiphoria* can be referred to as 'improper speaking' - the act of speaking of things, not truly factually, but in a way that makes the content of the communication easier to grasp, easier to picture, more beautiful, more memorable, or any combination of these or others. The antithesis of 'improper speaking' is 'proper speaking' which is to speak in a strict matter-of-fact way about the world.

An example of 'proper speaking' that was quoted in Chapter 2, from Isaac Newton is 'The rays, to speak properly, are not coloured'. He was informing readers that to talk of a pink flower, for example, is to employ a form of *Epiphoria* since colour is a perception and, therefore, belongs to observers and not to objects. In fact, our language is constantly transporting us away from straight, hard science by this means and our language is consequently full of *Epiphoria*, more so than metaphor by the narrower definition, which, as exemplified above, is nonetheless abundant.

Two more common examples of the way in which our language is transported into the realm of 'improper speaking' are 'personification', the giving to an inanimate entity animate terminology, such as 'he' or 'she', and 'figuration'. 'Figuration' is giving the concepts being communicated form. This is most commonly achieved through imagery. Imagery is central to the topic of synaesthesia, which forms the body of this thesis and it will be given much discussion. Synaesthesia is a rare condition but 'synaesthetic metaphor' is common. Synaesthetic language is, to an extent, metaphorical in the narrow sense of the word in that we use, as a *tenor*, an expression which refers to one mode of sensation, while having a *vehicle* which concerns another mode. Expressions such as 'an explosion of flavours', 'a sharp tone', and 'an off (sour) colour' all fit the category of synaesthetic metaphor since they link terms which relate to different senses by use of metaphorical model (with *tenor* and *vehicle*) and transport the speaker and listeners from one to the other (Marks 1978, pp 104-106).

Cross modal speech, which includes synaesthetic metaphor, can be classified according to the modalities which relate to each of the components. Synaesthesia, as we shall see, can be classified in the same way. Assuming that there are five senses (a controversial assumption, since smell and taste are connected and there are also, what Lours & Margery Milner referred to as obscure senses, such as the sense of time (Milne & Milne 1963 pp 160-177)) then there are a total of 20 (5*4) forms of trans-modality between any two senses. The forms of the above examples are, movement (and therefore touch) and taste for 'an explosion of flavours', touch and hearing for 'a sharp tone', and taste and vision, for 'an off (if taken to mean sour) colour'.

Synaesthesia, as a medical condition, rarely manifests itself between more than two senses; on the other hand, complex synaesthetic metaphor may have a third sensory reference involved. Taking our second example, 'a sharp tone', for the purposes of illustration, it can be shown that further cross modality may be added. We may, in one instance, add a visual element and further describe the tone by saying 'a sharp, bright, tone', 'bright' being an additional *vehicle*. The implication now, is that sound has visual and tactile properties. Even more implicit, but still clearly communicated to the receptive audience, is a third connection, one between the 'bright' and the 'sharp' - visual and tactile, since if both terms are said to apply to 'tone', then both are also related to each other. The developmental quality of complex metaphors also has a place in cross modal language. An example of this is cross modal use of the word 'spectrum'. The word is defined in the Oxford English Dictionary (definition 3a) as 'A coloured band into which a beam of light is decomposed by means of a prism of diffraction or grating' (Simpson & Weiner 1989). This definition, describing the phenomenon that Newton demonstrated, a gradation of visible light wavelengths from 400 nanometers (violet) to 700 nanometers (red), is the most widely accepted one. Spectrums of sound or flavours are, however, often referred to, and when they are, the word, 'spectrum', becomes a model for a complete set of terminology. This means that, metaphorically speaking, colours and flavours can then have 'top notes' and in the same way sounds and tastes can be allocated colours.

Note that this last point differs from synaesthetic associations themselves; under this scheme, the pitch distribution of a complex sound (actually called spectra in audiological terminology) might best be translated as, red for low sounds, green for middle sounds and violet for high sounds, and with all gradations in between (e.g. blue for a moderately high sound) This is probably unlike the sound colours of most synaesthetes or those imagined by non-synaesthetes and is also unlike the colour associations which Simpson et al found in children, where high frequencies were associated with the light, middle portion of the spectrum, yellow and green (Simpson, Quinn & Ausabel 1956).

The terminology just described is, nonetheless, useful terminology in discussing pitch distribution in sounds with most people, who are more aware of the visual spectrum than they are the audio range of frequencies. Using the spectrum model can help to explain, at least on a superficial physical level, why some sounds are colourful and others seem to be lacking in colour. In the same way, the presence of an excessive number of different light frequencies (colours, and especially if dealing with pigments) produces a muddy colour while sounds are often called 'muddy' owning to the number of layers of sound being imposed on top of one another, an auditory analogy to an excess of pigment mixture. The Light and Colour model of sound is as complex and as explanatory as the Water model of Finance and the War model of the Weather.

For effective synaesthetic transportation of an audience, metaphor itself is not essential - any metaphor related device can achieve *epiphoria*. This is probably attributable to the primitive level of experience which is aware of yellow tastes or blue wavy melodies not being sensitive to language itself, but rather to suggestion. Suggestion as a quality seems not to be as highly dependent on language structure as more cerebral communications are (Ortony 1988). Synaesthetic transportation is therefore a sensory indulgence, however it is produced. A fictional book, for example, may be very crudely written and lack all the subtleties of metaphor, but through its storyline and straight, explicit, similes, it may, nonetheless succeed in the riches of synaesthetic transportation, uniting the senses. This point regarding the linguistic quality of *Epiphoria* is illustrated with Edgar Allan Poe's (1809-1949) early poem 'Al Aarraf'. This is not particularly metaphorical, rather it is narrative, and linguistically not of a very high quality. The sensory cross modality in it is intense, however. While the poem is an immature work of Poe's, (a fact that probably goes a long way to account for its lack of structural sophistication), it can be speculated that an older poet may still have chosen a similar coarse style as it seems to carry the 'synaesthesia' and association well.

In everyday language, as in some antiquated poetry and literature (antiquated, probably, for the following reason), there are phrases which imply or state relationships between entities, but which, through their overuse, fail to achieve the effect of *epiphoria*. This is because such phrases have become so established, in a particular context, that the meaning of the two component words themselves is no longer considered. Sometimes even the words comprising what used to be metaphor are combined and corrupted. This is so in the case of 'daisy' - originally a poetic description of a daisy's appearance as a day's eye. This origin of the word is, of course, completely forgotten now, except in the context of historical and linguistic interest. When a metaphor has aged to this extent, it is 'dead metaphor'. Such dead metaphors are so called because while the words of such phrases have remained intact, sometimes unaltered, over time they have come to serve functionally as single semantic units. 'Dead metaphors' are therefore bereft of the original diverse meanings of, what were their *tenor* and *vehicle* components (Ortony 1988). Since we fail to recognise, without deliberate, conscious attention, the *tenor* and *vehicle* of the phrase, we do not experience *epiphoria*.

The notion of 'dead metaphor' is especially relevant to the issue of synaesthetic metaphor since in the current sense of the word metaphor is frequently dead. Phrases like 'bitter cold', originally a touch-taste metaphor, 'deep blue', touch (spatial, deep meaning low)-vision, and sour note, (taste-auditory), for example, are not given much conscious thought regarding their metaphoric components, and are, therefore, dead. Yet it is quite possible that these dead connections can still work in the pre-linguistic domain, in which case, while the conscious brain fails to register the dead metaphor, it nonetheless produces this sense of transportation pre-consciously.

It is true, for most of the time, that the metaphoric properties of phrases such as the above go unnoticed, but, as we have seen, metaphor is not essential for synaesthetic transposition. Diversity, on the other hand, is essential for cross-modality, since metaphors become dead when phrases are perceived only as wholes, with their unique meanings and components unnoticed. I am suggesting here, however, that this is only the case at conscious levels. At the more instinctual levels, where cross-modality exists, overused phrases do not really become hackneyed and dead. If this theory is correct, then an expression such as 'bitter cold', when grasped by the appropriate level of the consciousness, suggest both the cold referred to and the bitterness (Marks 1978, pp 121-122).

Synaesthetic suggestions produced by language are probably not accepted in every combination since metaphor and its family appear to have selective properties. This was emphasised by Max Black who saw metaphor, not as a direct comparison between *tenor* and *vehicle*, but as an interaction between the two elements (Black 1962). Using Richards' terminology, he suggested that the *vehicle* acted as a filter for the *tenor*. This means that the two components are given a new, collective meaning. This collective meaning, as we have stated, is apparent in dead, as well as living metaphor, but in dead metaphor is apparent at the expense of the original meaning of the two terms. By comparison, in a living metaphor, we are always aware of the nature of the object and filter's nature.

Taking the filter model of metaphor (which is, itself a metaphor for metaphor) and transforming the *tenor* and *vehicle* into a light blue, coloured object and a yellow, Perspex, filter, when the two interact, i.e. the filter is placed in front of the object, it gives rise to the new colour (new meaning), green, since it is the green part of the spectrum that the two colours have in common. Therefore a dead metaphor is seen through the eyes of an observer who is unaware that the green is the result of two separate pigments, while a living metaphor is where the observer can see some part of the colour of the unfiltered blue object (or at least remember it) and be aware of the presence of the yellow filter.

The filter model has many implications for the assumption that synaesthetic language implies a presence of synaesthesia. This theory is based on the argument that use of synaesthetic metaphor, or any other member of the 'metaphor family', is the preconscious, synaesthetic state rising to a semiconscious level. The filter model focuses on metaphor's selectivity which must apply also to those metaphors and other forms which contain contrasting components which relate to different senses. If we talk of 'bitter cold' (a dead metaphor, but, which we have argued, like all dead metaphors, is still synaesthetically active), we are emphasising certain properties of cold, those which penetrate through the 'bitter' filter. The entities 'bitter' and 'cold' have certain properties in common, the key property, according to Marks being unpleasantness (Marks, 1978, p 124). While 'bitter cold' has a meaning of its own to which 'unpleasant' does not serve as a substitute, both 'bitter cold' and 'unpleasant' have similar negative affective attributions - more will be said about affective attribution in Chapter 11. Bitterness is not coldness, however, since; the two are sensed by different senses, but the term encourages the reader to disregard that fact and attend, instead to what the two terms share.

Regarding colour temperature ('warm colours' and 'cool colours'), the filter model also shapes the way in which colours (the *tenor*), are conceptualised. Orange is typically seen through the 'warm' filter and blue through the 'cool' filter. Taking these two colours, there are differences, which surface less often. Orange approaches us while blue recedes from us; orange is clear while blue is diffuse; orange is seen clearly from a distance, whereas blue 'gets lost' easily. There are also similarities between the 'cool' and the 'warm' colour; both of these colours can be bright and, more importantly for this thesis, both are visual sensations.

There is one obvious physical link between red-orange and 'warm', and that is that red-orange is the usual colour of heat emitting objects. This is only partial rational, however, since even hotter emissions are white or, hotter still, blue; that is, physical colour temperature operates in inverse order to conventional (and psychological) colour temperature. It is just that red hot emissions are more common than blue hot emissions. Furthermore, properly speaking, there is no such thing as a cold emission; it is heat absorption, and a total lack of emission is black. Experience, therefore plays a part in our concepts of warm and cool colours, but only a selective part, the rest being predominantly rooted in metaphoric language. It is possible to regard colours in terms of another sensory modality, such as taste.

The terms 'warm colours' and 'cool colours' (or 'sweet' and 'bitter' colours) focus on one of many possible bipolar classifications in which to arrange colours, and it is, therefore, the choice of filter which makes language synaesthetic. While it is suggested later in the chapter that much literature supports a 'unity of the senses', it is worth bearing in mind metaphor's distorting properties and remain aware that it provides only filtered evidence to support the unity of the senses theory. If we use metaphorical filters to produce synaesthetic language, then that language can shape thought, as exemplified by 'warm' and 'cool' colours. Shaping of thought through metaphor is a further possible explanation of cross modal connections to be considered. The extent to which such connections relate to clinically defined synaesthesia is discussed in Chapter 12. Prior to this, the following survey of cross modal usage in literature raises other relevant questions, while at the same time exemplifying synaesthetic examples of metaphor and its family.

SYNAESTHETIC METAPHOR IN POETRY AND THE UNITY OF THE SENSES.

The best way to assess the use of synaesthetic metaphor in poetry is to deal with parameters that are universal to all channels of sensation. As we saw in Chapter 9, four of the key universals according to Marks are intensity, brightness, extension and duration (Marks 1978, pp 192-193). Intensity is how strong a sensation is. This is thought to be the most salient of these universal dimensions and brightness seems to be the second. It will be recalled that in terms of the visual mode, brightness clearly refers to the scale from black at the dark end to white at the light end whereas in terms of a light in an otherwise darkened room, brightness is correlated with intensity. It is for this reason that I have here stressed the potential complexity of image intensity - increasing the amount of dark ink on an image on white paper increases its intensity, but the image is still reduced in brightness; intensity can mean darkness or lightness whereas brightness can only mean lightness. In terms of sound, brightness corresponds to the frequencies of the most prevalent components in a sound. The notion of pitch brightness is important when discussing the use of vowel sounds in poetry. Chapter 9 illustrated that vowel brightness is mainly a product of the frequency of the second vowel formant (*f2*). The concept of non-visual sensations having brightness values has been extended to odour and taste as well. Juhasz found the odour of banana to be high in odour pitch, oil of cloves to be lower and geraniol (an alcohol) low in pitch (Marks 1978, p 196). For taste Marks found that many people regard bitter as low and sour and sweet as high (Marks 1978, pp 198-199).

Extension or size in the context of an object or a space is generally gauged by sight, or sometimes by touch. However, the nature of sound can also give subtle clues to this attribute, low pitches and long echoes suggesting high magnitude. In other words, all of the aforementioned senses are capable of giving information about the extent of physical space.

Marks called the above equivalence the 'Doctrine of Equivalent Information'. In the case of auditory assessment of space, however, impressions of size are often given that are abstract and have nothing to do with physical space whatsoever. If there is a lot of low frequency activity in a sound, largeness is implied, whereas if all of the frequency components are middle or high pitched then a much smaller size is implied.

Since this section relates to poetry and literature, it is especially relevant to look at the apparent size of vowels as a result of the prevalence of their pitch components. Vowel size has been reported by various writers (e.g. Bleuler & Lehmann 1881, Dudyha & Dudyha 1935). Since the both the 'size' of vowels and the brightness of vowels relate to formant frequencies, the two correlate closely. The subtle difference between the two is that the size of vowels is more strongly influenced with the lowest frequency peak, namely $f1$, than is brightness. This makes sense when it comes to using sound to assess physical size since the size of a room affects the lowest frequencies, where the $f1$ in vowels is placed on the audio spectrum, more directly than it does higher sounds. This means, for example, that while the sounds 'ee', as in 'meet' and 'i', as in 'mitt' both have high second formants and both are regarded as bright tones, the former, having a lower first formant than the latter, seems to suggest a larger body of sound. With dark tones this seems to be much less apparent, probably because the pitch of low second formants tend to predominate to a large degree over the lower first formant frequencies, since the filters in the vocal system give a strong preference to sounds around 800Hz with a very steep slope in the filter characteristics of frequencies that are lower. This means 'oo', as in 'moot' does not seem to suggest a much larger space than 'aw', as in 'more': both are large. Vowel size tends, more often than not, to be used in language to express the size or brightness of objects being described. Although there are exceptions to this rule, it is exemplified by the 'I' in the middle of 'trivial' as compared with the large 'aw' of 'important'. In summary, perceived size relates to what each sense says about an object Lyons (2001).

The final universal attribute of all the senses that are listed above, is 'Duration'. There seems little need to say very much about duration since it seems quite obvious that sensations in each channel last a particular length of time. Our immediate (visual or echoic) memory is thought to allow for one item of stimulation per sensory channel at any moment in time: thus we can 'memorise' a simultaneous sight, sound and smell but one only (Sperling 1960). It is experiments with inter-modal matching that have provided much of the evidence that time perception is united across the senses. Periods of time are subjectively longer if they contain sensory events than if they do not (O' Connor & Hermelin 1978). This applies to all sensory channels.

There are several examples in poetry and literature of metaphors which express relationships between different modes of sensation. Thus when the American writer Conrad Aiken (1889-1973) wrote '[The music] suddenly opened, like a luminous book' (Aiken 1953, p109), he was using a synaesthetic simile to express the vibrancy of the music. Otherwise put, Aiken was implying that the music, like bright colours, dazzled some united sensory centre. In other words, Aiken's implication relates to some sensory system whereby the senses are connected; the poetry thereby incorporates the kind of unity of the senses theory referred to here.

The above use of language stands in stark contrast to the practical use of metaphor, simile and imagery for the purpose of clarification as referred to earlier. In poetry metaphorical devices are rarely restricted to this function; the primary purpose of them is, rather, that of aesthetics. It is probably a good thing that the use of metaphor, imagery and simile is liberated in poetry from any practical purpose since while the above extract is quite clear in its meaning the use of cross-modal language is often confusing, since it implies connections between the senses without establishing them as entities. Consider the extract overleaf from Edgar Allan Poe's (1809-1849) aforementioned Al Aaraaf -

All nature speaks, and e'vn ideal things
Flap shadowy sounds from visionary things.

Marks analyses the passage as follows; it seems to liken certain sounds to shadows or darkness. The relationship between darkness and these sounds depends on the law of universal brightness described above. In these terms we are saying that the sounds and the shadows that are being connected with them are both 'dark', the sounds referred to probably being low. Even by acknowledging universal brightness between senses, the passage remains obscure since we are not usually consciously aware of the brightness or darkness of sound as we tend to listen primarily for meaning (Marks 1978, pp322-325). Since people are not usually aware of this brightness on a conscious level, the sounds that Poe is referring to are likely to be ambiguous on an intellectual level. Consequently, an exact meaning is not grasped on an intellectual level but on an instinctive level since we can obtain a feeling for the text. The poem is about a cosmic object of the name of the poem that was apparently observed which 'attained in a few days a brilliancy surpassing Jupiter and then suddenly disappeared'. Poe is attempting to describe an unspeakable sight and turns to magic, mythology and synaesthaetic metaphor in his attempt to convey some of what he wishes to put over regarding the experience, likening light and shadow to sounds. In this poem we have, as we do in the Aiken, expression of cross-modal intensity.

In some of Poe's later poems, it seems that he deliberately uses light and dark vowel and consonant sounds. A single verse work which is a good example of this is his 'Sonnet to Silence'. The poem describes the phenomenon of silence but out of necessity has, obviously, to use words. What is significant is that soft consonants [f, sh, s, th and w] prevail over harder sounds throughout while the use of vowels of different 'pitch sizes' and 'brightnesses' is stratified from line to line, the dark contrasts emphasising the profundity of nothingness while the light contrasts accompany semantic focus on the fearlessness of silence or nothing. Thus light and dark sounds enhance the work's expressive qualities. Silence can therefore be, in part, a metaphor for death. The poem is as follows: -

I *There are some qualities, some incorporate things*
II *That have a double life which thus is made*
III *A type of that twin entity which springs*
IV *From matter and light, evidenced in soft and dark*
V *There is a two-fold silence sea and shore*
VI *Body and soul one dwells in lonely places*
VII*Newly with grass o'ergrown more solemn graces*
VIII *Some human memories and tearful lore*
IX *Render him terrorless, his name's no more*
X *He is the corporate silence, dread him not*
XI *No power hath he of evil in himself*
XII*But should some urgent face (untimely lot)*
XIII *Bring he to meet his shadow (nameless elf)*
XIIIa *That ham'reth the lone regions where hath trod*
XIV *No foot of man, commend thyself to God.*

Line I Consists of fairly dark vowels and mainly quiet consonants, while the second line, with its sharp 'a' and closed 'u' sounds ('double' and 'made'), is more jarring. Line IV is a very expressive line; its words tell us that light is found in darkness, suggesting their being one and the same. The choice of words follows a scheme of vowel and consonant brightness where the line starts light and ends dark. Lines V - VIII express the 'darkness' of this silent world and the use of the sounds, 'oo', 'aw' 'o' and 'oa' allows the darkness to prevail at the end of this. At line IX, the tone suddenly becomes lighter, e, i and ay prevailing. Lines IX-XI express silence's innocence and harmlessness. At 'some urgent face' (XII) the tone becomes dark and large again. Line XIII, using light tones with the exception of for the 'oa' of 'shadow', increases this word's prominence. The sonnet concludes with dark but less intense sounds providing a feeling of conclusion.

Vowel duration also plays a major part in the expression of feelings in Edgar Allan Poe's four versed poem 'The Bells'. It has four stanzas whose themes are I Sleigh Bells, II Wedding Bells, III Alarm Bells and IV Funeral Bells. Duration is manipulated so that the verses become longer as they express things with deeper and more lasting meaning. The first verse gives the feeling of the toy bells as a rushing and short lived episode while the relative length of the second verse matches its deeper significance and the long lasting of a husband and wife relationship. The horrors of a war-time situation - The Alarm Bells - are here depicted as nagging torturously on the mind as the third verse is drawn out by obsessive alliteration and rhyming, for example 'frantic fire' and 'the angling and the wraggling'. The final stanza is not just 'drawn out' by the repeated use of similar sounds but a higher prevalence of repeated words. The poet also uses vowels of different 'sizes' in each verse to reflect the increasing importance of the subject matter. Table 15 overleaf summarises the vowel use in the poem.

TABLE 15

Stanza No.	I%	II%	III%	IV%
a (mat)	8	6	14	11
e (met)	19	19	15	16
i (mitt)	23	19	12	13
o (moth)	8	12	9	13
u (munch)	1	2	3	2
ay (mate)	2	1	5	3
ee (meet)	3	1	3	4
eye (mite)	7	3	6	5
oa (moat)	2	5	2	6
oo (moot)	4	7	4	6
-- (the)	12	12	11	13
ar (mar)	1	1	1	2
air (mare)	2	2	2	2
er (mirth)	2	3	4	2
aw (more)	3	1	5	3
ear (mere)	1	1	2	0

Aiken also expressed relationships between meaning, size, music and colours in his work. For Aiken music was central to his poetry and this operated on a number of levels. There are numerous examples of his talking about music in his work, for example 'Priapis and the Pool', where he writes 'Sing the pure phrase, sweet phrase, clear phrase in the twilight'. There are other works where he actually goes as far as to produce more definite associations, and the most typical of the latter kind is the 1942 poem entitled 'Music', a passage of which runs as follows -

The calyx of the oboe breaks,
Silver and soft the flower it makes.
And next, beyond, the flute-notes seen
Now are white and now are green.

