SKY-COLOR; A PRACTICAL STARTING POINT FOR PAINTERS.

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Abstract: This paper describes how the process of empirical analysis of the perceived colors in clear blue skies was used to find the most effective range of pigments to represent them through the painting systems available to contemporary artists. This set of colorants is very specific and requires of the manufacturers of artists' paints clarity in labelling and equally demands of artists who use these materials knowledge of what labelling information means.

Keywords: sky-color; pigments; labelling; Colour Index

INTRODUCTION

For many people gazing at the sky is the stimulus to a range of thoughts, sensations and emotions, often a sense of wonderment, sometimes to a state of reflective questioning. For the author as a landscape painter this is often the case, the phenomena of clouds and atmospheric color are a source of constant fascination. When looking at the sky questions arise as to why these phenomena appear as they do and specifically what are the colors that are perceived within them? For artists then there is also the question of how can these colors be authentically represented through painting systems?

Upon further reflection these simple questions quickly became much more complex and so more difficult to answer. For change is a constant factor of the natural world, everything changes over time, sometimes quickly, sometimes very slowly, but all changes nonetheless; and none more so than the sky around us, most obviously from night to day, but as well from early to late in the day and also because of weather; itself the product of the changes in atmospheric pressure and moisture levels. So how could one start to unravel this complexity and to find the means to meaningfully analyse it?

THE PROJECT

The aim of this project has not been to attempt to explain what sky color is, for this would require advanced understanding across a range of disciplines including; physics, meteorology, optics and perceptual psychology, and I am a painter not an authority in any of these disciplines. Its more modest purpose has been to describe the discoveries that dispassionate empirical observation of the sky could offer and to suggest to other painters some practical advice on color selection if they also attempted to accurately represent sky color. So the project had two related areas of study that had specific outcomes, namely the perceived colors of the sky and then the best pigments from those currently available to artists to simulate these perceptions.

While not engaging in broad speculation about the experience of color perception; whether color is an inherent quality of objects, or a neurological response to them, or a complex and subtle interaction between independent energy systems in an environment, it was felt as least necessary to evaluate the individual processes of color recognition that formed the basis of this study. Unlike science, fine arts activity operates around acceptance, even celebration of subjectivity; it allows individual and uniquely personal reactions to the world and for these to be revealed in art works. While acknowledging the necessity and value of this way of thinking, it can be an overstated attitude that denies the possibility of any commonality of perception between people. So in this study of sky color an attempt was made to be as truthful and as objective as possible to the observations in the hope that these would then have some validity for others. To this end the author's color aptitude was evaluated to gauge accuracy and acuity in color perception and so give credibility to the empirical observations. The combined score from the Farnsworth-Munsell 100 Hue Test and the Inter-Society Color Council Color Aptitude tests that were undertaken was at the 80th percentile and graded as excellent, and so this gave some confidence in this hope.

The project is not without historical precedents for painters have long evaluated sky color by empirical means. Early in the nineteenth century to assist this process the concept of the cyanometry was developed into a hand held device for comparing actual sky color against swatches of colored cards that were labelled with the percentages of pigments used to make up their variously painted colors. These same pigments ratios could then be use by painters to create their own sky colors. In the twentieth century the cyanometer was discussed by the Belgian biologist and astronomer Marcel Minnaert (1893-1970) in his highly influential book *Light and Colour in the Outdoors.* He described how it was used and the pigments that he considered appropriate for constructing it, that is by mixing "…zinc white and bister with prussian blue or cobalt blue in different proportions".[1] This was the practical starting point for this investigation, to re-evaluate Minnaert's procedures and materials and then to build upon them if necessary.

THE PROCESS

In attempting to answer these questions it was quickly realized that there was the need to drastically simplify the problem and set specific and controlling parameters. So instead of attempting to understand the whole phenomena of sky color, namely clouds in all their variety, times of the day and specifically sunrise and sunset (of long interest to painters because of their often spectacular color effects) and the atmospheric conditions of haze, fog, smoke and dust, the study was deliberately restricted. The study was limited to cloudless skies in summer and when the sun was at least 20 degrees above the horizon. Also because sky color changes with altitude the location from where the observations were to be made had to be defined, in this case Melbourne, Australia and at sea level. Even within these parameters it was quickly realised that the simple and glib term "sky blue" was meaningless for what specific color is meant by this phrase? The sky, across its whole vault, when observed under such conditions exhibits a range of colors, not