He is thereby stating cross modal properties in an unequivocal way. The last line with its sense of movement is also typical of the way in which he induces movement into his sentences, thus employing a third mode of sensation. He sometimes uses words to explicitly state movement as in 'The House of Dust' (1944) where he writes of violins 'weaving a weft of silver' and horns 'weaving a lustrous brede of gold'. Aiken wrote his poetry in this way in order to fix any fragments of the consciousness and was so extensive in his use of material to achieve this that a lesser writer, Randal Jarrel called him 'Midas' in that 'everything he touched turned to verse' (Hart 1995, p12). Aiken, in this way, specialised in making objects and subjects appeal to many sensory channels. Cross-modality in poetry, as it is in Music-Drama, is a means of expression. Sometimes, by the writer's own admission, it is deliberate - as in the works of Edith Sitwell, while in other cases it may be accidental and, arguably, present only in the eyes, ears, and other senses of the audience (Marks 1978, pp. 352-353).

It can be seen that what is, by the minimum definition, cross modal language, is very common. Worthy of brief mention here is the use of hashish and the hashish clubs around at the middle of the nineteenth century. The effects of hashish and other drugs are described in more detail in Chapter 12 in connection with the biological basis of synaesthesia. E.T.A. Hoffman and Charles Baudelaire were both members of the *Club des Hachinins* in Paris and both experienced and reported synaesthesia-like experiences, including coloured vowels, while under the influence. Other members of the club wrote occasional reports but did not take the experiences seriously knowing them to be the result of a drugged state. Baudeliare wrote about his experiences in much more comprehensive detail, especially in his Correspondences (1833-1856), realising that on one level different senses correspond to one another and that no experience could be created out of nothing (Burton 1995).

Odours played a large role in Baudelaire's cross modal world, as they did with Percy Bysshe Shelley (1792-1822). For both of them, the fascination of odours was probably a result of their preconscious intangibility referred to earlier and the fact that the sense of smell in mammals is linked most directly to qualities of emotion, yet the least capable sense of being 'pinpointed'. When Shelley unites auditory and olfactory suggestions with 'Such sounds as breathed around like odourous winds' (The Daemon of the World), his intention seems to be to make the reader aware of an analogy that was previously concealed that is to remain emotional and impalpable even after reading it. If the reader is receptive to the *epiphoria* then Shelley's attempt is likely to be successful.

In connection with the above, the olfactory sense seems to be least like the other senses, in that 'odour intensity' is less well defined than other intensities. It relates most to taste, which in turn relates well to touch and it is touch that seems to relate best in most ways to the remaining senses; size is an example of an attribute that can be perceived best by sight and touch. The issue of what degree this relates to synaesthesia as a permanent human conditions is a complex one and will be explored in the chapters on synaesthetic case studies. In Chapter 13, taking the composer Olivier Messiaen as an example, the question of how well we can expect to understand artistic works which are, to a large extent, based on an artist's synaesthesia is discussed. Following the use of synaesthetic examples and our relation to them, we are able to at least begin to address the key question which is central to this thesis; 'Are we not all, to some extent (consciously) synaesthetic'?

This chapter has given but a few of many examples of our everyday use of language and in poetry and literature of how the sensory boundaries are crossed to make its content more comprehensible, more beautiful, more vivid or to impart some other quality.

Cross-modality in language occurs with such regularity that, notwithstanding the sub-linguistic theory of the perception of *epiphoria* that I have referred to from time to time, it is reasonable to ask whether they relate to synaesthesia (in its wider context) at all. Certainly Marks thought that *epiphoria* in language was a synaesthetic manifestation, most modern researchers focusing on synaesthesia as a condition are more suspicious (e.g. Harrison & Baron-Cohen 1997).

The next chapter assesses the capacity of language to reflect properties that link concepts together. Using an example which is very apt in the context of a work on 'musical synaesthesia', it uses semantically differentiated pairs to assess what is going on when people express in language the notion that certain keys are certain colours.

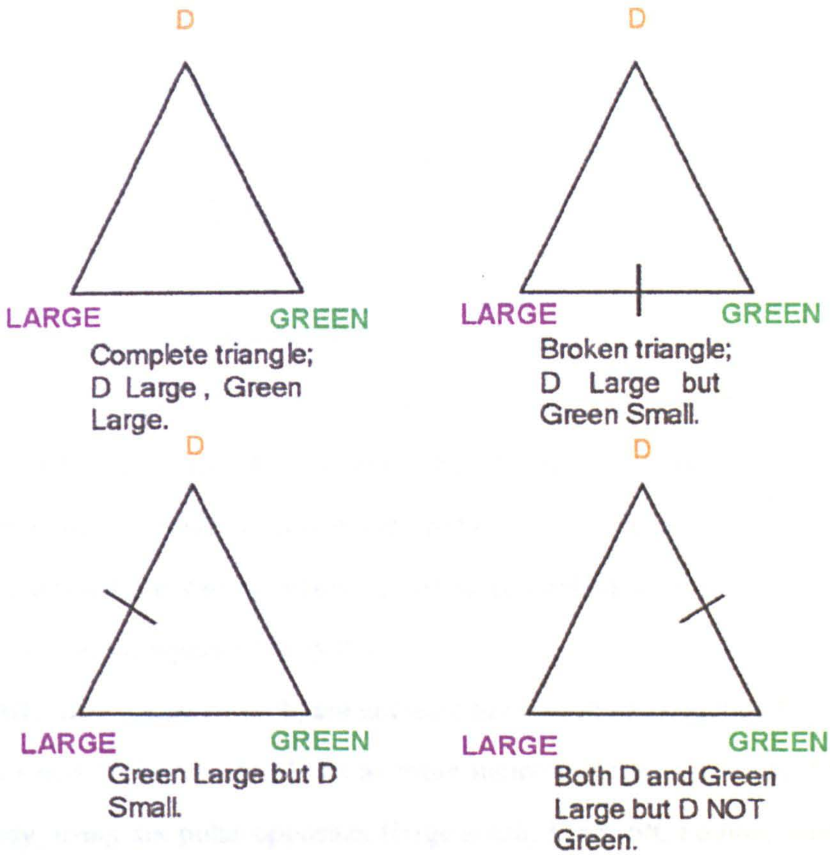
11. Semantic Differential Experiment.

INTRODUCTION

The main purpose of this chapter is to establish whether there is a qualitative difference between synaesthetic and non-synaesthetic associations. This is achieved by assessing responses to semantic opposites. Cytowic & Wood tested this and failed to find similarities between primary and secondary sensations with respect to Osgood's semantic space (Osgood 1971) in synaesthetes :- that is, if the note A was green for a particular synaesthete then this did not mean that A and green would share more semantic attributes than would have been expected by chance. For non-synaesthetes, however, they did find a relationship between two apparently trans-modally connected stimuli. It seems as if they consciously or semi-consciously devised an association (Cytowic & Wood 1982).

The current study is a re-assessment of Cytowic & Wood's findings for the non-synaesthetic sample and in a musical context, concerning key and colour. The study tested non-synaesthetes and assessed the extent to which keys and colours associated with each other share such semantic attributes. The subjective qualities used were the extreme polarities of Osgood's semantic differential scales (Osgood, Suci & Tannenbaum 1957). These scales were originally used as tools in social psychology for assessing attitudes. The semantic differential technique allocates participants' attitudes to words or concepts in semantic space (Crystal 1997, p103, after Osgood, 1952). However, a salient criticism of the technique is that it does not give any indication of the nature of the word in question itself (Clarke 1977). This is not a problem in this case since we are assessing linguistic connections for what they are, firstly in order to see if they will show connections in support of non-synaesthetes key and colour connections, and secondly to look at a respect in which the associations of non-synaesthetes are said to connect while those of synaesthetes do not.

If the association between keys and colours (or for that matter any other cross-modal transfer) in non-synaesthetes is a result of higher cortical function (Harrison & Baron-Cohen 1997) then a prevalence of positive three way relationships is expected. By three way relationships it is meant that if, in this case, C Major is given the colour red, and if red is 'strong' (as opposed to 'weak') then C also has 'strong' attributed to it. Such relationships are three way since they concern three attributes which all have to relate directly to each other if a semantic connection is to be inferred. In this case the attributes are key, colour and semantic value. The illustration overleaf shows a fully connected triangle and three triangles that are disconnected at one point. The top left hand triangle is fully connected and illustrates somebody who thinks of or 'sees' D major as Green, and sees both D major and Green as Large. The top right hand triangle illustrates a participant who also thinks of or 'sees' D major as Green, but who only sees D major as Large, seeing Green as Small (opposite of Large). The bottom left hand triangle shows the opposite of this, again the participant associates Green with D major, Green is attributed to Large but D major is attributed to Small. Finally, in the case shown by the bottom right hand corner D and Green are both Large but D is not associated with Green. The fact that the two share common properties is, therefore, not relevant.



In this study we are assessing the amount of semantic connectedness shown in the associations of the (non-synaesthetic) participants used. Metaphor was discussed in Chapter 10 and is therefore not addressed here except to reiterate its quality of *epiphoria* for enriching imagery in poetry and literature by combining suggestions of different types of sensation. The notion that something visual (colour) and something auditory (key) properties can be connected through common properties is rooted in Aristotle's notion of 'common sensibles'. This states that since we can determine what a given object is through more than one sensory channel, all channels concerned can be said to be supplying equivalent information, the information being received by the 'sensorium' (Barnes 1988). It is likely that this was the underlying thought behind the associative theories of Calkins, Harris and others and the issue of a common 'sensorium', as Aristotle put it, which is central to discussion of the manifestation of synaesthesia in non-synaesthetes.

In the case of someone who sees C major as 'red' and 'strong', the strong quality registers in what Aristotle called the 'sensorium' for both C Major and red. Although the common properties notion of this chapter ties in very well with Aristotle's 'common sensibles' notion, none of Aristotle's properties were abstract or subjective: all of them were palpable and objective. The full list of Aristotle's 'common sensibles' is movement, rest, shape, magnitude, number and unity. Some of the properties used in semantic differential studies, including some of those used here, are subjective and relative. Use of semantic differentials has demonstrated that the scales which generally give the most information are the most subjective and are known as 'affective attributes', which can be easily personified, i.e. can be related to people (good/bad, happy/sad, but not red/green or pointed/rounded) (Jaspars 1978, p 77).

Affective scales, as such, are not used here for the reason that they probably do not relate as easily to keys and colours as more material properties might. Moreover a short pilot study, using six polar opposites (large-small, hard-soft, pointed-rounded, good-bad, happy-sad and calm-angry), six colours (red, green, yellow, blue, purple and orange) and eight participants (none of whom were used for the study itself) showed that people are less sure about how to go about attaching affective attributes to keys and colours than they are scales of a less personal nature. In the same way, while most use of the Semantic Differential technique uses a graded Likert scale this study uses only the opposing extremes such as Strong and Weak. This is in order to force decisions and thereby attempt to amplify what might be relatively weak differences.

The twelve colour names that are chosen for this study are the eleven basic colour terms found by Berlin & Kay (1969) plus turquoise. Details of Berlin & Kay's study are given in Chapter 3, but of relevance here is that they claimed that of the wide variety of colour terms used only eleven are mono-lexemic, universally applied, not included in a more widely used category, and mean something to everyone.

The twelfth term added here may be included in blue or in green (i.e. may be included in a more widely used term), however it is difficult to determine which, if either, of the two terms closely describes turquoise, with the consequence that 'turquoise' is more generally used than the poly-lexemic 'green-blue'. Furthermore Berlin & Kay argued that language is still expanding, making it plausible that in our culture we now a have a stage seven *plus* system, stage seven usually having the full compliment of eleven colour terms that they listed (a minimum of eight), with turquoise as a further basic term.

It is not certain to what degree the written colour terms relate to the colours themselves. Baggelly found that written terms were perfectly adequate and that they produced similar results in assessing colour in music as compared to 'real' colours (Baggelly 1972). Gage also concludes that colour terms seem to be homologous with the experience of seeing colour in most people (Gage 1993, p 65).

Since the cross modal transfer between colour and sound in non-synaesthetes is likely to be based on metaphorical devices, and therefore conceptually close to language, positive three way relationships (e.g. 'blue' is 'small', 'E Major' is 'small' and 'E major' is 'blue') may be expected to significantly outnumber the negative ones (e.g. 'green' is 'small' 'A Major' is 'large', 'A Major' is 'green'), since, as stated in Chapter 10, metaphor likens something to something else by drawing attention to a common property. This means that in 'metaphoric mode' E major could be likened to blue as a result of both of them being small, for example. The assessment of the properties that a participants attributes to keys and to colours, in connection with which colours fit which keys can therefore be seen as a measure of the presence of this 'metaphorical mode'.

The experimental hypothesis is that there will be significantly more supporting cases than non-supporting cases. The null hypothesis is that any such variation will be due to chance variations alone.

PARTICIPANTS

20 participants (eight male, twelve female) were selected for the study. All were musically informed insofar as they could be presumed to have developed internal concepts of each of the twelve keys referred to in the experiment. This was felt to be necessary in order for them to be able to sensibly attribute one of each pair of semantically differentiated terms to the keys. Explicitly put, in order to make such attributions a certain familiarity with the various keys is needed. None of them had Absolute Pitch, and therefore probably did not all 'hear' the real pitches of the scales internally. Participants were resident in Northampton, Leicester, Blackpool, Sheffield and Nottingham areas.

MATERIALS

Questionnaires were given to each participant. These consisted of two parts. The first part, by far the longer, consisted of the names of twelve keys and twelve colours, making for 24 items in total. Beside each of these items were placed ten pairs of words with the members of each pair having opposite meanings (Actual/Imaginary, Dull/Stimulating, Dynamic/Static, Fixed/Flexible, Hard/Soft, Heavy/Light, Large/Small, Pointed/Rounded, Relaxed/Tense, and Strong/Weak), ten categories in all.

PROCEDURE

The top of part one instructed participants 'Please attach one of each contrasting pair of attributes to each of the keys and colours listed below. Mark each choice by circling it'. The second part of the questionnaire simply required colours to be given to each key, which need not contain all and/or exclusively the eleven basic terms plus turquoise, although they often did. Participants were also instructed to have a break of at least one hour between the completions of each part.

Each questionnaire was marked for consistency of selection of semantic pairs between related keys and colours. The basis of this is that for every key and colour association the choice of semantic polarities is checked for the key and the colour. Each case where both the key and the colour agree on a choice of opposites is regarded as supporting cases for a semantic connection between a key and a colour; whereas where the two disagree they are regarded as cases providing evidence against a semantic connection.

To illustrate this principle we will look at a questionnaire where a member of each contrasting pair was circled and where colours were given for each of the twelve major keys, facilitating 120 cases which may either show the same selection from a pair of opposites for both the key and the colour (e.g. key 'tense', colour 'tense') or show opposing ones (e.g. key 'relaxed', colour 'tense') for a particular key and colour that were connected in part 2. The first key for which a colour is asked for on part two of the questionnaire is G major and the participant (P19) gave 'orange'. Turning to part one and comparing 'G major' (item 7) with 'orange' (item 22), it can be found that both are attributed the qualities 'actual', 'stimulating', 'dynamic', 'light', 'large' and 'strong', six matching attributes, while orange is 'flexible', G major 'fixed', orange 'soft', G major 'hard', orange 'rounded', G 'pointed' and orange 'relaxed' and G 'tense', four opposing attributes. This makes for six supporting cases and four opposing cases.

E major (3) is given white (19), where only three attributes agree (flexible, light and large) while the remaining seven disagree. In a similar manner, B major and grey is given eight similar attributes and two dissimilar attributes. Continuing in this way, the relationships between keys and associated colours for Participant 19 can be tabulated shown in Table 16 overleaf.

TABLE 16

		Support	Not Support
G major	Orange	6	4
E major	White	3	7
B major	Grey	8	2
C major	Red	8	2
A major	Yellow	6	4
F major	Black	6	4
Db major	Pink	6	4
Bb major	Turquoise	2	8
Ab major	Brown	4	6
F# major	Purple	4	6
D major	Blue	8	2
Eb major	Green	2	8

These results give 63 supporting cases and 57 opposing cases. There is therefore a slight predominance of positive three way relationships over negative ones.

Participant 9 also had a high total score of associations (57 supporting cases: 55 non-supporting cases) giving colours to all keys but leaving a few opponent pairs blank. Participant 7 failed to complete many opponent pairs and failed to associate one key (Bb major) with a colour resulting in only 53 three way relationships being present. These mostly showed selection from the same pairs of opposites for each related key and the colour (41 such cases). Neither Case 2 nor Case 12 could give colour for any key and as a consequence no cases could be made.

RESULTS

The experimenter collected the questionnaires and counted how many of the 120 possible cases were positive, as defined above, and how many of them were negative, for each participant. These are shown in Table 17 overleaf. The null hypothesis stated that there would not be significantly more positive three way relationships than negative ones. A related measures t-test was performed on the data and the results were found to be significant ($df=19$, $t=3.22$, $p<0.005$).

Table 17

The number of positive and negative associations for each participant (half scores derive from participants selecting colours that lie part way between two of the twelve terms given e.g. Lime .5 Yellow, .5 Green).

Participant No.	positive associations	negative associations
1	62	43
2	0	0
3	45	33.5
4	22	14
5	75	45
6	58	44
7	41	12
8	45.5	25
9	57	55
10	55.5	38
11	38	34
12	0	0
13	83	37
14	68	52
15	64.5	28.5
16	16.5	18.5
17	68.5	27
18	78	42
19	63	57
20	68.5	51.5
MEAN	50.44	32.84

DISCUSSION

The results show that there were many more positive associations than there were negative ones, whereas if keys and colours were not associated with other the attributes from which the participants selected we would have expected close to half of the associations to be negative and close to half of them be positive, and by simple statistics would not have expected 17 out of the 18 selecting participants to all tend towards the predicted direction is very small indeed ($1 / (2^{17} / 18) < 0.0014$).

Unfortunately the t test was someone unreliable since the distribution of the negative and positive association values was too disparate, but this does nothing to alter the fact that these results occurred but were unexpected.

The experiment demonstrates a way in which metaphorical abstraction is believed to differ from synaesthesia as an organic condition (Cytowic & Wood 1982, pp 23-25, Baron-Cohen 1997, pp 11-12). Examination of nineteenth century reports of drug induced synaesthesia along with the respective authors' creative input (Hoffman 1812, Gautier 1846, Baudelaire 1857 &c.) indicates that trans-modal *epiphoria* is commonly experienced in those who do not generally perceive in that way normally, while writers whose style is strongly metaphorical have experienced something more akin to synaesthesia under these conditions. The discovery that certain drug states can transform a low metaphor thinker into a high metaphor thinker or a high metaphor thinker towards a condition akin to organic synaesthesia provides evidence for a continuum ranging from non-synaesthesia to synaesthesia. While it can be argued that drug induced synaesthesia is an intense pseudosynaesthesia, Cytowic demonstrated that drugs can affect the brain metabolism in a way that closely mimics synaesthesia, closely supporting the continuum theory. The work in this thesis with semantic differential techniques implies, however, that synaesthesia is an all or nothing situation. It can be held, nonetheless, that the pairing of colour with sounds in non-synaesthetes with aspects of semantic space (in this case the opposing word pairs) is evidence of 'mild synaesthesia' transmitted to a conscious level in a processed form, as opposed to rendering the individual subjectively aware of preconscious activity, which is what is thought to occur in organic synaesthesia.

The extent to which each of the 20 participants scored in the matching of colours to keys by way of their perceived similarity of qualities varied considerably from person to person. Two participants were unable to relate any keys to colours, despite being able to complete part one of the questionnaire. Consequently, one side of the triangle was consistently missing in all 120 cases so that both of these participants scored zero for both supporting and non supporting items. Only one participant (participant 16) had more non-supporting cases than supporting ones, and this participant had low scores anyway as a result of only being able to connect six keys to colours.

There were some quite strong tendencies between participants to allocate certain properties to certain colours. Such tendencies with respect to keys however were weak if existent. Key qualities seem to be much more individual. This can be seen from Table 18, showing attributions for selected keys and colours and for 'hard'/'soft' and 'relaxed'/'tense'.

TABLE 18

	Hard	Soft	Rlxed	Tense
E	7	6	7	8
G	5	6	6	8
Bb	8	7	5	5
Db	10	6	9	8
Red	13	5	4	10
Yellow	4	10	8	5
Green	7	9	15	3
Blue	10	3	11	6

As a consequence the colours and keys which could be expected to be connected as a result of similar attributions, as given in part one of the questionnaire, also varied greatly between participants. That is to say that even though the key, colour and attribute connections were internally consistent for most of the participants, the key and colour connections between those 18 participants who gave them showed no similarities.

In addition to the above, there was no consistent hierarchy for key allocation among the participants (It was not the case that everyone gave associations for A major, most for C major, half for F# major and only two for Eb major, for example). The associations of Participant 16 consisted of five 'central' keys, C, D, F, G & A) and included all of the four basic hues except yellow, which was possibly too light for the participant to match it to a key, and the two fundamental basic auxiliary colours in Berlin & Kay's (1969) hierarchy.

That Participant 16 gave associations between 'home' keys (C, G, F, D etc.) and fundamental colours but not between 'remote' keys (F#, Db etc.) and less fundamental colours is indicative of a hierarchy being adhered to, where 'basic' keys and colours have to feature before 'auxiliary' ones.

As a post hoc investigation, it is worth investigating the presence of this hierarchy amongst all participants, which is likely to be there since colours are, generally speaking, learned in a certain order which approximates the Berlin & Kay hierarchy, and keys are also learned in a certain order. For keys, this suggests that is if five keys are given colours then they might approximate those of Participant 16 (C, D, F, G & A). A participant with six associations might have all five of Participant 16's associated keys and colours plus one more. A participant with seven associations might have all five of Participant's associations plus two more, possibly involving the extra key and/or colour of the participant with six associations.

This was not the case for keys here. The completed questionnaires showed no such hierarchy. Participant 4 who, associated six keys with colours gave colours for D, Eb, E, G, A & Bb while Participant 7, who connected seven keys with colours, Db, Eb, E, F, F#, A and B). None of Participant 4's keys are remote keys but only three of the seven are in common with Participant 16. Participant 7's keys have a bias to the remote keys, with the average number of sharps or flats in the keys given colours to being slightly less than four.

In contrast the colours associated with keys showed a hierarchical relationship. Furthermore, this was close to the one given by Berlin & Kay (1969). The limited colours allocated to keys in the cases of Participants 4, 7 and 16 are shown in Table 19.

TABLE 19

	Participant 4	Participant 7	Participant 16
BLACK	YES	YES	NO
WHITE	YES	YES	NO
RED	YES	YES	YES
GREEN	YES	YES	YES
YELLOW	YES	NO	NO
BLUE	YES	YES	YES
BROWN	NO	YES	YES
PURPLE	NO	YES	YES
ORANGE	NO	NO	NO
PINK	YES	NO	NO
GREY	NO	NO	NO
TURQ.	NO	NO	NO
	P.4	P.7	P.16
% overlap with			
P.4	---	83	60
P.7	83	---	100
P.16	60	100	---

This regularity of the hierarchical order can be seen throughout the 18 fully completed questionnaires. The frequency of colour associations in full is: Red 18, Black 17, White 17, Green 17, Blue 16, Yellow 15, Purple 14, Grey 13, Brown twelve, Orange twelve, Pink eleven and Turquoise nine. These correlate closely with Berlin & Kay's hierarchy (+.914 (turquoise included as twelfth in hierarchy)) All participants (except 2 & 12 who did not complete part two) included Red. Participant 16 is alone in not including Black or White; the remaining 17 participants included both. Only one participant (P11) excluded Green.

Keys are associated with colours in an even distribution, ranging from eleven out of 18 in the home keys of F and G to the, not consequentially greater, 15 out of 18 for A major. Furthermore, both of the keys with the least associations in total were allocated colours by Participant 16, who had the least number of associations. This shows that there is no hierarchical structural evidence for a consensus in the priorities of the participants' allocation of keys to colours, but that there is much more concerning the priorities by which participants allocate colours to keys. What this suggests is that while the participants were working in linguistic mode, the colour terms were called into play in the order in which they learned them, showing that identification with the colour terms is easily accessed. For keys, this was not the case to the same extent, if at all. This offers some clues with regards to the processing methods used during this task.

The principal result of this study is that the participants' concepts of coloured keys were more often than not in accordance with those that they gave to bipolar adjective sets used to describe the keys and colours. This suggests that in their colour to- key associations similar mental processes are occurring to those that occur with synaesthetic metaphor. These processes do not operate with synaesthesia (Cytowic & Wood 1982).

The highest possible total number of supporting cases and non-supporting cases (120) was attained in six cases. Three of these maximum case participants had at least one and a half times as many supporting cases as non-supporting cases, while the other three had more even quantities of each (although they all had slightly more supporting cases than non-supporting cases). Since most of the participants did not give a selection every time and therefore did not make 120 assessable three way relationships, it is possible that a more forced choice regime would have further amplified the differences found in the study, as would increasing the number of contrasting pairs. An alternative to this is finding more participants who felt equipped to allocate such qualities to keys and colours. Nonetheless, the related measures t test suggests that these findings used here may very well be generalised to the larger population.

Despite the significance of the results, it cannot be ruled out that memory played a part in ensuring that a colour labelled as 'Stimulating', for example, is attached to a key so labelled, or a 'Pointed' colour is attached to a key labelled as that. Many participants commented that they could not help remembering how they filled in part one while filling in part two of the questionnaire. It is also possible that some participants guessed the hypothesis and that that might have influenced the responses given. The lack of 'affective attributes' on the questionnaire would have minimised desirability factors (Pointed and Rounded and Hard and Soft are less affectively loaded than Good and Bad or Polite and Impolite, for example), but this is unlikely to have taken care of the way in which memorisation and intellectualisation influenced the results.

Regarding extraneous variables, interference questions, multiple parts to the questionnaire distributed separately over a period of time and other means of generally inhibiting the role of conscious memory would probably be quite useful, and a more elaborate method of this nature seems as if it would be more useful than re-testing these results for reliability again in future - although this should perhaps be carried out at least once as well.

Assuming that the above factors did not force a supportive result where there would not otherwise have been one, it can be stated that keys are associated with colours in the minds of musical non-synaesthetes, although the keys and colours share attributes, as distinct from the connections of chromaesthetes, which are linked pre-linguistically and are related per se.

Even if memory factors played a part and E major is allocated red because the participant remembers giving the key and the colour similar profiles, the way in which the questionnaires were answered nonetheless shows that people's imagined cross modal associations are based on an associative framework. The associative basis is put in the context of other theories and of synaesthesia in synaesthetes in the next chapter.

12. Theories of Synaesthesia

The Oxford English Dictionary definition of 'synaesthesia' incorporates the term 'secondary sensation' and states that a synaesthete perceives sensations that are not actually present (Simpson & Weiner 1989). Their Secondary sensations can be distinguished from hallucinations by the following: - i) they are always simple perceptions (this will be explained in more detail later) while hallucinations, especially those associated with advanced pathological states are often complex; ii) they have occurred throughout the living memory of the synaesthete, and probably even before that; and iii) they occur in the absence of any pathological symptoms (Cytowic 1997). It is not surprising that there was, until recently, no plausible explanation of synaesthesia, and that the sensations were often simply dismissed as not real. Synaesthetes have no doubt of the authentic nature of synaesthetic experience, which for some almost constantly bombards them. It is this vivid reality of the images, the fifth of Cytowic's criteria for synaesthesia (see below), that is the key to one likely cause of the condition.

Before these findings are discussed in any detail, it is appropriate to outline the major nineteenth century theories of synaesthesia. Generally speaking, these theories are sound in part but were flawed by incomplete and imprecise understanding of the brain's workings. As the different approaches all focus on certain aspects of synaesthesia, a fairly detailed inclusion of them can be justified here. Collectively, these theories demonstrate the degree of attention that synaesthesia received in the nineteenth century. These theories can be divided into: - I Sensory Incontinence or Leakage theories, II Linkage theories, and III Abstraction Theories (Cytowic 1994, pp 82-84).

Sensory Incontinence theories focus on neural messages leaking between different areas of the brain. The theorists of the time seemed to underestimate how well insulated neural pathways really are (Cytowic 1994, p 83). Theories that explained synaesthesia in these terms focused on what synaesthesia is; a condition where sensation floods between channels which in the rest of us are kept apart. Was synaesthesia to work in the simplified way that the theorists claimed, however the hardwired cross modal connections that synaesthetes make would not have any consistency, whereas reports from synaesthetes reveal that there are consistent cross modal connections that are unique to each synaesthete, as demonstrated by Myres subject who was tested seven years apart and had similar colours to similar sounds (Langfield 1914) (see Chapter 7).

Linkage theory is based on the notion that we are born with connected senses. This is, to a degree, in line with the most commonly accepted understanding of the condition today. In some people, the theory argues, the neural paths never mature and the cross modality remains. A classic outline of the situation was given as follows: - 'When an infant reaches for an object, then all four limbs move, rather than just the one that the infant is attempting to use to grab the object'. This was seen as evidence that all parts of the body are conceptually inseparable at birth, but that with maturity separation is attained for most people, yet not synaesthetes (Cytowic 1994, p 83). Apart from this example suggesting that action and perception are directly related to each other, Linkage Theory also suggests that the brain of a synaesthete is in some way underdeveloped. This would make it more probable that the synaesthete would be severely mentally impaired. This is clearly not the case as most synaesthetes are of above average intelligence (Cytowic 1997).

A variant on the Linkage Theory is Associative Theory. This theory suggests that links exist, but they are not a result of lack of insulation or other 'hardwiring' faults, but rather suggests that links are learned as a result of chance associations. It can also, however, be the result of the synaesthete discovering that distinct perceptions in different sensory modes have shared properties. Unlike the main model for Linkage Theory, this is capable of accounting for the consistency of synaesthetic associations. Associative Theory was proposed by Mary Calkins in 1892. It gets round the problem of regarding synaesthetes to be mentally undeveloped, and is an early example of behaviourism, a school of thought which argues that we learn associations from chance pairing in the environment (Cytowic 1994, p 84).

52 years after Calkins, Howells attempted to demonstrate the notion that coloured hearing can be learned. For the demonstration he used military personnel as subjects. The subjects were placed in a room and were presented with auditory tones and coloured lights. The tones were sometimes at the pitch of middle C (262Hz) and sometimes the pitch of the G above (392Hz). The C's were consistently paired with a red light and the G's were paired with a turquoise light, red's opposite. These pairings continued for over 100 sessions all conducted on one day and each session consisted of 100 presentations accompanied by the respective light. Following this, many more pairing sessions took place where they were usually given a red light for C and a turquoise one for G but very occasionally (less than one per cent of the time at first) were given the 'wrong' coloured light. When such cross pairings occurred, some subjects reported seeing the 'expected' colour transforming into the correct colour (G accompanied by a red light would be seen as a turquoise light changing into red), indicating that the conditioning may have caused them to see a colour that was not present, which the experimenter likened to synaesthesia. It must be observed, however, that it took many pairings to achieve this and also that the subjects, having had their C-red G-turquoise routine disrupted, were left ill at ease (Howells 1944).

The above factors led Howells to conclude that boredom and experimental neurosis were more salient factors in the experiment than synaesthesia was. Since Howells' learned pairings took so long, it can be concluded that coloured hearing, or any other form of cross-modality, is very hard to acquire. This raised the question of whether 'acquired synaesthesia' was observed at the end of the experiment anyway.

Apart from the side effects, which did not undermine the experiment's 'achievements' per se, the repeated pairing exercise resulted in its subjects seeing the wrong colours as a result of operant conditioning It did not encompass the emotional properties of synaesthetic experience, such as those referred to by Cytowic (1994, p78) in the context of synaesthesia being 'emotional and noetic'. As with other behavioural studies, it did not account for, or even attempt to account for, conscious events. As a result, the experiment defines its supportive results exclusively in terms of what can be observed as opposed to considering what the subjects actually felt. The monotony-induced confusion under which Howells' subjects reported false colours, could hardly have been more disparate from the rich experience of synaesthesia in synaesthetes. At the time of his experiment being written up, Howells showed that had become aware of this flaw by acknowledging it.

The importance of these emotional factors led to Calkins proposing the Emotional Tone theory in 1895. The essence of the Emotional Tone theory is that the trigger and secondary sensations of synaesthesia possess certain emotional properties or 'tones' (Cytowic 1994, pp 83-84). The implication of the triggers and the secondary sensations sharing affective properties is that synaesthesia is made up by the mind. According to this theory a pleasant sound will always produce a pleasant colour whereas we have now seen reports from synaesthetes showing that this is not necessarily the case: Pleasant sounds can produce unpleasant colours for synaesthetes.

The disparity of affect between primary and secondary sensations is demonstrated by a coloured hearing synaesthete who distinguishes between favourite composers who are such as a result of the accompanying visual experience and those who are favourite composers as a result of the primary auditory experience (Case 16 in Chapter 14). A more substantial problem with the Emotional Tone theory is that it overlooks the subjective reality of synaesthesia. Synaesthesia is involuntary, and must be triggered by an external stimulus: Emotional Tone theory tends to deny this. The main benefit of this theory, however, is that it accommodates many of the important factors of synaesthesia, albeit it muddying the waters between synaesthesia and the abstraction that we all experience.

Non-synaesthetes have devised the above kinds of abstraction, which caused confusion in the formation of the nineteenth century theories of synaesthesia, throughout documented history. Reference was made in Chapter 4 to the Babylonian notions that Pythagoras brought back to Greece in the sixth century BCE which included allocating each of the seven spheres (the six inner planets, minus the Earth, plus the Sun and Moon) to its own colour. Kirscher (1602-1680), who was very much influenced by these notions produced correlations between colours, musical intervals and other entities as overleaf:-

	EnnerachordI	E/chordII	E/chordIII	E/chordIV	E/chordV
	E/chordVI	*E/chordVII*	*E/chordVIII*	*E/chordIX*	*E/chordX*
10th	Architypes *Trees*	Spheres *Aqua Crtrs*	Minerals *Birds*	Stones *Quadrupeds*	Plants *Colours*
9th	Seraphim *Fruits/Berries*	Firmament *Stellar fish*	Salt *Egptn Vulture*	Astrites *Pather*	Stellarherbs/flwrs *Varied colours*
8ve	Cherubim *Cypress*	Saturn *Tunny*	Lead *Owl*	Topaz *Ass/Bear*	Hellebore *Dark*
7th	Thrones *Lemon*	Jupiter *Sturgeon*	Copper *Eagle*	Amethyst *Elephant*	Betony *Rose*
6th	Dominations *Oak*	Mars *Psyphais*	Iron *Falcon/Vltr*	Adamant *Wolf*	Absynthe *Flaming*
5th	Virtues *Lotus/Lrrl*	Sun *Dolphin*	Gold *Cock*	Garnet *Lion*	Snflwr *Gold*
4th	Powers *Myrtle*	Venus *Trout*	Tin *Swan/Dove*	Beryl *Stag*	Orchid *Green*
3rd	Principaliries *Apple*	Mercury *Beaver*	Quicksilver *Parrot*	Agt/Jspr *Dog*	Peony *Blue*
2nd	Archangels *Pod Bearers*	Moon *Oyster*	Silver *Ducks/Geese*	Slnte/Chstl *Cat*	Honesty *White*
(Unison)	Angels *Fruits*	Earth *Eel*	Sulphur *Ostrich*	Lodestone *Insects*	Wheat *Black*

The main differences between abstraction and synaesthesia are qualitative rather than quantitative. Cytowic found five such differences (Cytowic 1994, pp75-78). Firstly, as I have stated, synaesthesia is involuntary; synaesthetes can pay more or less attention to their secondary sensations but have no control over their experience of them: Secondary sensations come always and only in the presence of specific triggers. The second factor that Cytowic found was that synaesthetic images are normally projected outside the synaesthetes personal space.

This is only the norm with the synaesthesia, however and is a secondary factor for, rather than a requirement of synaesthesia. Thirdly, synaesthetic sensations are definite, consistent through a lifetime (as demonstrated by Myres' subject), and simple (generic). Its generic forms are often multiple rods, blobs or spirals. These are believed to be the form constants of perception, whereupon our higher orders of perception are based (Sheppard 1990, pp 205-206). In other words, form constants are the only forms that capable of being generated or recognised preconsciously. Synaesthetic perception never becomes more specific than shapes, colours and simple sounds and textures. The fourth finding of Cytowic is that the secondary sensations of a subject are better remembered than the trigger sensations. Synaesthetes can often, therefore, use their secondary sensations as a memory aid, and facilitated Luria's subject's (Luria 1968) extraordinary faculty of memory. It is also possible for a synaesthete to confuse different items on the grounds that the secondary sensations are the same for each of them. Using coloured hearing for an example, a high and a low pitch may be confused if both are, for the subject, the same colour of blue. Finally, synaesthesia is emotional, akin to the light-bulb 'Eureka' experience - a feeling that cannot adequately be put into words. The inadequacy of language in describing such experiences can be explained by their predominantly involving the pre-linguistic mental function. This is why this aspect seems to hold a key to explaining synaesthesia.

This origin of synaesthetic experience was demonstrated by Cytowic's findings for MW with secondary sensations of shapes produced from gustatory triggers. Cytowic used radioactive gas to measure the level of activity in different parts of MW's brain. He found that the activity on the surface of the brain, the part often referred to simply as 'the brain' - the cortex, was unusually inactive, so much so that the scan made the subject appear dead (Cytowic 1994, pp 144-152).

During synaesthesia, the level of activity appeared to be even lower in the cortex but it was also observed that there was a greater level of activity in earlier parts of the brain (the midbrain and especially the limbic system). The limbic system, so named because of its resemblance to a ring or limbus which surrounds the thalamus, was discovered by Broca in 1878 (Schiller 1988). As defined now the limbic system consists of well over 20 different structures. It is regarded as a system because all of the structures are interconnected and probably developed simultaneously. The system, collectively, has many functions, including hormone release, memory formation, the inhibition of instinctive behaviours, and emotion. Since the impressions generated by the limbic system occurs before stimuli reach consciousness, we are not normally consciously aware of them in raw form but in a modified form whereby rationale filters some sensations, such as synaesthetic ones in non-synaesthetes, out (Cytowic 1997, 30-32).

MW's low cortical activity and high limbic activity during synaesthesia suggested to Cytowic that synaesthetes may not have their synaesthetic operations overridden, with respect to consciousness, in the same way that the rest of us do. There is a prevalent school of thought that these areas account for the vivid, emotional, known-ness of synaesthesia, along with its memorability. Although this is a generalisation based on one case, the reports of people with synaesthesia are remarkably alike, indicating that these findings are almost likely to be duplicated in other synaesthetes. In any case, the cortical activity observed in MW was, by far, the lowest recorded in any examination and only fell to that level as he sensed his secondary sensations, strengthening support for the connection between his having synaesthesia and his extremely low cortical activity.

The findings of Cytowic certainly go some way towards explaining both the nature of synaesthetic experience and how it can be that a small minority of people are synaesthetic while the rest of us are not. We can assume from these findings that at a preconscious level all senses are sensed alike. Non-synaesthetes are aware of this level in some drug induced states (e.g. Gautier 1846) and in certain kinds of religious experience (James 1928, pp 58-69) This suggests that we can all, to some extent, be aware of the level of the brain in which all senses are one sense.

The very way in which the senses combine to form experience leads me to query one claim of Cytowic's, that of there being no continuum between synaesthetes and non-synaesthetes. According to Cytowic's work one either is or is not aware of this form of pre-cortical activity. It seems possible to me, however, that we all have glimpses of the synaesthetic world, and even though usually banished from consciousness, this may affect behaviour. Many experiments on colour and musical pitch, including my own (Beaumont 1997), have been performed on non-synaesthetes. Many of these have found definite associations between colours and keys or pitches. I would suggest that these studies have tapped pre-conscious synaesthesia in non-synaesthetic individuals, preconscious experiences that they are unaware of. Synaesthetic metaphors - descriptive phrases that address more than one mode of sensation - might be manifestations of this.

Following this argument, abstraction could be a form of synaesthesia, with its source kept unaware to its possessor. One line of evidence of this concerns the colour and musical pitch associations that have been found as exemplified by Chapter 7 in this thesis. This study implies a link between preconscious AP and synaesthesia since the two have several properties in common, as listed overleaf.

i) Both are thought to be preconscious functions. The case for synaesthesia being pre-cortical, and therefore preconscious, is made above, while the inferiority of AP possessors at certain musical tasks as a result of their involuntary pitch class categorisation is related by Miyazaki to AP's deep rooted-ness (Miyazaki 1992).

ii) Both are thought by researchers cited in Chapter 7 to occur in the new-born and then disappear in the majority of people (in the case of AP, presumably owing to its lack of relevance in musical life).

iii) 'Pitch class', which which those with AP are easily able to identify, shares terminology with colour, thus 'chromaticism' in music.

iv) Sir Isaac Newton, on discovering the way in which white light split into its components, labelled the colours by musical scale degrees.

v) Most colour keyboards, such as those designed by Castel, E Darwin and Rimington, followed a scheme where pitch height was represented by luminosity (the higher notes being lighter than the lower notes) and pitch classes were distinguished by different hues where two notes one or many octaves apart were the same hue), (see Chapter 5).

This seems to be a large body of evidence for the interconnectedness between two apparently rare faculties: synaesthesia and AP. It follows, therefore, that any research performed concerning either one of these two mixed blessings, whether from a neuroscientist's standpoint, a developmental standpoint, a genetic standpoint, or any other standpoint may assist in the understanding of the other.

13. Case Studies of Two Musical Chromaesthetes: (Messiaen, Skryabin).

Since this thesis is dealing with musical synaesthesia, composers whose music is influenced by notions of music possessing a direct analogy with colour are absolutely central to it. To an extent, colour and music connections have been made by a large number of composers since about 1830. Examples of those composers include those which Sabeenev listed as being strong in sense of colour; three of those are Berlioz, Wagner, and Debussy (Sabeenev 1929).

In some cases the colour and music connection has been an essential influence in the composer's output. This is so much the case in a few cases that colour and music connections are actually documented. Below two such composers are examined. The second composer discussed here is Skryabin who, as previously described, based 'Prometheus', with its colour organ part, on his key and colour associations. Before Skryabin is examined in this way we turn to Messiaen.

Messiaen consistently referred to colours in relation to note clusters and modes. Colour dominated his perception of music to such an extent that he referred to music that was coloured and music that was not coloured, at the expense of any other form of categorisation.

> There aren't any modal composers, tonal composers of serial composers. There is only music that is coloured and music that is not.
>
> (Samuel 1994, p.63).

Messiaen's life and works are summarised by two main sources within his lifetime, The aforementioned 'Technique of my Musical Language', first written, in French, about 1940, and his interviews with Claude Samuel, which took place in 1966 and 1967, from where the above quote comes from. As implied by its title, the first of these sources is concerned strictly with the musical language, with no deliberate attempt to explain what it is supposed to mean or represent in terms of colour. Consequently this source is useful or the purpose of studying what the composer actually wrote, partly or wholly as a result of his synaesthesia but does not address the subjective nature of his synaesthesia. The Samuel-Messiaen interviews are the principal source of information relating to the composer's condition and accordingly they are used in this chapter. These interviews are witness to the composer's not believing that he had synaesthesia, a condition that he believed occurred when there was a 'disorder of the optic nerve' (Samuel 1994, p 37). On the other hand, Messiaen goes on to say that he has 'a sort of synaesthesia' that is in the mind rather than external. It will be recalled from Chapter 12 that projection of the synaesthete's secondary sensations is one of the factors of diagnosis for synaesthesia listed by Cytowic (1994, p 76), but unlike the other four, it appears to be a second rank factor.

We are at a fortunate advantage in determining whether or not Messiaen had the first rank symptoms of synaesthesia since unlike Skryabin, his condition is well documented. Messiaen, it would appear, was an 'internal synaesthete' but nonetheless still a synaesthete. There are reports of several such synaesthetes who fulfil the four basic criterions, but whose images are not externally projected, examples of such synaesthetes include the subjects of Harris (1908) and Luria (1968). My research has also found this to be the case with Tony and Steve two individuals discussed in the next chapter (Cases 16 & 20). I wish to demonstrate, therefore, that Messiaen's 'kind of synaesthesia' (Samuel uses the term 'synopsia') was as real that of any other synaesthete. Applying Cytowic's remaining criteria to the wealth of evidence concerning Messiaen, it is possible to demonstrate this by examining the four remaining criteria.

The first of these criteria is that synaesthesia is involuntary. If synaesthesia was optional for him, it can be argued, then he would probably not have needed to suffer uncomfortable cross modal dissonances, such as one concerning a violet lit fountain and Beethoven's music in the key of G major which was for him any colour but violet (Samuel 1994, p 42). Being involuntary also meant that Messiaen's sound-colour relationships had no rational formula. The composer expressed a wish to explain rationally the correspondences between chord complexes, and other considerations and his colours but was unable to do so partly because of his lack of control over these colours. Synaesthesia's being involuntary also means that a synaesthete cannot choose to experience certain colours at certain times. This was so for Messiaen, who could only (and did always) see coloured secondary visions by reading or listening to, what was for him, coloured music. Messiaen's colours were a reality which just happened.

Regarding the next criterion, consistency of the composer's coloured hearing, Messiaen stated on many occasions that various chord complexes and the Modes of Limited Transposition are certain colours and that these never change, provided, that is, other factors such as timbre are constant. These Modes are pitch class sets that are derived from interval patterns that repeat two, three, four or six times per octave. This means that a mode which is identical if transposed by a minor third has as many minor thirds available as there are notes (in the case of Mode 2 there are eight). In the terminology of pitch class set analysis referred to below, intervals that occur in a set as any times as there are notes are said to be 'maximised' (Babbitt 1962, Forte 1973). It can be hypothesised that limited transposition modes (Messiaen lists seven but 19 such modes exist) are, for some people, especially coloured as a result of the dominance of certain intervals (e.g. the tone and tritone dominance of the whole tone scale) and the artificial harmonics that these result in.

Generally speaking, for example, the first transposition of the second mode {C, Db, Eb, E, F#, G, A, Bb} centres around certain blues, violets, mauve and rose for Messiaen. Other transpositions of this mode are seen as different colours, the second {C#, D, E, F, G, Ab, Bb, B} concerning gold and silver spirals (note, a form constant) against a background of brown and ruby red stripes and the third {D, Eb, F, F#, G#, A, B, C} producing prairie and foliage green as the dominant colours. These differences between different transpositions of the same mode show that Absolute Pitch (AP) and not just the relative pitch of a mode is important in determining a composer's secondary sensations. The composer did not find much importance in certain keys being certain colours, however, calling such connections 'childish' and preferring to focus on more complex relationships between very specific colours and sound complexes. Nonetheless, as referred to above, he found G major very dissonant with violet (although he would not say what colour went best with G major) and in his interview with Samuel expressed a relationship between E major and red. Additionally Paul Griffiths correlated Messiaen's stated colours in works with their musical features and found that A major was predominantly blue (Griffiths 1985, p 41).

Regarding Messiaen's synaesthesia being discrete, durable and generic, and specifically addressing the last of these, the colours of his music were strikingly specific, especially when they were interlinked with 'chord complexes'. 'Generic' means anonymous, non specific and belonging to a class, yet colour terms like 'prairie green', 'milk white', and 'ruby red' seem very specific. It has to be remembered, however, that the colours we see, however complex they might seem, can be reduced to three dimensional colour space and we can only see a surprisingly small and finite range of colours (no more than about 2000 can be held in memory at one time). Uncensored sound-colour connection in the preconscious brain, is probably capable of 'producing' all distinguishable colours as secondary sensations and therefore any of the colours that the composer experienced but without, of course, the complex names.

Colour names, as shown above, involve language and, therefore, it is possible that the composer elaborated his secondary sensations in consciousness. Determined to describe his synaesthesia in music and in extramusical description, it is no surprise that he did just that. Therefore, the descriptions that he gave of colours were not directly of his synaesthesia but of the conscious interpretation of it, which would be rationalised as opposed to 'raw' and generic.

It seems that the patterns which they formed conformed to generic simplicity (form constants) as checks, dots and spirals. One possible exception was a reported form in the third mode's second transposition {C#, D#, E, F, G, G#, A, B, C}. He reports for this mode, which was dominantly grey and mauve, 'flaming gold letters of some unknown script' (Griffiths 1994, p 64). This is probably an example of the cognitive elaboration described above since the original 'letters' could have been the kind of unelaborated form constants described in Chapter 12 and they were only transformed into letters by the composer's consciousness.

Regarding durability, Messiaen's synaesthesia was at least as consistent as that of other synaesthetes. It was clearly more consistent than some over time than Myres' patient's (Langfield 1914) whose colours modified slightly in over a space of five years. Radocy & Haack also found remarkable consistency over time, yet subtle differences, with their cases (Radocy & Haack 1981). The absolute consistency of Messiaen's colours and forms could, like the complexity of colour names, also have been due to cognitive factors insofar as he may have elaborated his instinctive coloured responses into a colour-sound 'cipher'.

The fourth criterion, of memorability, was fulfilled by Messiaen, as can be shown in several ways. As stated earlier, for most subjects the secondary sensations that are induced are remembered better than are the triggers that cause them. For Messiaen this meant that his sound complexes were used as if they were the colours themselves. Listeners to the music hear how he combined his chords to form quite distinctive compounds in his work.

While listeners may possibly appreciate the colours as part of the music's significance these remain a means to an end. From the composer's point of view, however, the chords were superimposed 'as a painter mixes colours'. The quote given earlier, where Messiaen said that there were no tonal, modal or serial composers but only music that is coloured and music that is not coloured is also supportive of this. In other words harmonic language, choice of modes and tonality determined how well coloured music was, while the latter was what finally mattered. At the outset of this chapter I paralleled this with Tony (Chapter 14, Case 16) insofar as he likes some music more than others on account of secondary sensations, and is sure that without synaesthesia he would have had different musical preferences.

Therefore it seems that Messiaen had synaesthesia and that this played a large part in his music. The two were connected at a very deep rooted level and it seems likely that were he to have lost his sense and memory of colour, as Oliver Sacks' subject Jonathan I did his musical world and the other interconnected aspects of his life would have become meaningless (Sacks 1995).

The composer describes in tremendous detail how he organised large chords in his work in terms of register so that some colours 'appear' in dark 'shades' and others in lighter 'shades' in a way that makes the process sound like a scientific exercise, but when Samuel pointed this out he said 'I only limit myself to saying what I feel' (Samuel 1994, p 95). Hsu relates Messiaen's early coloured memories concerning stained glass windows and also relates the early memory of the violet fountain and G major music referred to earlier (Hsu 1996, p 23). Messiaen states that he 'feels synaesthesia intensely' and that 'it is an inward reality'.

It is the emotional factor which describes the quality of synaesthesia. In Cytowic's book, description of the fifth criterion is followed by a collection of essays on 'The Primacy of Emotion'. These are spiritual writings which deal with the biological bases of the intangible and ineffable. Messiaen's synaesthetic experiences were clearly interconnected with spiritual meaning and with his music. To give one of many examples of such spiritual and synaesthetic involvement in music, in *Le Couleurs de le Cite Celeste*, the music is, for him, the colours of the stone of the Celestial City.

Messiaen's association between perceptual experiences and other entities is shown by the way in which the Samuel-Messiaen conversations persistently shift between, among other things, the composer's academic-seeming musical language, colour, coloured musical connections, childhood experiences, love of nature, and his Catholic faith. Regarding the last of these areas, his gnostic spirituality far transcended Catholicism or Christian orthodoxy. He knew his spiritual place and meaning as inward reality, in a similar sense that his coloured images of music were real to the composer. Colour and spirituality were therefore one and the same, and consequently most of his musical output is sacred. The composer quoted Chagall, the painter, also believed to have had synaesthesia, when he said 'All sacred art is a rainbow of sound and colours' (Griffiths 1985, p 142).

The conclusions outlined in this thesis, especially those in Chapter 12, suggest that internally known or 'gnostic' experiences such as Messiaen's are removed from the influence of the reasoning consciousness and that subjects of such experiences will not feel that they have any conscious control of them. Furthermore, an experience that presents itself as 'truth' in such a way as surpasses language cannot be processed by the cortical brain. Experiences that are 'emotional and noetic' are usually also 'involuntary', as they were in this case. The quality of knowing may also serve to explain why synaesthesia is 'memorable', as Messiaen's clearly was, since human memory remembers significant things and synaesthesia presents itself as very significant.

Since truth in the above sense is internal, there is also reason to expect that where these criteria apply there is also the consistency of connections found in Messiaen or at least the near consistency of cases like Myres' subject. From the information available we find that Messiaen fulfilled the four most important criteria for the diagnosis of synaesthesia. But our demonstration of the validity of these criteria goes a stage further than this because many of Messiaen's references to coloured hearing sometime refer to two or more of these in the same sentence. This indicates that the four criteria support each other so that any one implies the others. In particular the noetic nature of the composers' coloured hearing explains why it was also involuntary, consistent and memorable.

Although Messiaen denied experiencing synaesthesia on the grounds that his visions were not externally projected, this is less directly related to emotional experience than the other four criteria are. Messiaen's experiences contained all of the substance of synaesthesia and also show that the four main criteria for diagnosis are interconnected.

It is difficult determine in any certain way whether or not Skryabin had synaesthesia in terms of the condition described in the previous chapter. His case is very complex since all reports and evidence for his seeing colours in conjunction with music are bound up with his personality and music. Skryabin's early compositions were fairly conventional in nature, his piano writing being similar in style to Chopin's, 50 years earlier. His philosophy, by contrast became individual and distinctive early on. Believing himself to be a natural manifestation of God, he became aware of a spiritual mission that he was pre-destined to achieve. The last movement of his first symphony, written in 1900, has the title 'Hymn to Art' and it glorifies art as a religion. 'Hymn to Art' is an early trace of the sense of mystical empowerment which culminated in 'The Mystery':-the name which he gave to the force under which he felt driven to write his later works such as *Prometheus* and the last four piano sonatas.

Skryabin's believing himself to be divine burdened him with responsibilities: he often asked question such as 'why had he not made the world as he would wish to have it made'.

On his early visits to the composer Boris de Schlozer described him as mentally absorbed, tense and nervous, he writes

> Whatever he was doing or saying, an intense inner process accompanied his actions which never ceased and of which he was seldom aware of. A random remark, a leading question was sufficient for him to become absorbed in his thoughts, to begin to expound them, persuading, or so it seemed, not so much the listeners as himself.
>
> (de Schlozer 1987, p 54).

Skryabin, in this way, took his divinity to heart and took on not only the discipline not only of doing what he was destined to do, but also the discipline if thinking as he was destined to think. He was always ready to change his philosophy in order to accommodate new insights towards truth. The seemingly involuntary nature of the composer's thought processes, which was fuelled by the irrational thought process that haunted him throughout his life, has something in common with the state of synaesthesia, namely the intense, intuitive known-ness character which gives the experience a religious quality. This 'religious' quality, it will be recalled, is a preconscious function. De Schlozer goes on to describe how the thought process could often induce 'almost physical pain'. It seems likely that because the pain accompanied the ecstatic and frenzied process of thinking certain thoughts, it did actually get perceived as pain. This would have been a type of synaesthesia where thoughts or concepts trigger sensations. This was once called 'psychochromaesthesia' but more recently 'pseudochromaesthesia'. The latter term is misleading (and condescending) since this kind of synaesthesia is less subjectively real than other forms are.

Skryabin's great plan was destined to involve him in writing compositions that combined colour with odour, textures and music; not in the Wagnerian, music drama sense, where the experience consists merely of different stimuli occurring simultaneously, but in a spiritual sense. This spiritual super-sensation would create a super-art form called 'Omni-Art' which was supposed to have great powers. It was believed by the composer that correlating the senses to the ideal formula would produce great energies, in the same way that the ancients believed that riches could be formed by correlating stars, planets, metals, colours and musical pitches.

When Skryabin made plans for trans-modal compositions, he already knew the connections between the senses - he knew what went with what. He would often play his compositions to his friends and spoke as if he could see the colours as the music sounded. This supports the notion that Skryabin was synaesthetic, as do the implications of writers who knew Skryabin. However, there are no explicit statements of this; correspondence of his colours to keys is often referred to, but it is never made clear whether or not the colours are 'wishful thinking' or subjectively real. The lack of direct reference to synaesthesia might be explained by the condition being unknown to Skryabin's biographers who seemed to explain his subjective reports away. De Schlozer gets closest to implying the existence of synaesthesia, he writes.

> As he played its opening bars (of *Prometheus*) on the piano for me, he remarked that violet light should permeate the hall at that point and it became clear that the chord represented, in his mind, both a sound and a colour
>
> (de Schlozer 1987 pp 84-85).

It seems that Skryabin was unable to use words to describe the accompanying secondary sensations, which highlights the possibility that the sounds not only represented the colours, but, for the composer, actually *were* the colours. The next chapter shows how common it is for synaesthetes to go through much of their life unaware that most people do not perceive the world in their way. Even when synaesthetes do realise this, many of them do not discuss their secondary sensations for fear of ridicule. Skryabin's conviction of sensory unity in 'Omni Art' and the way in which he communicated such ideas constitutes evidence of the condition and this cannot be refuted because of the lack of explicit references to this. That notion that synaesthesia was unknown in Russia at the time is reflected in Kandinsky's 'Concerning the Spiritual in Art' in which he cites a case of coloured gustation (possibly the same one as Case 8 in the next chapter) but does not call it 'synaesthesia' (Kandinsky 1977, pp 24-25).

Skryabin saw each key as possessing a colour and seems to have assumed that everyone experienced keys like this until he accidentally raised the issue with Rimsky-Korsakov in 1907 McBurney (2002). Rimsky-Korsakov also had key and colour associations (but was probably not synaesthetic) but these did not match Skryabin's. At the time when Skryabin discussed his colours with Rimsky-Korsakov he was working on his fifth piano sonata and first realised that universal (i.e. trans-modal) art was a function of his personality. He reported to de Schlozer that music existed outside him in images that he was unable to express verbally. He continued explaining that he felt himself not to be creating the music but was unveiling what has always been but never realised. This last point appears to be a key factor in preconscious phenomenon. It appears that the composer's musical output reflected, for him, this hidden knowledge of sensory unity.

The colour associations indicated in the front of the score of *Prometheus* (see Chapter 7) show that two of the colours are duplicated for two different keys. This means that two tonalities in each case are given the same visual accompaniment while being different in sound, thus making any direct sound to colour basis unlikely. This is one retrospective criticism of Skryabin's concept of *Prometheus*. A more significant problem is that an audience has a much higher tolerance of speed with respect to the transformation of musical key centre (i.e. tonality) than they do of change of visual colours. Skryabin's later works are very chromatic (Some theorists, e.g. Forte (1973), regard them as atonal, but it can be argued that the existence of shifting key centres makes them tonal by definition, although in a liberal sense) but its chromaticism is by no means intolerable to most listeners. The rapid changes or coloured light, however, were found to be very difficult to cope with in the work's, aforementioned, first light accompanied performance in 1915, inducing headaches and other side effects (and this was with the dim lighting determined by the limited technology of the time).

However inspired Skryabin's *Prometheus* is it was destined not to work in practice. This is typical of the composer's ideas; he was constantly involved in mystical, other worldly problems since inner compulsions took over. While this meant that the practical considerations were neglected, it is not true that his works are without system or are unanalysable, quite the contrary holds true. The entire composer's output, especially after 1905 was written with the strictest discipline and control. In order to provide constraints for his creativity he devised systems which almost constituted formulae, and which allowed him little or no room for manoeuvre once he had set them. In Skryabin's mystical mind, these schemes were spiritual recipes which if strictly adhered to would provide the whole universe with the divine fulfilment it needed. On a functional level these recipes gave the composer a focus point without which, it is commonly held, he would have lost his sanity completely (de Schlozer 1987, pp 119-120).

Skryabin's schemes, in order to 'write the music by themselves', so to speak, covered all aspects of the compositional process: harmony, rhythm, structure etc. These are best exemplified by looking at the harmonic aspects of the language, partly because more analysis has been performed on harmony than on other aspects of his composition, and partly because it facilitates a parallel comparison between Skryabin's and Messiaen's compositional languages which is made later in this chapter. A set of pitch classes which Skryabin felt to be well disposed to colour and which obsessed him in his late years (after about 1905) was what he called the 'Mystic Chord'. This chord is applied almost constantly in *Prometheus*. It can be regarded as a whole tone scale with one note flattened. Its inversion, the whole tone scale with one note sharpened also appears after about 1910. This set is sometimes found as a chord with the pitch classes arranged approximately, or sometimes exactly, in the order of the harmonic series (with the third partial (perfect fifth) missing).

The extent to which this use of chords is tied up with the composer's general sense of mystical (and therefore preconscious) awareness and his mission, makes it appear almost certain that Skryabin deliberately ended up selecting certain pitch class combinations because they possessed for him certain unutterable qualities which may have manifested themselves as colours.

I have previously suggested that the connection between his music and synaesthesia is in no way undermined by the composer's lack of mention of synaesthesia since Skryabin and his biographers did not have a name for synaesthesia. Skryabin took his experiencing of colours as being normal at least as late as 1907. Even after that he accepted that some experiences including his awareness of colour in sounds could not be put into words. Consequently he never named the phenomenon.

It is of relevance to both Skryabin and Messiaen is the notion that the use of certain pitch class sets makes music take on certain characters that are predetermined by the sets. The notion of pitch class sets was proposed by Babbitt as a means of compositional analysis (Babbitt 1962, pp 108-121) and was later developed by Forte and others as a means of analysing early twentieth century atonal music (Forte 1973). A property of pitch class sets which affects their quality to a large extent is the number of combinations of each interval class available. The whole tone scale includes only major seconds/minor sevenths, major thirds/minor sixths and tritones. The lack of strong perfect intervals, allowing definite tonal cadences, combined with the lack of the direction of semitones gives this pitch set a very diffuse and wandering quality owing to the inability to establish any tonal centre. It conveys an impression of vagueness and in my view suggests certain colours. The profiled availability of intervals within a pitch class set is called a vector. Vectors are presented as six digit numbers with the first digit representing the number of semitones (or major sevenths), the second digit representing the number of tones (or minor sevenths), and so on.

The vector for the whole tone scale (Set 6-35) is [060603] since there are no semitones, perfect fourths or minor thirds (and their inversions). The mystic combination (Set 6-34) with just one semitone different has a completely different vector, [142422]. This modified whole tone scale has all the intervals in it but a relative lack of perfect fourths, minor thirds and semitones (and their inversions). Colours apart, the 'Mystic Chord' combines an essence of the whole tone scale with a sense of tonal pull from the 'odd' note. With respect to colour, I would suggest that the union of a kind of tonality with a predominantly whole tone scale, combined with the natural harmonic order of the chord, results in a definite sense of colour which is distinct from the whole tone pitch set. It seems that most selected pitch sets that are diverse from the, fifth dominated, diatonic sets imply strong moods and that, in many people, who are especially aware of their preconscious activities, colours or other secondary sensations.

This examination of Messiaen and Skryabin shows that the two composers had similarities, but also vast differences, with respect to their colour and music associations. To summarise the similarities first, both composers placed a great deal of emphasis on colour and music and in both cases it was interconnected with the composers' deep-rooted emotional life. With Skryabin, however, it was more of an obsession than anything else, perhaps baring some similarity to Ostwald's patient (Ostwald 1964), whereas with Messiaen it was more of a reality.

There were, however, many qualitative differences between the colour and music relationship in the two cases. Skryabin's music-colour scheme was, by far, the more straightforward of the two. Messiaen, it will be recalled, described Skryabin - like key-colour associations as 'childish'. Messiaen's own were much more complex and required, pitch class related colour being produced by the omission of certain notes to form modes. Differences in the lexicon are expected between different synaesthetes and in itself Skryabin's simple basis for associations certainly does not rule out the possibility that he, like Messiaen, had synaesthesia.

Compared to Messiaen, Skryabin's reports do not appear to contain the same convictions that the colours are there and are emotionally loaded and independent from conscious control, or that they fulfilled the diagnostic criteria of synaesthesia suggested by Cytowic (Cytowic 1994, pp 75-78). It seems, therefore, that Messiaen had synaesthesia but that Skryabin did not. Despite this, Skryabin gave evidence for some degree of emotional, albeit obsessive, involvement with his chromaesthetic connections and for the purposes of investigating the nature of synaesthesia he may appropriately be considered alongside the, some doubtful, cases in the next chapter.

14. Other synaesthetes.

The previous chapter has looked at ways in which Messiaen and Skryabin saw colours in relation to music. These composers are quite well known for their colour and music connections. The cases below, however, include some quite well known artists whose synaesthetic way of looking at the world is not renowned. Those familiar with Nabokov's work, for example, are generally unaware that he had chromo-lexical synaesthesia, while Luria refers to synaesthesia in his subject but focuses predominantly on his memory feats. Unlike the documents on Messiaen and Skryabin, the studies below offer disinterested and thorough studies of synaesthesia. It is unlikely that Messiaen or Skryabin would have been prepared to, or to understand the need to discuss their coloured secondary sensations from an adequately objective point of view for these purposes. The 20 cases examined here, five of which I have interviewed for the purposes of this study (case numbers 16-20), provide such a level of objectivity. Each of these cases fulfils all or most of the criteria that Cytowic gave for the diagnosis of synaesthesia, as shown in Table 20 overleaf:-

TABLE 20
How 20 Cases Fit Five Diagnostic Criteria of Synaesthesia.

	Involuntary	Projected	Durable	Memorable	Noetic
Case 1 Cytowic's MW	YES	YES	YES	YES	YES
Case 2 Cytowic's Victoria	YES	YES	YES	YES	YES
Case 3 Rogers' 1	YES	NO	YES	YES	NO INFO
Case 4 Rogers' 2	YES	NO	YES	YES	NO
Case 5 Rogers' 3	NO	NO	YES	YES	POSSIBLE
Case 6 Rogers' 4	NO	NO	YES	NO	NO INFO
Case 7 Ostwald's	YES	YES	YES	YES	Probably
Case 8 Downey's S	YES	NO	YES	NO INFO	YES
Case 9 Collins' S	YES	YES	YES	YES	YES
Case 10 Nabokov	?	YES	YES	YES	YES
Case 11 Langfield's	YES	NO INFO	YES	YES	YES
Case 12 Luria's S	YES	?	YES	YES	YES
Case 13 Julie R.	YES	YES	YES	YES	YES
Case 14 Alison Motluk	YES	NO INFO	YES	YES	YES
Case 15 Elizabeth S-J.	YES	NO INFO	YES	YES	YES
Case 16 Tony	YES	NO	YES	YES	YES
Case 17 Andy	YES	Probably	NO	YES	YES
Case 18 Aiden	YES	NO	YES	YES	YES
Case 19 Stuart	?	YES	YES	NO	YES
Case 20 Steve	YES	NO	YES	YES	YES

Additional details of the cases are as follows: -

Case No. Type of synaesthesia and details.

1. Gustatory-Visual/Tactile.

Sees and feels shapes that can be divided into two lobes, each of which is entirely symmetrical while each lobe can vary within a spectrum from flat to sharp.

(Cytowic 1994).

2. Auditory/Olfactory/Gustatory-Visual.

Tastes and hears colours. High notes are pink and low notes are blue. Other colours are occasionally seen in connection to tastes but pink and blue are the main ones.

(Cytowic 1994).

3. Auditory-Visual.

Coloured pitch classes. Rogers' participants, unlike most of the other 16, have Absolute Pitch (AP).

(Rogers 1987).

4. Auditory-Visual.

Coloured pitches. As with Cases 3, 5 and 6 this participant has AP.

(Rogers 1987).

5. Auditory-Visual.

Coloured pitches. This participant has AP but is a somewhat doubtful case of synaesthesia since the secondary perceptions are voluntary to an extent.

(Rogers 1987).

6. **Auditory-Visual.**

Coloured pitch classes. The participant has AP. Doubtful case of synaesthesia from the point of view of Cytowic's criteria since the colours do not monopolise the pitches.

(Rogers 1987).

7. **Auditory-Visual/Tactile.**

Very comprehensive range of colour sensations covering every sound that the subject heard. Also occasional secondary sensations of pain. She was referred to a psychiatrist because of her obsession with her synaesthesia rather that because of the condition itself. Upon diagnosis her coloured words were tested by an audiologist who found them to be very consistent.

(Ostwald 1964).

8. **Gustatory-Visual.**

Coloured tastes and mouth-feels; not tested with aromas. Most consistently sour was green and bitter red-brown. Most of the colours were exclusively in the black-white and red-green dimensions. However if Kandinsky (1977, p 24) was referring to this case, then it is significant that he reported the subject's seeing blue.

(Downey 1911).

9. **Multiple Senses-Visual.**

Colours occur in connection with both sensations and concepts (psychochromaesthesia). Had a keen interest in colours similar to that of Case 7 but without the same level of obsession.

(Collins 1929).

10. Chromo-Lexical.

The subject saw all the letters of the alphabet as each having their own distinct colour. These colours could be produced simply by thinking about the forms of the letters. Sounds did not affect him.

(Nabokov 1967).

11. Auditory-Visual.

Had consistently coloured pitch classes which facilitated AP. The subject was tested for consistency both in 1905 and 1912 and showed very minor modifications of the same basic colours.

(Langfield 1914).

12. Auditory-Visual.

Colours and/or forms seen in connection with nearly all auditory stimuli. These facilitated the subject's excellent memory. If auditory material was presented at the wrong speed the visual sensations became bombarding.

(Luria 1968).

13. Auditory-Visual.

Colours are seen in connection with most auditory stimuli. The participant's social interaction is severely limited because of her inability to cope with certain situations such as crowds because of the extra stimulation caused by her secondary sensations.

(Crewe 2001).

14. Auditory/Psycho-Visual.

Colours seen for most sounds and concepts. Has undertaken her own research on synaesthesia including a comparison between her colours and those of a painter, Case 15, Elizabeth Stewart-Jones.

(Motluk 1997).

15. Auditory/Psycho-Visual.

Colours triggered by most sounds and concepts. Compared to Case 14 she experiences a much wider range of colours.

(Motluk 1997).

I have investigated the last five cases (16-20) for the purpose of this study.

16. Auditory-Visual.

Has coloured pitches, vowels and musical timbres. Possesses AP, presumably as a result of synaesthesia. Unlike most AP synaesthetes his colours do not follow octave consistency - if A 220 is green, A 440 need not necessarily be so. Coloured vowels follow the double formant system proposed by Marks (1974) but with different allocations to those that he found in non-synaesthetes. Here a high *f2* produces violet, a low *f1* blue or green and compactness produces brown or yellow.

17. Auditory-Visual.

Music and some individual pitches are coloured. Can attend more or less to his secondary sensations, which have modified slightly every time but always remained similar. The participant is a musician but without AP, only having good relative pitch. He feels, however, that synaesthesia has made him a better musician.

18. Auditory-Visual/Tactile.

Music takes the visual form of shapes and textures. The participant refers to 'sharp and blunt textures' and 'wobbly edges'. They are mainly just light and dark with very little saturated colour occurring. Colour is seen, however, with the sounds of people's voices. Something akin to synaesthesia can be induced by closing his eyes.

19. Auditory-Visual.

Participant sees textures and unsaturated colours ('sound bubbles') in connection with music and other sounds. Sharp sounds sometimes produce colour which often survives into long spells of chromatopsia where objects are perceived in inappropriate colours. Participant has a history of mental illness and has a hysterical fear of white. The lack of durability of the participant's secondary sensations means that he is a borderline case and there is certainly more here than just synaesthesia.

20. Auditory-Visual.

Music is coloured, as are some other sounds. Prior to this study (when he was 35 years of age) he assumed that everyone saw the world in this way.

- The above cases reveal the following common threads: -

1. SYNAESTHESIA HAS A GENETIC BASIS.

That synaesthesia might have a genetic basis is exemplified by the fact that two of my five cases are brothers. Genetic theories of the condition were held by many earlier researchers (e.g. Galton 1883 and Calkins 1893, Collins 1929). Harrison & Baron-Cohen (1997) and Bailey & Johnson (1997) are among the contemporary researches that tend towards genetic theories of synaesthesia. The current investigation's two brothers are Andy (Case 17) and Aiden (Case 18). Another of my participant's relatives (Tony's (Case 16) son) is also synaesthetic, and cases 10 and 12 had synaesthetic relatives.

2. SYNAESTHESIA IS INVOLUNTARY BUT ATTENTION TO IT CAN BE CONTROLLED.

Andy (Case 17), while fulfilling all of Cytowic's five criteria including synaesthesia being involuntary points out that he is able to attend less or more to the secondary sensations and that they are to that limited extent under the control of will. This seems to be the experience of many cases (notably 1, 15 & 16), but this contrasts with the obsessive and controlling synaesthesia of others (e.g. cases 7, 12 & 13). This difference between synaesthetes should hardly be surprising as synaesthesia being a preconscious condition will be adopted by the conscious personality of the synaesthete, which will be different in each case. Collins' S (Case 9), like cases 16 and 17, was able to attend less or more to her synaesthetic sensations (Collins 1929), further supporting the notion that conscious faculties such as attention have an independence from a primary, preconscious experience such as synaesthesia.

Tony (Case 16) noted that he could attend more, or less, to the secondary sensations produced by auditory stimuli, while the sensations themselves remain completely involuntary. This distinction highlights the difference between synaesthetic experience and cognitive functions such as attention since here involuntary experience is subject to the faculty of attention. This is the limit to how 'voluntary' synaesthesia can be, while in some cases it is not even 'voluntary' in this sense (Cytowic 1994 p 75). Deliberate utilisation of the chromaesthetic 'colour organ' applies in many AP synaesthetic cases. Tony, along with Rogers' first two cases (Cases 3 & 4) and Langfield's (Case 11), gives evidence for this and is an example of a case where the colours are more memorable than the pitches themselves.

3. SYNAESTHETIC PERCEPTIONS ARE FIXED AND UNIQUE.

Cytowic's cases (1 & 2) were tested alongside controls for the nature of their synaesthetic experiences and it was found that it was the limited range of responses that distinguished them from non-synaesthetic controls, who presumably tended to guess responses in an attempt to imitate what they thought synaesthetic responses were supposed to be, possibly taking pains to select every form or colour available. This demonstrates that synaesthetic parameters are within limits but as is the case with other parameters of manifestation these limits are very wide for some synaesthetes (e.g. Cases 11 & 15) and very select for others. The final criterion that Cytowic gave of synaesthesia being emotional and noetic is suggested by the occasions during the interview when Andy (Case 17) stated that he lacked the language to describe what being synaesthetic is like. Nabokov's (Case 10) emotive reference to colours being 'wrong' indicates his strong inner sense of rightness regarding his experiences.

4. SYNAESTHETES HAVE SIMILAR RELEVATION THAT SYNAESTHESIA IS NOT THE NORM.

This multiple survey reveals that synaesthetes tend to remember realising that they are synaesthetic when and only when they realised that not everyone perceives the world in their way. Steve (Case 20) went through the first 35 years of life unaware that most people do not see colours in conjunction with sounds, that they do not experience the world in his way. Alison Motluk writes 'The astonishing realisation for synaesthetes is not that these characters [or sounds] are imbued with colours but rather that a world could exist in which they were colour free, neutral, and characterless. It would be like finding out one day that, while you have been savouring the smells of freshly baked bread, of brandy, of chocolate, all your life, your friends have only been able to taste them. You can't believe it. You try to explain how scent influences you - it is harmless, you say, yet so meaningful' (Motluk 1997).

Of the cases being assessed here, cases 10, 16 and 17 also spoke at length of the shock of the discovery that other people did not see the world in the kind of way that they did. It is probable that these cases made this discovery by accident. Connected to this is the way in which synaesthetes begin life taking the meaning which these secondary perceptions give them for granted. Alison Motluk, for example, grew up not questioning the way in which some letters and numbers are inherently stronger than others. For her people and places with these stronger letters dominant are 'intrinsically more demanding'. Devices such as this 'give order to her world'. She has a memory of discovering, to her disappointment, that balcony was 'balcony' and not 'valcony', the splendid rich purple being replaced by a darker and less romantic blue.

5. DISADVANTAGES OF SYNAESTHESIA.

Another general finding is that synaesthesia is often regarded by its possessors as an exclusively positive asset and this is indeed the case for all of my participants (Cases 16-20). It is only in rare cases, such as Case 7, who was referred for treatment because of her obsessions with her condition, that there is there any mention of serious drawbacks in connection with the condition. Case 12 (Luria's subject, (Luria 1968)) is another exception as the secondary sensations seem to appear in actual physical space, rendering real objects invisible if the secondary sensations are directly in front of them. This contrasts with the majority of synaesthetes including most of those addressed here where this does not seem to happen; the two types of sensation being sufficiently different in quality to be distinguished, in the way that Messiaen described (see Chapter 13).

Bombardment is a problem for Case 13, Julie R. Julie; a retired music teacher cannot cope with certain situations, especially crowds. This has severely limited her social interaction, and in this respect she regards her condition as disabling. Nonetheless, even Julie, like all the other synaesthetes referred to in this thesis, regards synaesthesia as an asset on balance, giving her life a certain dimension of meaning that she would not want to be without, a feeling and attitude which resembles the other cases in this chapter.

CONCLUSION

Studying these 20 cases has enabled a general picture of the synaesthetic condition to be created. Of particular significance for this summary is the comparison of Cases 14 and 15. The similarity of the quality of the experiences in these cases, combined with their actual secondary sensations being very different from each other makes a good summary of the findings of all of the cases addressed in this chapter, with the possible exception of cases 4, 5 and 6. For cases 14 and 15 (as with cases 1, 7, 12, 16 & 20), all or most stimuli within the synaesthetes respective modality(s) trigger secondary sensations. In other cases, however, synaesthesia is much more selective, only certain sounds being coloured, for example. This does not mean, however, that for the latter cases the secondary sensations are any less 'real' or 'subjectively present' as they are in those whose synaesthesia falls into the former category. Investigation of the participants here indicates that all synaesthetes feel subjectively integrated in their world of secondary sensations. That all synaesthetes start life unaware that the way in which they see the world is any different to the way in which most people see the world, seems to confirm the subjective reality of the sensations:- they have, after all, never experienced differently. The occurrence of their first synaesthetic memories, first realisations that most people do not perceive the world in the same way, current attitude to synaesthesia, to name a few details, reflect Cytowic's impression that the numerous synaesthetes who wrote to him might as well all have written the same letter (Cytowic 1994, 112-113).

To summarise the findings, synaesthetes do not all have the same or even similar secondary sensations to each other and not all synaesthetes find the condition disabling although some do some of the time. More surprising, but not strongly evidenced in this study, is that synaesthetes do not come predominantly from artistic backgrounds. Synaesthesia may, in fact, be no more common in people with artistic backgrounds than those with others. It may just appear that way because the nature of the work of synaesthetes from artistic backgrounds means that their condition gets more interest and attention, both from themselves and others. Synaesthetes do not normally have other functional abnormalities, although dyslexia and attention deficit disorder are slightly more common than in the population at large. Finally, synaesthetes do not necessarily have their secondary images projected into material space, although more than half do, sometimes to the extent of the images interfering with visual perception. This is the predominant cause of inconvenience from what is otherwise seen as a life enhancing condition.

15. Experiment in Visual Deprivation and Audiovisual Synaesthesia.

This thesis studies the ways in which colour and sound link up in people with and without synaesthesia. Whilst the study has found that the cross modal associations of non-synaesthetes are found to be qualitatively different from those of synaesthetes, as demonstrated by the Semantic Differential Study (Chapter 11), there are several states that resemble synaesthesia in some respects that can occur in non-synaesthetes. Cytowic identified six such states; LSD induced synaesthesia, photographic memory, sensory deprivation, temporal lobe epilepsy, release hallucinations and direct electrical stimulation of the cortex (Cytowic 1994, pp 127-137). By 'resembling synaesthesia' Cytowic meant that in these states subjective phenomena occur which are common to the experience of synaesthesia in synaesthetes. In several of these states coloured hearing is known to occur. Of these states a partial form of sensory deprivation, namely visual deprivation, is used in this study with the aim of finding out whether this produces coloured hearing. The study further investigates whether the coloured hearing caused by visual deprivation shows the kind of internal consistency that occurs in synaesthetes.

Full sensory deprivation is known to cause hallucinations (Heron, Doane & Scott 1956). Hallucinations are also found to occur with the partial loss of one channel. There are cases of quite complex hallucinations occurring in people who have blind patches interjecting in their visual field. In those areas where the cortex is awaiting visual information yet none is forthcoming, internal imagery is sometimes substituted. This phenomenon is often a result of the neural pathways being severed. There is, for example, a report of a woman who saw men moving about within her blind field whenever and only whenever she read or watched television (Brust & Behrens 1977). Such phenomena can also occur on a temporary basis on a small scale simply as sensory deprivation in one channel (Cytowic 1994, p 129).

This study looks at whether people make reports of colour or images if the visual channel is blocked while they are presented with music, and if so whether the resultant hallucinations would be influenced by the music. An experiment was conducted to test this, where participants were asked to report any colours or other images that they saw while music was being played. In order to provide the music an audio track lasting slightly less than 43 minutes was prepared on a cassette. This contained eleven extracts from compact discs, each of various styles and genres, and by the composers who Sabeenev lists as being colourful composers (Sabeenev 1929) or else composers whose music is described as colourful by other sources (Scholes 1983, Samuel 1994).

Participants were run individually in an experiment lasting 45 minutes including introduction time. The first minute or so was silence while the participant became accustomed to wearing white translucent goggles, which enabled them to see light but not shape or form. This was followed by the 43 minute audio track. As each participant reported any cross-modal experiences these were written down by the experimenter in a notebook, making a note of the place on the tape where the respective participant made each association. This facilitated analysis of the results when the experiment had been run on all of the participants.

The experimental hypothesis was that for some or all of the participants coloured impressions or images would accompany the music in the absence of any actual stimuli, and that that could be traced back to the music. The null hypothesis was that no colours were seen other than those that might be expected during 45 minutes of visual deprivation.

PARTICIPANTS

Since the experiment was designed to look at the occurrence of synaesthesia under deprived conditions, and also any consistency between different people, it was necessary to use a fairly large number of participants for the task, none of which were to have synaesthesia. It was found to be quite an enjoyable experiment on the part of those participating and for this reason 30 participants were not difficult to obtain (Sabeenev used 32 sets of associations in his key/colour study (Sabeenev 1929), Baggelly tested key and pitch height association with studies of between 22 and 60 participants (Baggelly 1972) and my own 1997 study used 50 (Beaumont 1997)). Ten were females, 20 males; seven were self-declared musicians, 23 non-musicians. They were recruited on an opportunity basis and were living in Northampton, Blackpool, Sheffield or Manchester areas. Some were enthusiastic about the study while about a third of the participants were sceptical but cooperative.

MATERIALS

Eleven extracts of music from 'colourful composers' were recorded on one side of a 90 minute cassette from compact discs; these are listed in Table 21 overleaf.

TABLE 21

Composer	Work (extract)	Director (if applicable)	Performer(s)	Label	Year
FAURE	Requiem (In paradisium)	John Rutter	Members of city of London Sinfonia	Collegium	1984
BACH	Brandenburg5 Roy Goodman (second movement)		Brandenburg Consort	Hyperion	1992
R STRAUSS	Alpine Symphony (Night)	Georg Solti	Bavarian Sympony Orch.	Decca	1980
MESSIAEN	Vingt Regards (L'echange)		Hakon Austbo	Naxos	1994
MOZART	Grand Partita (Adagio)	Neville Marriner	Academy of St Martin in the Fields	Philips	1986
GESUALDO	Sicus Ovis	Peter Philips	Tallis Scholars	Gimmel	1987
SKRYABIN	Poem Op.32 No. 1 (F#)		Vladimir Ashkenazy	Decca	1987
SKRYABIN	Poem Op.32 No. 2 (D)		Vladimir Ashkenazy	Decca	1987
WEBER	Symphony No.2	Neville Mariner	Academy of St. Martin in the Fields	ASV	1982
SCARLATTI	Sonata Kk. 132		Colin Tilney (harpsichord)	Decca	1981
BRITTEN	Peter Grimes Sea Interlude Sixth in opera.	Bernard Haitink	Chorus and Orchestra of the Royal Opera House Covent Garden	EMI	1993

None of these extracts was thought to have any obvious extramusical associations with the exception of the Britten which was inserted last to avoid it interfering with earlier responses. In the experiment room this cassette was played on a stereo cassette player to each participant through speakers. The cross modal reports of each participant were noted in a book and a clock was used to keep track of the tape duration.

PROCEDURE

Participants were run individually in a room with a tape recorder. On entering the room they were generally welcomed and made to feel at ease. Goggles were put on and then they were given the following standardised instructions.

> The goggles are to prevent you from seeing any features in the room, anything external. This will enable you to concentrate on any of your own internal imagery that you may experience during the 44 minutes that you will be wearing them for. For the first minute of this period there will be quiet while you become accustomed to the diffuse light. If you experience any vivid colours or forms during this period could you please report them. It is much more common however for such experiences to be reported in connection with music. You will be listening to music for the 45 minutes following the period of silence and during the music you are to voice all visual experiences and these experiences will be written down. Any questions?

The participants then wore the goggles and spent about a minute in silence. The tape deck was then switched on. When the soundtrack had finished, the experiment was over and the participant debriefed.

Each participant's responses were noted during the experiment and were later analysed by the experimenter and compiled onto a series of five maps which are shown below this paragraph. The synaesthetic responses of each participant were examined and common features between participants were looked for. Most of the assessment was post-hoc but the pre-planned assessment included tests for differences in response levels in relation to Extraversion and Neuroticism on Eysenck's scales.

CHART 1

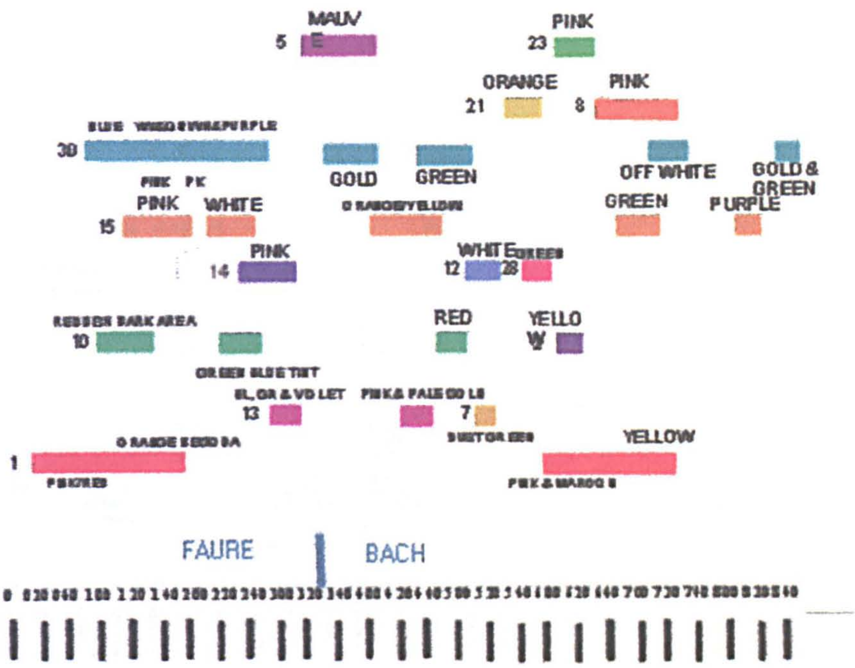


CHART 2

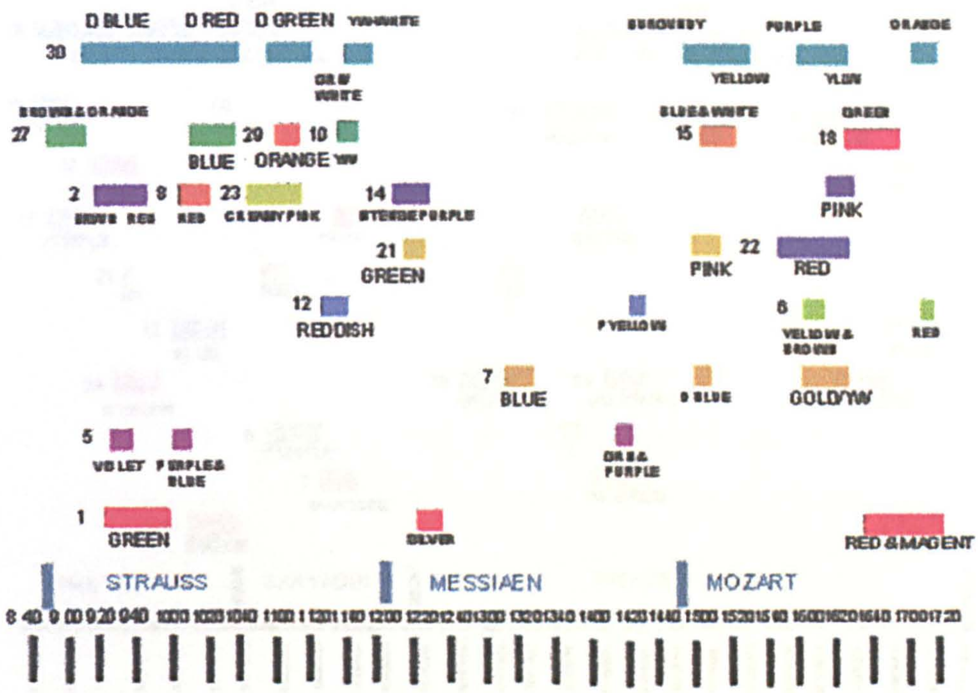


CHART 3

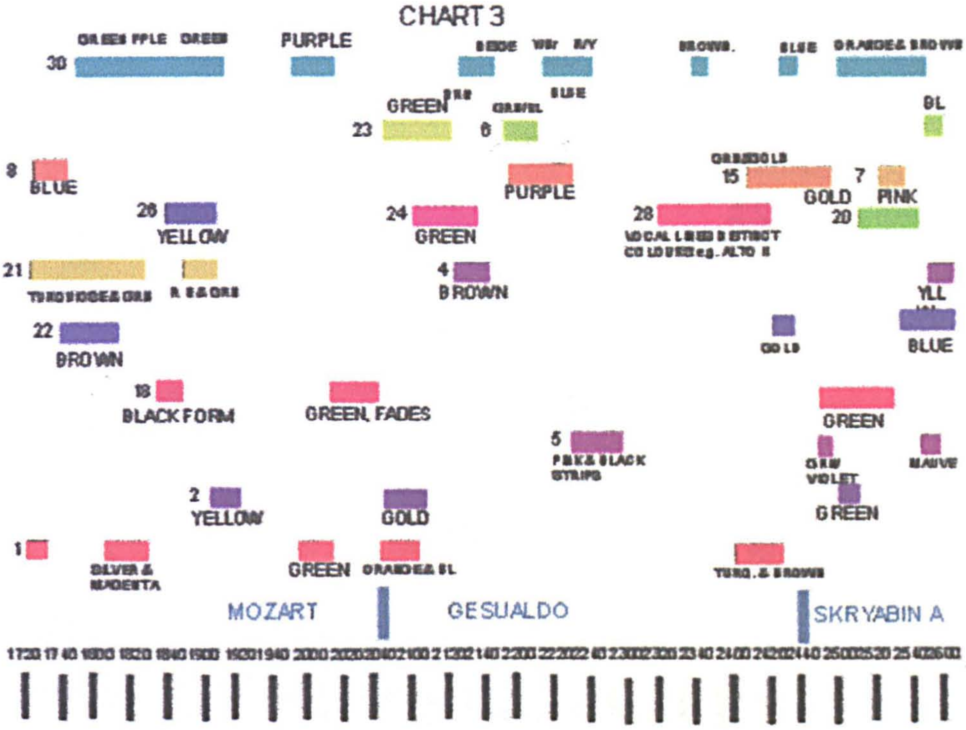


CHART 4

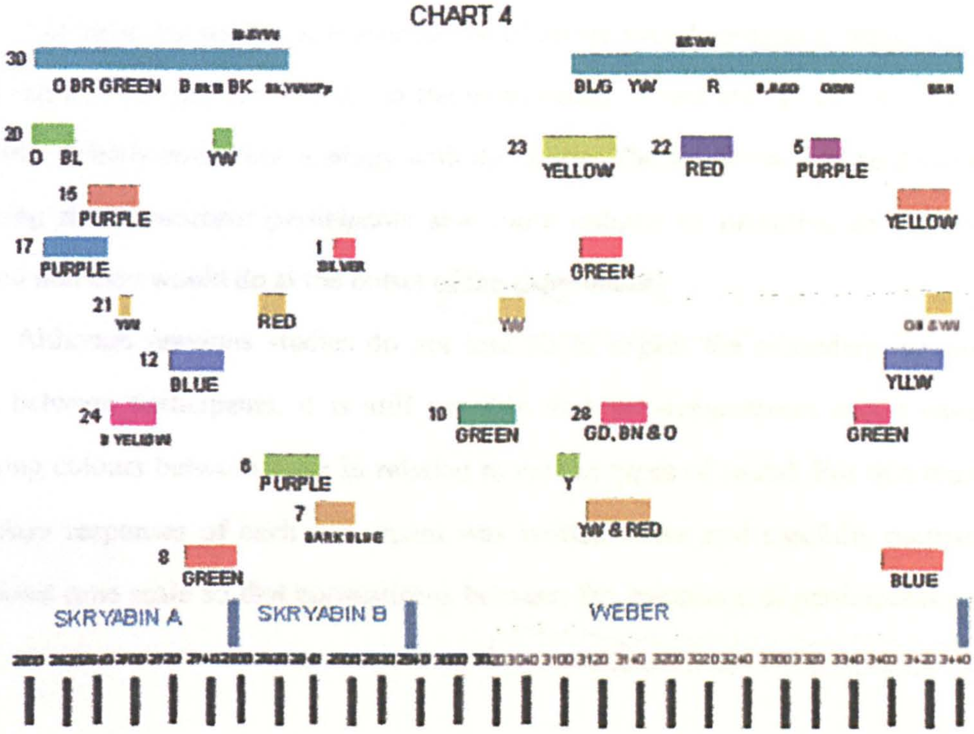
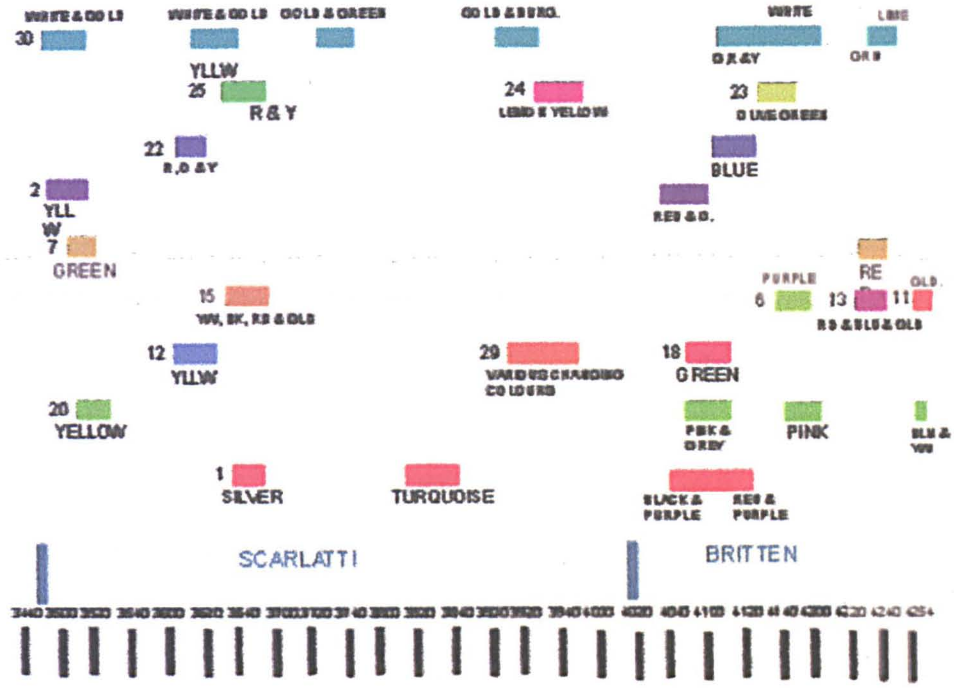


CHART 5



AIMS

The main aim was to demonstrate that blocking visual sensations from the physical world can produce internal colours in the participants. It was also an aim to demonstrate that these colours bore some analogy with the music. The former was to be demonstrated if during the experiment participants saw more colours or primitive forms than they claimed that they would do at the outset of the experiment.

Although previous studies do not lead us to expect the secondary sensations to relate between participants, it is still possible that non-synaesthetes might have some matching colours between them in relation to certain types of sound. For this reason, the secondary responses of each participant was written down and carefully mapped on a horizontal time scale so that comparisons between the responses of participants could be made.

Measuring each participant on the two standard personality scales meant that it could be seen whether a basic measure of two simple dimensions had any relation to peoples' proneness to 'seeing' colours with music, (or willingness to report them).

RESULTS

The study found a greater number of synaesthesia-like associations than would be expected in normal conditions. 18 participants experienced more secondary sensations during the 44 minute period than they claimed to have done at the outset of the experiment. Only one participant experienced less (the remaining eleven saw roughly as many secondary sensations as they expected).

The personality dimensions were normally distributed and not correlated with each other. Their distribution is summarised in Table 22.

TABLE 22

	Extraversion	Neuroticism
Mean	10.08	6.5
Median	10	6.25
Mode	10	4

That the mean Neuroticism score is less than ten could be a result of an unrepresentative selection of questions from being made by the experimenter or it could be due to a comparative Neuroticism difference between Eysenck's subjects and the sample in this instance. This bias was neutralised in analysis by treating the average score of the participants as the neutral point rather than ten (that is 6.5 for Neuroticism).

To relate the personality dimensions with responses, participants were categorised according to how many of the eleven pieces of music they associated with colours. Five categories were used, up to two pieces, three or four pieces, five or six pieces, seven or eight pieces and more than eight pieces. The mean Association Level was 4.63 (median 5, mode 4).

Chi squared tests were performed to test for Association Level between Neuroticism and more than six colour connection pieces, Extraversion and more than six colour connection pieces, Neuroticism and less than five colour connection pieces, Extraversion and less than five colour connection pieces, Neuroticism and five or six such pieces and Extraversion and five or six such pieces. The High Association group was found to be associated with Extraversion (chi squared = 5.39, $p<0.02$). Emotional stability – low scoring for Neuroticism – and high association was almost significant (chi squared = 3.51, $p=0.054$). The Low Association group, on the other hand, did not have strong associations with either dimension. Curiously, the Medium Association group (five or six pieces) were strongly associated with Neuroticism (chi squared=13.5, $p<0.005$), with introversion and middle scoring being just significant (chi squared = 3.70, $p<0.05$).

Spearman's rank correlations were also performed on the data for correlations between Association Level and the Extraversion and Neuroticism scales. Extraversion did not show a significant correlation with this (+0.201), but Neuroticism was negatively correlated with a higher association level (-0.333). In this study the dependant variables of Neuroticism and Extroversion were slightly more closely correlated than Association Level and Extraversion were (-0.265). These, it will be recalled, are not supposed to correlate.

A possibility regarding emotional stability and a tendency to either give very few or very many associations is that participants who had a low Neuroticism score are the more decisive as to whether or not they consciously accepted any secondary sensations from the preconscious or not. According to this theory, in those cases where an emotionally stable individual chose to accept the sensations, the score for coloured associations was high, whereas where the emotionally stable individual chose not to accept them, the score was low.

In the cases of those who scored high for Neuroticism there was more ambivalence. And intermediate scores were the result. It has been suggested that people with high Neuroticism scores have a poorer adjustment to internal illusion (Eysenck 1985).

The positive correlation between Extraversion and Association Level may be due to the sensation-seeking aspects of high scorers on the Extraversion scale. In other words those individuals who are measured as extraverts are likely to seek new experiences more than those who are measured as introverts. The extraverts are, therefore, more likely to be receptive when these experiences occur.

Participants gave an average of 35 reports each during the experiment. Of these, many of them constituted commentary on the music, or else elaborate images that must have been consciously embroidered. In neither of these cases was it felt that participants were providing evidence for the generic synaesthesia related phenomena that this study was designed to examine. Such reports have not, therefore, been included in the commentaries below nor on the charts above.

What is of interest for the current purposes is where participants reported fields of bold colour. Such reports, where present, were given priority over those that consisted exclusively of light and dark when compiling the commentaries. Light for high pitches and dark for low pitches, it will be recalled (Marks 1974 (see Chapter 9)); have already been established as standard in non-synaesthetes. Monochromatic sensations are also more likely to occur as a result of 'noise' on the retina or in the optic nerve than bold images of colour are (Padgam & Saundey 1975 p. 51). It was for these reasons that light and dark in the absence of chromatic colour are only referred to in those pieces, such as the Messiaen, where few chromatic reports were made.

In cases where coloured objects were reported, an attempt was made to determine whether the colour or the elaboration, i.e. the naming of a specific object such as S21's 'green lolly', was especially significant. In doubtful cases, participants could be, and often were, questioned by the experimenter at a later stage regarding what was meant by their reports. In cases where it was deduced that the conscious elaboration had more significance than the generic field of colour the report was not included in the commentary below. Since all 700 or so reports were written down by the experimenter as the tape was playing, a post hoc selection could be, and was, made according to these criteria after the experiment.

Furthermore, the commentaries below give priority to reports which are representative of the ways in which colour choice can be related to musical material. An example of such a relationship is where a participant reported different colours for different timbres. In the cases of different colours closely relating to different orchestrations/timbres or keys, all reports have been preserved in the commentary.

While the commentary is necessarily selective in order to be concise and to make its point, the charts above can afford to be more comprehensive and include all reports that fulfil the above criteria. These charts, furthermore, place all of these reports from the various participants alongside one another so that their reports relating to musical events can be compared.

The following observations were made by participants, for each piece:-

FAURE In Paradisium (Principal Key Eb Major)

Only six of the 30 participants mentioned colour in connection with this piece. Five of these associated pink with it at various times, although the reddish phase of Nick (S10) ended in its opposite colour, green-blue, which suggests of negative afterimages. Philip (S13) also saw cool blue-greens towards the end of the piece. For Ian (S14), pink was the sole colour association given for this piece, while in the cases of Brian II (S15) and Helen (S1), pink evolved into other colours.

Selecting a participant who made reference to colour in almost half the extracts (Jim - S20), another who encountered colour in almost all of the pieces (Rosie - S22), and a third who had almost constant colour responses (Michael - S30); speculative attempts are made to connect some of their experiences to the music.

Of these three only Michael saw a wide range of colours here, all of which were fairly light. Blue was seen at the end of bar 6 when the sopranos' part ascends to the first high F (698), (the end of *deducant*). This is likely to be caused by the pure quality of the voices and by their landing on a perfect fifth above their starting note. The fifth is a slightly purer interval than the fourth is (the previously outlined (Bb-Eb) interval on *In paradisium* (bars 3-6)). Blue is generally associated with purity. This is an example of how the connections that result from such coloured hearing can be quite complex. Pink at bar 21 coincides with the arrival of a modulation into Ab major (second syllable of *Jerusalem*). There is a sudden reduction in volume at this point which may have affected the colour perception. Pink is often perceived as a colour of softness. The conclusion of this modulation sounds especially prominent because of the descent of a ninth in the bass, so that the bass is suddenly increased as the overall volume is reduced. Yellow and green were seen 20 seconds later (also on the word *Jerusalem* this time moving back towards Eb major). The chord is consonant (G minor first inversion) with the bass note in the dominant producing a feeling of instability. There have been a few bars of dramatic but somewhat ambiguous modulation. Now the arrival back to the home key (in paradise) is promised and all that is needed to fulfil the resolution is the gradual and patience demanding lowering to the middle vocal lines via a little dissonance. Michael's coloured reports refer to previous ones in the piece.

BACH Brandenburg Concerto No. 5 (ii) (Principal Key B minor, Pitch A 420, Mean Tone (For the purposes of identifying the octave, all the pitches quoted are conventionalised to equal temperament and modern concert pitch, e.g. Middle C is given as C 262, not C 251, and the A above it as A 440, not A 420)).

14 participants responded with colours in this piece. The clearest observation is that the colours mentioned are concentrated in one part of the colour circle, namely that from orange to green, thus including yellow, gold and brown. While red, pink, and purple get referred to occasionally by participants along with maroon (Paul I - S2), blue does not get a mention in any of the 28 coloured reports. Steve (S7) experienced an elaborate colour sensation, a brownish, dark dust green in the distance. Nick (S10) experienced greys, textures, and a bit of red at 4:35. While an autumnal palette predominated in this piece it is the lack of colours on the opposite side of the circle that is perhaps of most significance.

For Michael green was perceived at the modulation into D major, quarter of a bar before the modulation's perfect cadence was completed (i.e. at the end of bar 9). At the start of the bar 42-43 harpsichord solo Michael had a perception of 'Reddish grey'. It is relevant that people who have real visual experiences in the absence of physical stimuli, such as synaesthetes or those subject to photographic memory (e.g. the mnemonist, S (Luria 1968)), experience visual adaptation phenomenon such as afterimages. Michael saw green from about 4:19 to about 6:50, less than a minute before the experience of reddish grey, suggesting that the red component could be a result of such an afterimage effect. Gold and green returned one bar into the final repeat of the above passage providing further evidence that the particular passage is, for the participant, specifically these colours, and no others. Subsequently he said that green and gold predominated the whole piece, further supporting the afterimage hypothesis concerning the reddish grey at bar 42, (the red had a bit of purple in it).

STRAUSS Alpine Symphony (I Night) (Principal Key Bb Minor)

In this piece 15 participants gave significant responses. Rod (S27) stated, in this piece; one of just three occasions when he reported colours, that he did not expect to see anything. Given the mood of the piece it is not surprising that most of the colours mentioned here were dark. There were exceptions, however; Helen (S1) found the opening bright and Nick (S10) saw yellow before the music brightened. The soundscape has mainly low pitch spectra. Marks (1974) found pitch spectra to correlate positively with associated colour value (lightness). Richard (S4) also selected dark tones in this piece, while Paul I (S2) associated warm dark colours with the piece. For Jean (S5), the blues and violets which characterised most of her responses were darker than elsewhere. Darkness, warmth and ghastliness were also the themes of Carol's (S29) response, 'orange street light glares within the darkness'. Considering the obvious dark bias of the piece, fairly little consistency was obtained in the piece apart from the unpleasant, dark, ghastliness as exemplified by Carol's responses.

Jim's associations at the opening were also dark. At the nadir of the descent, the participant added the word 'ominous' to references to black and dark grey (start of bar 9), a reaction to the low spectra of the overall sound. Jim later reported 'Light breaks through, sunshine'. At the end he reported 'light breaks through the cloud' and there is 'sunshine'.

Michael's six associations also followed the light and dark scheme but also included colour. The first three colours, which were dark, were all seen before the 'brightening' of tone, while the last three all involved white. 'Dark blue' was reported in the middle of bar 3. The dissonant cloud of sound is low in harshness here, relating to blue being generally thought of as a restful colour. The two are therefore related by common attributes.

As with other pieces, the orchestration and general texture are different to what it is where other colours are given. 'Dark red' was reported at the end of bar 14 where the key is starting to move towards the major. There are more dynamic changes of chords in the non-stringed instruments, which include a considerable amount of powerful, low pitched brass. The chords move in strong progressions against the background of clusters. The dark nature of the above mentioned passage combines with the introduction of the more dynamic and defined elements resulting in red. Dark green was reported at bar 25. There are fewer instruments playing here than elsewhere, producing a less cluttered sound. Thin, clear sounds cause the participant to see green elsewhere in the experiment.

Green and white were reported in bar 36, as the horns and heckelphone ascend. Here the upper end of the orchestra is simple and consonant. It might be that the clean nature of the sound is responsible for the green, while the muted high violins give a 'washed out' sound which results in the white. Michael correlates yellow with tonal brilliance and white with high pitch more. When 'yellow and white' are seen (bar 45), the highest fundamental pitch in the texture is D natural (2350) in the piccolo, while the lowest notes are sparser, accounting for the lightness in colour, with the yellow resulting from the high overtones of the clarinets and brass.

MESSIAEN 'L'echange' from Vignt Regards(Key not applicable)

Despite Messiaen's own experiences of synaesthesia, only eleven participants made mention of colour. Nonetheless the associations obtained seemed to possess a complexity close to the composer's. Mention was made of temporal, dynamic factors such as 'shimmering' (Jean - S5), 'persists' (Rod - S27), and 'appearing' (Ian - S14 and Rod - S27). Complex textural reports were also given, such as 'blue crystals' (Steve - S7), 'splodges' (Ian - S14) 'glass' (Helen - S1) and 'green ice lolly' (Charlotte -S21).

Michael made a total of 73 responses during the experiment and the three in this piece were the only ones that were monochromatic. This is probably accounted for by the fact that unlike the other ten extracts there is no obvious variation in orchestration or texture. The first 24 of the 30 bars are twelve repetitions of a two bar construction, modified each time by a simple transpositional process, so that changes to the music are exclusively of harmony and gradual modification of contour. Although Michael did not see chromatic colour, the grey that he observed split into graded bands ('black, white and grey') as the music briefly felt tonal (A major). The tonality may have made the music subjectively clearer producing the separation. Rosie saw dark blue at the point where the subjective perception of the change of pitch contours is thought to be its most rapid. In objective terms the process is steady but the notion of subjective pitch contour perception is based on studies of how some intervals are perceived as small, some medium and others large, according to critical thresholds (Lindley, Campbell & Greated 2001).

MOZART Grand Partita (iv) (Principal Key F Major in this performance (Original Key Eb Major), (Modern Instruments))

During the Mozart 16 of the participants had colour associations or images. Colours given were bright (except for Participant 17 whose reports were exclusively monochrome and Participant 23 who had light creamy colours) and varied. Helen (S1) alternated between two complimentary colours implying internal afterimages. Glen's reports (S18) show the start of a series of secondary sensations based on two forms; reporting (16:19) an L shaped luminous green pattern which reappears at 16:49 and also at the end of the piece. At 18:19, he sees part of a large, black, bird: the second recurring form. Seeing a limited repertoire of sensations is something akin to the experiences of synaesthetes, MW, for example (see Chapter 14). Glen also reported these in Skryabin A and the Britten.

Jim reported 'A brightly lit ballroom' (bar 4), where the first oboe is on a sustained high C (1047) (performance pitch in F Major). The sound of the sustained high note on the oboe, with rhythmic subsidiary parts involving most other instruments is bright. The oboe does not have many harmonics at this pitch, but the second to fourth harmonics are strong, 2, 3 and 4 kilohertz falling into the 'brightness band' (higher harmonics creating some hardness in the sound). Rosie perceived a 'very rich red' at bar 18 where the first oboe jumps a minor tenth from C (523) to Eb (1244). The general tesitura falls, and the last chord of bar 17 and the first of bar 18 constitute a perfect cadence in C minor with the rich basset horns predominating. The harmony and timbre is brighter than it was previously and the participant's rich red is a similarly bright colour. The timbre and texture are the same as they were where Jim (S10) had his associations.

Michael reported all colours except blue. For the accompaniment only (bar 2) 'burgundy/maroon' was given. When the oboe melody starts on the high C at bar 4, 'yellowish' (a complimentary colour) is reported. There are no horns at bat 7 and a 'purply' colour was seen. The small hue difference between here and bar 2 results from the absence of horns (brass instruments) has been connected to the colour red (e.g. Scholes 1983). At bar 9 both yellow and purple are reported. The music is in the home key and there is a high basset horn part which may be high enough to relate to the previous yellow association. As with the previous association, the lack of red tint may correspond to the lack of horns. The rapid stepwise ascent of a ninth from the oboe, from A (440) to Bb (932), at the end of bar 10, produced orange. This span is central to the instrument's range so that the lower notes are in low register and the higher notes in high register. A wide range of timbres is therefore heard. This is combined with the second oboe sustaining C523 making the sound distinctly 'bright' and probably too rich for yellow; orange results instead. The horns in octaves may be partly responsible for the red element.

'Yellowy orange' was reported at bar 17. The key is C major and instruments are in unison rhythm. The yellowness ties in with what occurred previously. In the Faure, yellow was seen at bar 28 where there was maximum unity between the parts. This may be of some relevance; the sound here, however, is such as to imply brighter colours.

Green and yellow were reported in bar 26 where main melody is in the bass and the higher lines are ending. The horns have started playing, predicting red, yet here we have colours other than red. The findings of Chapter 8 suggest that despite the consistency of synaesthetes colours with specific sounds, there is little pattern evident. It is therefore to be expected that some experiences reported, like the one here are difficult to explain. The response is unique to this sound: it is dissimilar to bar 4, which was yellow and dissimilar to bar 7 which was purple. In the 'dark' Strauss piece, 'Green and white' was given for a sound that had started to 'brighten'. The addition of green to white could be a trans-modal conversion of low spectra which contradicts Marks' law of universal brightness. Purple was experienced in bar 32 where bass and accompaniment predominate. In the surrounding bars a clarinet and basset horn sweep between low and high register. They are both low, adding richness to the sound while keeping their lines hidden. The connection with purple is thereby consistent with previous observations in the piece.

GESUALDO (Predominant modality of piece most approximates A Minor (Pitch c440)

The Gesualdo work had 14 participants associating colours with it. Pete (S28) is of particular interest here since at 23:32 he found that each voice had its own colour, which blended with 'gold and brown'. This has some similarity to the experiences of some synaesthetes who claim that their internal, yet projected, colour coding helps them to identify the lines of a particular piece of music thereby clarifying it. After the experiment, the participant was asked what he meant by this statement, and found the meaning beyond words except for being able to name a few colours, a general feature of synaesthetic experience (Cytowic 1994, p 78).

Jean (S5) gave an example of a primitive form constant with a thin pink strip on a black background. Brian III (S24) showed complimentary colour effects between 24:30 (green) and the end of the piece (purple). Green, brown and orange (sand for Participant 22) seemed to be the predominant colours for the start of the piece, a scheme akin to that in the Bach. The only colour outside this range amongst the participants was given by Alex (S7) who reported 'a mix of green and blue'.

SKRYABIN A (Principal Key F# Major)

Along with the Weber piece, this has the most colour associations with 17 participants mentioning it. Helen (S1), who gave associations for all other pieces, made no mention of colour here. Most of the 17 participants only gave one association. Visualisations of coloured objects with were also mentioned. Glen (S18) saw more green sculptural images. It is not certain whether these related directly to the music but when asked the participant claimed that the imagery seemed connected to it.

Jim reported 'A fiery orange' in bar 13. The sound level is loud and A# (932) follows a B# grace note. The music is in C# with the bar containing the seven tonal pitch classes, so it is rich and moderately high with a strong tonality analogous to the bright, fullness that Goethe, Steiner and Kandinsky attributed to the colour red. In the repeated 'cantabile' section (bar 27) 'blue' was reported. The top line is falling in pitch chromatically (D#-D natural) making the tonal centre B minor (with F_x added). Blue may reflect the above transformations of tonality and tempo. Towards the end 'yellow' is reported, following the subdued activity of the second 'Inafferando' section where there is a straight F# major chord covering three octaves and a third. The chord's quietness is likely to be a significant factor regarding the participant's seeing yellow, as the colour is low in saturation.

Michael had six associations that are significant, according to the criteria stated at the outset of this chapter, during the piece. That this is less than in most of the other pieces used in the experiment is probably because a result of it being on one instrument, where timbre seemed to be the most common cause of seeing colour. 'Orange, very dark and brown' was given in the middle of bar 4. The sustain of the notes means that the sound is very full and rich, with the low F# (93) left slowly decaying at the bottom of the texture. The end of the first 'Inafferando' produced 'sunset orange'. This orange is also warm and tranquil, but sunset orange is, by definition quite saturated. The sound of the respective bar (23) is quiet, low in pitch, and in the dominant key. The tempo is faster than the 'andante cantabile' section, making for more attacks, which produce greater harmonic spectra. The sound is full, but is confined to a single chord. Orange as compared to the orange - brown association demonstrates the consistent colour scheme which is operating. Two bars later, when the content and tempo of the first section return, Brown returns, this time dark. Although not the same brown as bar 4, it supports the idea that slower tempi and sparser notes are linked with lower saturation.

Green is reported in bar 31, where there is quaver movement in the middle and upper bass range (C 131 to A# 466). The high treble notes are sustained and sound clear and bright. The tone is quiet and the harmony is an inversion of Skryabin's mystic chord (Babbitt's pitch class set 6-34). The clearness and lightness of the sound, with its 'quiet boldness' is similar the bright, slightly yellow, green, exemplified by the one seen at the end of the Britten being clean. Regarding the mystic pitch class set there is, unfortunately, little similar to compare it with elsewhere in the study.

SKRYABIN B (Principal Key D major)

Only nine participants mentioned colour with this extract. The nature of this piece, in terms of intensity and register, was similar to the Strauss and produced much darkness and occasional contrasting lightness. Yellow and purple were the predominant hues, the exceptions being an unsaturated blue, turning to dark blue at 28:51 (Steve - S7), and Charlotte (S21) whose only image was a red velvet curtain at the outset.

Michael had four associations. The first three, near the start of the piece, all included black, the second and third, also yellow, and the third purple as well. New colours were added as new 'angles' turn in the music. Black alone is given where the upper melody starts. The pitch is quite low and the sound is loud and dense suggesting black. 'Black and yellow' were reported in bar 6, where the density of the music increases. The yellow may have been caused by the accented high note (F 698). Tonality is unlikely to be a factor in this piece, since this place in the music approximates Ab major and the third association (the above colours plus purple) was given in connection with another key, A major. At the third association the highest note is a diminished fourth lower than at before (C# 554). Because it is lower the band of yellow is probably smaller than in the previous image (presumably yellow occupied half the visual band there, but only a third here). The high melody note is accented which may have been the cause of the bright colours and intense contrasts (purple and yellow are almost opposite). The black may relate to low triplets, and the yellow to sustained notes. The alternation between the two chromatically differentiated notes, E# and E natural, give an effect of unstable tonality which may contribute to the image. Purple is an 'unstable' colour, which depending on the colours that surround it, is perceived primarily as a 'kind of red' or a 'kind of blue'; (the purple of this association has given it slight blue dominance, which in turn has tried to 'green' the yellow, which has tried to resist, and so on).

From bar 29, to the end of the piece, white was seen. The tonality stops changing, the top voice is moderately high; the chord's clarity therefore enforced the white. The colour white appears to be reflective of the way that the densities and tensions, which previously produced black, purple and, to a lesser extent, yellow resolves towards simpler textures.

WEBER (Principal Key F Major (Modern Instruments))

With 17 participants having 'seen' colours in connection with this piece, coincidence of colours between participants is quite large. Yellow was most prevalent colour followed by green. Nick (S10) reported a general greenness while Jim (S20) reported faded greens. Gary (S12) and Brian II (S15) experienced yellow towards the end while Betty I (S8) experienced the near complimentary, blue, at this point. The total number of associations between participants is lower than the in many other pieces with most participants offering only one. Basic colours predominate, with Michael's (S30) experience incorporating all four of the basic colours (see below). The only participants who suggested more complex colours were Jean (S5) and Pete (S28), who suggested purple and gold, and orange turning to green, respectively. Jim's (S20) green report was vague compared to his others and is therefore likely to be of less consequence. It may, however, be taken as a reflection of how synaesthesia-like experiences occur in non-synaesthetes in the experimental circumstances.

Michael saw 'Blue changing to green' at the start of bar 3 and blue and green at bar 9. In the former case the viola is on the highest note of the main theme (A 440), the other instruments being violas and horns. Generally speaking, high harmonics weaken at a more rapid rate than do the lower harmonics and the fundamental, giving the tone increasing harmonic purity. Since unique blue is darker than unique green the colour modulation can be attributed to the loss of roughness over time, darkness and roughness being conceptually related (although both are pure insofar as they are unique, the green is purer than the blue probably because the green cones afford the greater resolution, see Chapter 2). In the second case short notes from the viola and first bassoon coexist with sustained notes from the horns and second bassoon.

Yellow was seen at bar 12. This colour tends to accompany high frequency spectra. The oboe solo part's first note is A (880), and even harmonic number eight (7040Hz) is likely to be powerful. The dynamic marking is 'pianissimo'. Since yellow is the lightest yet the least saturated of the four unique hues, this fits the prevailing scheme. Yellow and blue were seen in bar 19. The orchestration is the same as that of bar 12 but the notes are a fifth lower. Blue was probably seen in addition to yellow because of the increased depth. Towards the end of bar 21 'A bit of red' was reported. The upper string accompaniment is a C major arpeggio and there is a bassoon; the latter having several harmonics. The sound is consequently bright, but with strength in the lower pitch spectra which is absent in the 'yellow' bars.

In bar 51, 'White and green' were perceived. White did not correspond to pitch brightness, as yellow did, but rather to thinness of sound. The low pitch horn note (B 123) with its weak fundamental provides the only low frequency content and the tone colour is thin. Since red was seen in the very opposite regime, the green can be accounted for in this way.

In the second half of the bar, a bassoon enters, intensifying the sound; 'dark green' was reported. The denser spectra resulting from the addition of the bassoon meant that 'white' no longer related to the auditory experience. The green's being darker now and being the only example of a 'complex' colour reported in the piece suggests an afterimage. The white and green returned in bar 54 where the sound is richer. The full orchestra is playing here, but most instruments have sustained notes. The greenness here supports the harmonic decay theory suggested above.

The bassoon's link with red is supported by the report of bar 57 where and red and green are reported. The horns Fs fill out the audio spectrum, producing further redness. The green may be derived from the decaying spectra in the bassoon's long notes. The bassoon's red was referred to at the end of the piece where the report was 'Bluish red'. Relating to earlier experiences of the colour blue, this might be caused by short notes on the horn, which maintain their range of harmonics. Also, as blue was the first colour observed, its presence at the end may be indicative of the music's returning to its source.

SCARLATTI Sonata Kk. 132 (Principal Key Eb Major, Pitch A 415, Mean Tone (The above is disregarded when pitches are referred to, these are specified as equal temperament equivalents at concert pitch))

This piece is significantly different to the other pieces in terms of sound spectra since the harpsichord, especially in the upper range, has extreme upper partials. Consequently it contains at least as much energy at the top of the audible range as it does in the middle frequencies. This is reflected in the colour associations that the 14 associating participants gave. For Jemma (S17), lightning occurred throughout the piece while Paul (S2) saw a stab of yellow at the start.

While every participant who associated with this piece mentioned lightness or white (except Participant 2, who mentioned red and Participant 29, who mentioned a flurry of all colours on the keyboard), only two participants (Alex -S6 and Rosie -S22) referred, at any point, to darkness. Brian II (S15) saw colours of a harlequin suit (36:13), which were red, yellow, blue and gold. No-one mentioned of purple or violet, probably because of their inherent darkness.

In bar 25 Jim saw 'yellow and white flowers'. There are two voices, neither of them low in fundamental pitch. The decorative nature of the lines is partly responsible for the association. Rosie reported 'log fire colours, red, orange and yellow' at the lower pitched arpeggios in the repeat (bar 2). With the instrument's vast array of harmonics the lowest notes contain the largest number of audible ones. Sympathetic resonance is also maximised in the lowest passages. The intervals being thirds and fifths means that there is much correspondence to the harmonic series so that the sound can be described as 'possessing great warmth'. Rosie reported a 'bus of light and dark brown' (bar 22). There is a motif of crotchets in F minor which alternates between the treble and super-treble octaves. It seems likely that the brown is derived from the minor key while the light and dark correspond to the alternating octaves. This may be explicable in terms of movement translating to something like 'as the front window of a bus being followed by the next window, and then the next, and so on in alternating light and dark browns'.

The timbre of the harpsichord produced a more limited palette for Michael than usual, being predominantly gold for all responses. Gold is a lustrous colour, its hue is yellow with a leaning towards brown or orange, but it also tends to reflect large amounts of all colours of light that strike it in such a way that they are reflected at high intensity at different places and at different times. This reflects the extensive harmonics characterising the instrument.

Bar 42, in the repeat was reported as 'gold with the addition of green'. The lowest note in the bar is F (88), while the right hand part is all in the bottom half of the treble clef. The key is Bb major, the dominant. It is possible that the added green could result from the deviation of key, supporting the theory that the participant related relative key to colour. Gold prevailed, despite the lower register and the opposing key owing to the multi-harmonic nature of the instrument. This relates to the role that gold played in the Bach. 'Burgundy', approximately opposite to green, was seen in the second part (bar 99). The tonality returns to Eb major and there is a suspension with a ninth and a major seventh. The 'burgundy' looks as if it might relate to dissonance. Darkened reds, with their burnt-like rough associations, are often associated with harmonic roughness. Afterimage effects caused by the green of bar 42 are also a possibility.

BRITTEN (Partly Atonal but with leanings to Bb)

16 of the 30 participants mentioned chromatic colours in this piece. Only two such associations were made at the start of the piece (Terrence (S26) and Pete (S28)) both of which concerned darkness rather than hue. Helen (S1) saw dynamic lustrous forms in conjunction with a full orchestral chord. Glen's (P18) small repertoire of forms returned in this piece; florescent green at bars 4 and 12, the latter taking on the form of the eyes of creatures. The green theme continued until the end of the piece when a large, black, bird reappeared (bar 24 onwards). It is here that Alex (S6), Steve (S7) and Philip (S13) had their coloured images. Philip found his fiery, metallic coloured palette particularly unpleasant. Tim (S11) mentioned gold towards the end of this piece. This was Tim's only coloured report in the study. There was a wide range of associations between the participants which can be accounted for by the wide variety of intervals, harmony, tesiturra, and, most especially, orchestration in the piece. I have identified nine sections that are distinct mainly in terms of instruments used, but also in the other respects mentioned above.

The music produced pink for Jim (S20) until the end of the piece where 'blue and white' were seen. 'Pink and grey dawn' was reported in bar 3. It is likely that this is linked to the muted fog horn sound as the sustained chord takes the highest pitches which could match the participant's light coloured experience. The dawn given in bar 14 is brighter with only 'pink' reported. The horn chord continues and there are violins and an oboe. While this chord is coloured by low instruments in bar 3, here it is coloured by high ones. The violins have played before this point but it is only here that they are heard with equal clarity to the horns. The 'pink dawn' is seen as the fog horn sound begins to be heard clearly again. At the end of the extract, where the horn chord is alone, 'blue and white' were reported. On their own the horn sounds are fairly high, but not high enough to generate white. This cannot be explained in terms of contrast effects since nothing lower than D (147) occurs in the last five bars, and the horns are still playing the D7 chord, which would be expected to reinforce the pink.

Michael saw 'red, yellow and green' where the tremolos and sustained chord are present. The presence of the three colours in distinct bands suggests that the complexity of orchestral activity triggered the experience. As shown elsewhere red and orange are generally linked to brass; the other colours probably being linked to the soundscape's softer features. The three components to which colours are thought to relate to are tremolos (treble), the sustained notes of the horns (middle) and the loud moving brass (bass). Yellow connects to the treble strand, red the bass and green the middle. The horns are in a different key and are less 'brassy' in sound than the other brass; the cooler green connects by way of comparison. Michael's second report occurred where the oboe diminishes in volume facilitating a clearer horn chord.

Towards the end greens are reported, in bar 26 (mid green), and in 27 (lime green). Close observation highlights what these bars have in common. Both have tremolos and grace notes. In the first case, the tremolos are high on the violins. There is a wide compass with the double basses at the bottom of their range. There is also plenty in the middle range with the strings divided over many notes. The overall effect is a rich but thinly spread sound. The addition of yellow to green in the second case may be attributed to the high piccolo doubling (with A 3520). The colour of lime green could also be a reflection of the lower density of pitch classes in this bar, compared to the previous one which contains eleven of the twelve pitch classes (no C#s) this bar has eight, producing a clearer, less muddy sound. Further, one practical difference between woodwind and string choruses, as described in most textbooks on orchestration (e.g. Piston 1955) is that the former sound quite disperse while the latter tend to fuse together.

DISCUSSION

The experiment revealed that more colours were 'seen' during the music than could be expected in normal circumstances. The number of associations was negatively correlated with Neuroticism, possibly because the higher the Neuroticism score, the more anxious participants would be to report sensations that they would regard as unusual. Middle scores (five or six pieces) were found to be even more positively associated with neurotic introversion, possibly showing that this personality listens more selectively, and will respond predominantly to certain music types. A possible reason for the ambivalence of high Neuroticism scorers regarding colour and sound associations was suggested in the results section of this chapter.

While more colours were seen than most participants expected to see, care must be taken to ensure that these colours relate directly to the music. The analysis of the participants' responses was an essential measure of this, and was necessary if the colour sensations are to be related directly to the music. Deprivation hallucinations alone are a possible explanation for the colours. The importance of the analytical methods used here is their comparison of formal and textural content to the secondary sensations experienced. Simple deprivation hallucinatory imaging alone may suffice to explain the secondary sensations' occurrence in some cases. Nonetheless, it is likely that in Michael's case, and probably in some of the other cases, that the music influenced the colours since the range of colours can be connected directly to attributes of the music playing at or just prior to the time of the reports. Assessing both the soundtrack and the reports of colours constitutes the principal form of examination in the study. A means of assessing the quality of the experience is to study the words which participants used to express that they saw something (e.g. 'I spied', 'I had an impression of' or 'I witnessed'). These were assessed by ten independent judges for two categories; Visual Reality (i.e. to what extent does the word mean that their image resembled seeing a physical object) and Gnostic Level (i.e. to what extent does the word suggest that they inwardly *knew* that they were seeing the image. Four of the independent judges were male and the other six female. They covered an age range of 25 to 74, thereby being representative of the ages of the participants of the experiment. All had a good grasp of the English Language with four of them having University degrees in related subjects. The allocations for this are shown in Table 23 overleaf.

TABLE 23

The 0-20 Scores for Visual Reality and Gnostic Level Implied by 44 Terms Connected to Perception as Judged by Ten Independent Judges.

	V.R.	G.L.		V.R.	G.L.
apprehend	6	18	(are) aware of	11	17
capture	7	9	catch	12	10
come upon	9	13	(are) conscious of	5	16
detect	14	7	discern	13	15
distinguish	15	8	encounter	17	12
entrapped by	9	15	envisage	3	12
espy	11	7	experience	14	16
fathom	5	10	feel	2	14
form mental picture (of)	4	11	glimpse	11	12
have the impression of	7	7	hit upon	16	16
identify	8	13	imagine	2	14
know	11	20	look on	18	15
make out	11	11	note	15	13
notice	17	11	observe	15	15
perceive	17	19	pick up	11	14
picture	6	11	realise	10	18
recognise	14	19	see	20	13
sense	16	15	single out	15	10
spot	16	13	spy	15	14
take in (by)	16	18	think of	1	12
view	16	12	visualise	3	15
(are) watching	18	17	witness	19	19

That way it was possible to establish which of the 30 participants were more likely to have been influenced by the music which was played. Compared to normal conversation eleven of the participants used words for the above meaning which are more meaningful ('Gnostic Level' in Table 23) and compared to metaphorical terminology they used terms which relate much more to physical sight ('Visual Reality' in Table 23) These participants are also among those who had the most consistent colours, thereby showing a degree of intrinsic validity between the above two criteria regarding the ends of assessing whether the colours reported relate to the music. These participants are S1, S2, S5, S8, S10, S12, S15, S20, S22, S23 and S30.

Optical effects of complementary colours may have resulted from the first colour, only if part of the physical visual mechanism was stimulated. This is of great interest here since this could only have happened if the visual mechanism was stimulated by the sensations, at least in part. This is thought to occur in visual deprivation hallucinations, but not in synaesthesia (Heron, Doane & Scott 1956). Even so, the opposite colours could have been complimentary as a consequence of chance alone and need not have involved the physical visual system.

Focusing on the three cases that are studied in additional detail, systematic colour experiences over time are most common in Michael (S 30) who experienced colours with the music most frequently, with Rosie showing slightly more consistency that Michael. Jim saw chromatic colours some of the time, he had many more monochromatic associations. In the Strauss, for example, he saw almost exactly the same scheme as another participant, Richard (S4) - dark followed by brightening with the orchestral tone. For Jim, the first Skryabin piece resulted in different colours for different dynamic levels, pitches and sound textures, even though each was seen only once, making testing for consistency difficult. The colours during the piece were red - orange for a full sound, blue for a gentler cantabile and yellow for quiet resolution on the ending chord.

Rosie's associations were likewise found to be mostly of similar quality to those of metaphorical analogy. She gave warm colours for sounds that are generally referred to as warm or vibrant, the middle-high register of the oboe and the brilliantly scored harpsichord. She saw grey with the return to the tonic key in the Bach and blue as to accompany the transpositional process in the Messiaen as the perception of intervals changed most prominently. Michael gave more associations of specific colours in relation to specific sound qualities than any of the other 29 participants. Not quite all of his reports provided evidence of a consistent internal colour organ but the vast majority did.

Some colours occurred more often than others and these also showed the most consistency with sound qualities. There are, for example, inconsistencies with the blue reports, while the soundscapes resulting in red, orange/gold/yellow and green are more frequent, precise and consistent. Green was seen for sustained sounds with reduced overtones, Yellow, orange or gold for large proportions of high frequency sound, as produced by high oboe or harpsichord, and red where the sound was harmonically rich and full. The reddening effects of richness can further be observed in the modification of yellow towards orange and blue towards purple on occasions.

Tonality seemed to have had a more limited influence for Michael with grey or white being seen in conjunction with the home key. Diversions from the home key produced colours other than white, which were usually also influenced by timbre. As stated in Chapter 12, in synaesthesia trans-modal connections are consistent over time but often consist of only a limited number of triggers and secondary sensations. Assuming that this study has been able to track down enough of Michael's 'rules' for cross modal transfer then it may be concluded that red, yellow and green and sound spectra factors are consistently related to each other, while rhythm, melody, vocal textures and other colours are much less consistent and, presumably, when Michael reported them his experience was less akin to synaesthesia.

In general, high frequency spectra in the music related to high values for the associated colours, an analogy that was demonstrated more generally by Marks (Marks 1974, 1978). The end of the Strauss piece lightened dramatically and for most participants the Scarlatti was light and the Britten was dark. Some pieces had strong definite colours, even between participants but others did not. Future studies might involve ways of assessing results such as these in terms of statistical significance. If a similar study were to be carried out with a larger sample then it would be possible to look at a more limited range of hue areas and discrete timeslots, for example, and we could test for association between different time slots with similar material in them.

While we are unable to extrapolate these results to speculate that certain sounds produce certain colours in visually deprived conditions, the similarity between participants' responses, nonetheless, implies a possibility that these exist. The overriding finding here is that 26 participants out of 30 experienced colours at certain stages in the music, and 18 of these stated prior to the experiment that they did not expect to do so, expressing surprise when at a later stage they did. Because of this, it can be concluded that the reported experiences are not commonplace for most non-synaesthetic people and that visual deprivation had an inductive effect on a condition that is, in some respects, similar to synaesthesia.

16. Conclusion.

This thesis has demonstrated several aspects of the nature of synaesthesia and of cross-modal thinking in non-synaesthetes with special regard to colour and music. It has established the relevance of visual colour and metaphorical language to synaesthesia. It discusses colour at some length in connection to its impalpability, its being a paradoxical, non physical phenomenon. In addition to this, colour plays a major part in most synaesthetic experience. The earlier discussion on the significance of colour shows that for those who live in a world of colour it has an inexplicable and poignant meaning that is fundamental to us: it is the same with synaesthesia in synaesthetes. The importance of colour is exemplified at the end of Chapter 2 regarding the deep sense of loss that Jonathan I experienced.

The way in which the qualities of colour become integrated into language is dealt with in Chapter 3 where the notion of a language hierarchy is introduced. How this language relates to attempts to combine audiological factors, such as musical pitch, with colour is dealt with in exploring selection of opposing pairs in the Semantic Differential Experiment (Chapter 11). Although sensations, including colour and music, can never be adequately expressed in language, the richer the complexity of association networks is the more empowered humanity feels to express them in words. This is perhaps underlying reason for the complex colour symbolism in various cultures and religions. This is the conclusion reached in Chapter 4 and explains why in modern linguistic times synaesthetic concepts have so often been expressed in literature. If this is the case then it introduces the possibility discussed towards the end of Chapter 6 that by sharing the language of the senses it might be possible to increase the quality of blind people's concepts of colours, if vivid enough non-visual equivalents are used.

While this thesis is partly about the experience of synaesthetes, it is also very much involved with the manifestation of synaesthesia as a more widespread phenomenon. On assessing the story of visual-auditory connections in art there seems to be a contagious quality to its expansion, as if when, for example, Arcimboldo painted his motet with pitches corresponding to colours, it became a great part of the collective human consciousness to combine coloured and musical properties in future projects. In the 1700s, therefore, there were several such experiments, and by the early 1900s and up to the Bauhaus period this became a very major aspect in visual art and in music. Consequently, however, this fascination waned very rapidly, as if the epidemic had reached its zenith and all areas of art became immune to it for a while. It seems now, however, that synaesthetic art is on the increase again.

The role of Chapter 9 in this thesis is to examine the basis by which sensations from visual and auditory channels connect and draw upon various sources of study. The main focus is, however the Marks-Stevens Universal Properties, properties that seem to be illustrated by the degree of consensus with coloured vowels in non-synaesthetes and how certain words suggest their meaning as a result of their sound structure. These universal properties are, generally speaking, ignored in adults as they are not useful and might be obstructive to everyday thought. We, therefore, have an 'unlearning theory' to parallel those relating to synaesthesia and of AP. Although focusing on vision and hearing, the chapter addresses how these largely ignored universal attributes apply to the other senses as well. It is likely that in addition to the unlearning of these universal attributes, a certain lack of relevant language for united senses attenuates our impressions of their unity. In this connection, psychochromaesthesia is mentioned. Psychochromaesthesia, the mental colouring of concepts and objects, increases the sense of context which colours have. A 'psychosynaesthesia' which contextualises musical sounds has also been heard of. Certain other trans-modal common properties were probably manifest in some of the results of the Visual Deprivation Experiment (Chapter 15).

From the viewpoint of cross modality, the issue of metaphor (Chapter 10) is one of familiarisation, making things seem 'real' that without metaphorical devices would not seem that way. *Epiphoria*, which is involved in all metaphor related phenomena, is the key aspect for transporting sounds into the world of colours, or colours into the world of odours: this synaesthetic transportation is seen vividly in Edgar Allan Poe's 'Al Aarraff'. Cross modal language can be classified in the same ways as synaesthesia, insofar as it describes a sensation relating to one of the five senses and transports it to one of the other four, so that there are 20 types of cross modal language. We have seen how Lakoff & Johnson reject this model, regarding all metaphorical devices as convention. While convention certainly explains the adaptability and flexibility of metaphorically based language it says nothing of the amplification property of the making of these additional connections. Nor does it explain how the vast diversity of original metaphorical applications works: the metaphorical spectrum, like colour in art, can be functional or can be free and abstract. The latter is exemplified in the aforementioned Al Aarraff, which uses scarcely any metaphor in the classical sense of the word but uses original and often crude metaphorical devises whose success can scarcely be explained by Lakoff & Johnson's model.

How language can relate to abstract correlations like key and colour is one of the purposes of Chapter 11. It examines how non-synaesthetes' related keys and colours by assessing the words which they attached to them. Since this experiment is testing for a consistency, a metaphorically reliable model, which is not found in the associations of synaesthetes, the grounds for carrying out the experiment imply that *epiphoric* language is not synaesthesia, even thought it can be admitted as part of the 'wider phenomenon' that the thesis addresses.

The presence of common attributes in non-synaesthetes that was revealed by the Semantic Differential Experiment is supportive of Associative Theory. We have seen that Associative Theory explains how certain sounds, or days of the week, for example, can acquire certain colours but also that it is too simplistic to explain synaesthesia, Howells' behavioural study having little, if anything, to do with synaesthetic experience at all. Finding an associatively positive result in the Semantic Differential Experiment, for non-synaesthetes, thereby tends on the side of synaesthesia being an all or nothing condition, the participants of the experiment showing only mental associations between keys and colours.

This study has examined how the shared attribute theory between different types of sensation has led to many correlations over the years and this is exemplified by some of the symbolic notions mentioned in the first few chapters on colour, and is at their height with the colours used in the Qabbalah and with Kirscher's table (Chapter 12). The comparative study of theories of synaesthesia (Chapter 12) relates how Associative Theory was one of a number of theories which were developed in order to explain the phenomenon of synaesthesia at the end of the nineteenth century. In retrospect, we realise that each of these theories was partially right but also had its problems explaining some of the properties of synaesthesia. Prior to synaesthesia being defined and given its name, no theories were called for since synaesthesia could be explained away and/or dismissed as 'not real'.

Assessment of Messiaen and Skryabin (Chapter 13) shows that the former seems to fulfil the criteria for the diagnosis of synaesthesia, and all seems to show evidence of connection between the qualitative properties that are referred to in Cytowic's criteria. It has been acknowledged that at first sight the complexity of Messiaen's colours in relation with chord complexes is anything but generic (part of the third criterion) since they are described in great detail. It is recalled however that all of the colours that we can see can be represented on a three dimensional diagram and that however complex colours may look to the educated eye, they are essentially generic phenomena. The more developed connections with the chord complexes may suggest something less generic but it was suggested that different pitch class sets, especially those consisting of restricted intervals (i.e. modes of limited transposition) tend to have the most colour in them for several people, synaesthetic or otherwise.

The allocation of Messiaen's modes and chord complexes are also contrasted with the simple key and colour system of Skryabin's, which Messiaen called 'naïve' Skryabin, I conclude, has synaesthetic experience that is qualitatively different to that of Messiaen, consisting of a kind of abstraction whereby he convinced himself that certain keys and chords were certain colours. Nonetheless, with respect to his 'delusions' and convictions, it seems likely that his emotional experience of experiencing secondary sensations was fairly akin to that which Cytowic described as the fifth diagnostic criterion of synaesthesia. The possibility was also explored that synaesthesia was not mentioned by his biographer because synaesthesia was not known about in Russia at the time. Skryabin realised above all that universal art was a function of his personality and this may reasonably be regarded as testament to the notion that whatever the composer experienced in connection with music and art which most people do not experience was totally real.

These studies led to studying other synaesthetes, or probable synaesthetes who we were able to take a more objective stance on. Messiaen and Skryabin showed common strands although they can only be studied by non-scientifically aimed case studies, extending the studies gave an opportunity to provide some more concrete information.

The synaesthetic cases reviewed and the further new case studies for this thesis provide support for the validity of Cytowic's diagnostic criteria. Those people who experience the world in such a way as can be called synaesthetic follow these criteria, with the possible exception of the second ('Synaesthesia is Projected'). My five participants, including Case 19 - a doubtful case in some other respects -, all claimed that they have no control over their synaesthesia except for the ability to choose whether or not they pay attention to their secondary sensations. None of these participants had elaborate images, only simple generic stimuli, and all of them reported that their secondary sensations had remained more or less constant throughout their lives fulfilling the third of these criteria. The fourth of the criteria was demonstrated by the isolation of frequency components in the experiment reported in Chapter 8. It must be remembered, however, that no part of an experiment which addresses what synaesthetes' secondary sensations are can be used to falsify their genuine experience of synaesthesia. The final criterion is that synaesthesia is emotional and noetic, and most of the synaesthetes studied in the thesis, including my five (Cases 16-20) have made some expression that synaesthesia is meaningful. The thesis has also provided support for the most usual form of synaesthesia being coloured hearing, with all exceptions apart from Case 1 involving visual secondary sensations while a sense other than auditory was the trigger sense.

As was set out in the Introduction, this is not the complete picture. The final experiment, for example, showed that some non-synaesthetes may become temporarily synaesthetic in certain situations - in this case partial sensory deprivation. Although less than a third of the participants reported intense secondary sensations, which could usually be interpreted in terms of a direct relationship to the music, this is still evidence that synaesthesia is something that some non-synaesthetes can be prone to. The fact that most participants' reports did not take such a shape while a few did could be seen as support for the existence of a continuum of some kind.

Another challenge to the all or nothing model rests with the possibility that some people may have the pre-cortical brain experience suppressed, as is believed to happen in non-synaesthetes, but that its content survives to just sufficiently to affect cortical experience subliminally. Such 'partial synaesthesia' might have been brought to the forefront for participants of the key and colour experiment reported in Chapter 7 where keys were probably precociously identified in the absence of conscious Absolute Pitch (AP). It is suggested that the presence of preconscious AP in non-synaesthetes might also have played a part in the development of the assumed characters of different keys described in Chapter 6. Even this idea, far fetched as it may seem, is supported by research suggesting that AP exists in preconscious, cortical form. The colours of Skryabin's keys with their cycle of fifths – colour circle pattern seem to have developed gradually starting with just three keys and three colours. These probably evolved into colours for all twelve major keys as a result of intellectualisation, a form of internal conventionalising. It is noteworthy how little evidence there was of Skryabin like, cycle of fifths – colour circle, associations in the Chapter 7 experiment.

In addressing the issue of keys taking on certain characteristics before about 1830, another factor is important, temperament, the fact that unequal tuning meant that all keys sounded different to each other. It is suggested that many keys acquired specific characteristics during the unequal tuning period and that these somehow continued when equal temperament became the norm. The discussion on key and colour also attempts to explain how non AP possessors perceive different keys as being different in any way at all. Theories regarding the open notes on string, brass or woodwind instruments and the way the piano is usually tuned, using A 440 as its base are considered. This kind of explanation may have some value in it but is unsuccessful in explaining the way in which the characteristics of keys seem to be universal between instruments.

Attempts are also made to explain how non AP possessors may be aware of certain key differences because of the way the ear works. Place location in the ear allows discrimination of intervals of about a minor third or larger but not smaller intervals. Supposing that that form of pitch perception is the only one that forms permanent memories, then that would explain why many non AP possessing individuals claim that F# major is very different to C major but that C major and D major are indistinguishable in sound in the absence of a reference point. The problem I found here is that semitone differences in key also seem to be vastly different. Although not explaining this I developed a theory of key relatedness regarding keys a tone apart as being the most similar, it is in this connection that colour contrasts in paintings and key contrasts in sonata movements are compared.

There are several other states and contexts which can be regarded as 'partial synaesthesias in non-synaesthetes'. These include synaesthetic metaphor and coloured vowels. It can be objected, however, that neurological synaesthetes show extremely reduced brain metabolism during synaesthetic episodes. This unlikely to occur in non-synaesthetes, even when they are making metaphorical cross-modal connections or else experiencing them due to sensory deprivation allowing the neural pathways to be exploited by passing thoughts in connection with auditory input as exemplified by the experiment of Chapter 15.

It seems that in terms of subjective existences there could be a synaesthetic continuum, but that in terms of hardware (i.e. metabolism) there is a definite set of specifications by which someone may be defined as a synaesthete. Even for synaesthetes the conscious experience should probably be assumed to be cortical (assumptions being necessary since we can never know for sure) which would suggest that non-synaesthetes can have comparable experiences even though the brain metabolism is not as such as to produce the constant experience in the way that it is manifested for synaesthetes.

To summarise, synaesthetes are different to the population at large in few or no respects other than in their perception of secondary sensations in response to triggers. However, the population at large is sensitive to varying degrees to ways in which the senses may connect to each other so that sounds may, for example, possess certain colours. This is distinct from synaesthesia it is usually voluntary and less emotionally meaningful. Synaesthetes' responses, by contrast, can never be controlled and are 'meaningful' manifestations. The associations (or sensations) of non-synaesthetes may be as consistent as those of synaesthetes and may follow a scheme of rationale since such consistency can depend on cortical functioning (i.e. memory) alone. The findings of semantic differential studies have found a greater concordance between triggers, secondary associations and qualitative attributes in non-synaesthetes than in synaesthetes.

The above is the case presumably because the former faculty relies on memory so that the connections are necessarily concrete and cognitive, rather than deep rooted, 'ethereal', and cognitively impalpable, as they are in synaesthetes.

There are a few exceptions to the above generalisation, many of which were listed at the outset of Chapter 15. All of these exceptions, including deprivation synaesthesia which the chapter investigates, involve intermeddling in some way or another with neural flow in the brain. Some of the exceptions are rare while others are commonplace. Synaesthesia-like experiences are quite a commonplace feature of the hypnagogic state, demonstrating one of the capacities by which most people are synaesthetic. To an extent, Cytowic's preconscious brain model acknowledges this since it works on the basis that the subjective experience of synaesthesia exists in all humans, even though what ultimately becomes identified as an individual's sense of actuality becomes excluded from it.

This implies that were it possible to rearrange neural connections in a way that enables preconscious functions to influence perceptual construction in the cortex, then this might introduce synaesthesia itself. It is not, at present, possible for such tampering to be of adequate accuracy and the risk of devastating side effects are far too high to consider executing such an operation even on a totally willing volunteer. Side effects apart, for an adult to acquire the 'gift' of synaesthesia could, I feel, constitute inflicting some quite adverse subjective changes. The muted unity imaginary/cognitive 'Unity of the Senses' is as much part of the subjective world of non-synaesthetes as the vivid and penetrating 'Union of the Senses' is for synaesthetes. Any dramatic change to an individual's subjective world (as distinct from the more gradual changes that occur throughout someone's lifetime) must be disconcerting at the very least.

As with those under the influence of hallucinogenic drugs, individuals treated in order to acquire synaesthesia may not be able to make accurate comparisons of experiences before and after the operation, although their reports would obviously be of some value. Additionally, the artificial creation of synaesthesia by recreation of synaesthetic brain function is not the equivalent of understanding the condition. Therefore, the combination of lack of material gain, ethical problems, and the extreme intricacy of the operations concerned suggest that this might not be a viable or productive way forward.

The above does not automatically mean that if as a result of a chance brain haemorrhage someone was so affected, that the case would not be of interest, although, once again, what are the chances no other function being affected? Brain haemorrhages are usually accompanied by transient amnesia, making the last hour or two, or even a day or longer, of such an individual's being non-synaesthetic, i.e. prior to the accident, become erased (or at least unrecoverable) from memory. This period of oblivion would thereby separate the subjective worlds of 'before' and 'after' making comparative reports of having and not having synaesthesia still vaguer.

It is possible that such a case as this has already existed and may have been documented but lost, neglected or destroyed since. As acquired neurological mishaps usually involve speed and power (i.e. machinery), then they would more likely have occurred post Industrial Revolution, which increases our likelihood of discovering their documentation by accident. Such study(s) would still be deficient in objective information, not least since the word 'synaesthesia' did not appear until 1872, so that before that year there was no 'coat hanger' on which to place the experiences.

It seems that without such fortunate finds, *unfortunate accidents*, or close encounters with ethical issues and very brave participants we can do little more than hack away at the edge of the condition's nature in ways as diverse as the analysis of synaesthetic composer's music, looking at associations on non-synaesthetes that could relate to synaesthesia, testing the schemes and structures of synaesthetic sensations and attempting to induce partial synaesthesia in ways less dramatic than those described above. Perhaps with such an open approach we are not too far away from asking the right questions!

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Appendix.

THE FREQUENCY COMPONENTS IN THE COMPOUND TONES USED ON THE TAPE.

Tone No. Components in Hz (Relative amplitudes in brackets).

1 PITCH 1267(85), 1448(82), 1629(78), 1810(76), 1991(73)
2 NOISE 721(99), 137(53), 4673(52), 1448(82), 193(62)
3 PITCH 137(53), 411(83), 685(98), 2055(72), 2593(63)
4 NOISE 127(51), 685(98), 1043(90), 157(59), 5983(48)
5 NOISE 381(82), 298(75), 1099(89), 1991(73), 3667(56)
6 NOISE 1133(88), 889(94), 596(94), 314(76), 3667(56)
7 PITCH 127(51), 381(82), 1143(90), 1641(78), 2149(71)
8 NOISE 927(93), 2867(63), 447(84), 1267(85), 965(93)
9 PITCH 157(59), 314(76), 2699(65), 3611(58), 4673(52)
10 PITCH 206(65), 309(75), 721 (99), 927 (93), 1133(88)
11 PITCH 193(62), 965(93), 1351(82), 2509(67), 5983(48)
12 PITCH 137(53,) 411(83), 959(93), 2055(72), 2867(63)
13 PITCH 447(84), 596(94), 745(100), 894(94), 1043(90)
14 NOISE 889(94), 411(83), 894(94), 3611(58), 305(75)
15 PITCH 103(49), 206(65), 721(99), 824(97), 927(93)
16 NOISE 824(97), 381(82), 2593(66), 1810(76), 2509(67)
17 NOISE 2509(67), 2593(66), 785(98), 2172(70), 4439(53)
18 PITCH 127(51),381(82),889(94), 1143(90), 1387(82)
19 PITCH 157(59), 1099(89), 2699(65), 3611(58), 4673(52)
20 PITCH 298(75), 447(84), 596(94), 1043(90), 1192(87)
21 NOISE 103(49), 2149(71), 596(94), 1099(89), 1621(78)
22 NOISE 206 (65), 959(93), 745(100), 314(76), 1351(82)
23 NOISE 103(49), 1387(82), 596(96), 314(76), 2353(69)
24 PITCH 127(51), 381(82), 889(94), 1387(82), 2149(71)
25 PITCH 596(94), 745(100), 894(94), 1043(90), 1192(87)

26 NOISE 1143(90), 959(93), 298(75), 2172(70), 5983(48)
27 PITCH 137(53), 685(98), 2055(72), 2593(66), 2867(63)
28 NOISE 309(75), 1641(78), 411(83), 3611(58), 4439(53)
29 NOISE 206(65), 1641(78), 959(93), 1629(78), 1351(82)
30 PITCH 157(59), 785(94), 2699(65), 3611(58), 4673(52)
31 NOISE 309(75), 1387(82), 411(83), 745(100), 193(62)
32 NOISE 2149(71), 411(83), 745(100), 785(98), 3667(56)
33 PITCH 193(62), 965(93), 3667(56), 4439(53), 5983(48)
34 NOISE 824(97), 1641(78), 785(98), 1810(76), 5983(48)
35 PITCH 298(75), 596(94), 745(100), 1043(90), 1192(87)
36 NOISE 206(65), 1143(90), 894(94), 1991(73), 2509(67)
37 NOISE 2149(71), 2055(72), 447(84), 3611(58), 5983(48)
38 NOISE 103(49), 1387(82), 1192(97), 1448(82), 3667(56)
39 NOISE 309(75), 959(93), 298(75), 2353(69), 4439(53)
40 PITCH 137(53), 685(98), 959(93), 2055(72), 2867(63)
41 PITCH 103(49), 206(65), 721(99), 824(97), 927(93)
42 PITCH 1629(78), 1810(76), 1991(73), 2172(70), 2353(69)
43 PITCH 193(62), 1351(82), 2509(67), 4439(53), 5983(48)
44 NOISE 1133(88), 127(51), 2867(63), 1043(90), 4673(52)
45 PITCH 127(49), 889(94), 1143(90), 1387(82), 1641(78)
46 NOISE 381(82), 745(100), 2699(65), 1267(85), 5983(48)
47 PITCH 1267(85), 1448(82), 1629(78), 1810(76), 1991(73)
48 NOISE 927(93), 1387(82), 1099(89), 2172(70), 4439(53)
49 PITCH 157(59), 314(76), 785(98), 1099(89), 2699(65)
50 NOISE 103(49), 1387(82), 2055(72), 596(94),1629(78)
51 NOISE 1387(82), 2593(66), 447(84), 3611(58), 3667(56)
52 PITCH 206(65), 309(75), 721(99), 824(97), 927(93)
53 NOISE 824(97), 2149(71), 785(98), 1991(73), 5983(48)
54 PITCH 137(53), 411(83), 2055(72), 2593(66), 2867(63)
55 NOISE 206(65), 685(98), 1192(87), 2699(65), 1448(82)
56 PITCH 157(59), 314(76), 785(98), 2699(65), 4673(52)
57 PITCH 193(62), 965(93), 1351(82), 2509(67), 3667(56)
58 PITCH 157(59), 314(76), 1099(89), 2699(65), 4673(52)
59 PITCH 137(53), 411(83), 685(98), 959(93), 2867(63)
60 NOISE 1133(88), 959(93), 894(94), 314(76), 1810(76)
61 NOISE 1641(78), 596(94), 3611(58), 2353(69), 1351(82)
62 NOISE 824(97), 1143(90), 2055(72), 1192(87), 2509(67)

63 NOISE 1641(78), 2867(63), 157(59), 1448(82), 965(93)
64 PITCH 137(53), 685(98), 959(93), 2593(66), 2867(63)
65 PITCH 127(51), 889(94), 1143(90), 1651(78), 2149(71)
66 NOISE 309(57), 889(94), 137(53), 894(94), 2172(70)
67 NOISE 1133(88), 381(82), 685(98), 2699(65), 193(62)
68 PITCH 298(75), 447(84), 745(100), 894(94), 1192(87)
69 NOISE 103(49), 1387(82), 1043(90), 4673(52), 1351(82)
70 PITCH 193(62), 965(93), 1351(82), 3667(56), 4439(53)
71 PITCH 1448(82), 1629(78), 1810(76), 2172(70), 2353(69)
72 NOISE 721(99), 2593(66), 447(84), 1991(73), 4453(53)
73 NOISE 1641(78), 2055(72), 298(75), 1099(89), 1810 (76)
74 PITCH 157(59), 785(98), 1099(89), 3611(58), 4673(52)
75 PITCH 447(84), 745(100), 894(94), 1043(90),1192(87)
76 PITCH 103(49), 309(75), 824(97), 927(93),1133(88)
77 PITCH 193(62), 2509(67), 3667(56), 4439(53), 5983(48)
78 NOISE 206(65), 127(51), 894(94), 1099(89), 2509(67)
79 NOISE 824(97), 685(98), 4673(52), 1267(85), 965(93)
80 PITCH 103(49), 309(75), 721(99), 824(97), 1133(88)
81 PITCH 1267(85), 1448(82),1810(76), 1991(73), 2353(69)
82 PITCH 298(75), 447(84), 745(100), 894(94), 1043(90)
83 NOISE 927(93), 889(94), 137(53), 1629(78), 1351(82)
84 PITCH 309(75), 721(99), 824(97), 927(93), 1133(88)
85 PITCH1267 (85), 1810(76), 1991(73), 2172(70), 2352(69)
86 NOISE 685(98), 745(100), 157(59), 2353(69), 2509(67)
87 NOISE 309(75), 2593(66), 447(84), 3611(58), 2172(70)
88 NOISE 1397(82), 745(100), 785(98), 1267(85), 1351(82)
89 NOISE 927(93), 2149(71), 2867(63), 298(75), 965(93)
90 PITCH 1267(85), 1448(82), 1629(78), 1991(73), 2172(70)
91 PITCH 127(51), 381(82), 889(94), 1641(78), 2149(71)
92 PITCH 103(49), 206(65), 721(99, 927(93), 1133(86)
93 NOISE 103(49), 1143(90), 2867(63), 314(76), 3667(56)
94 NOISE 206(65), 1641(78), 411(83), 447(84), 1099(89)
95 NOISE 1133(88), 381(82), 1043(90), 2699(65), 1351(82)
96 NOISE 309(75), 411(83), 298(75), 1448(82), 193(62)
97 PITCH 127(51), 381(82), 1143(90), 1387(82), 1641(78)
98 NOISE 824(97), 1143(90), 959(93), 1192(87), 785(98)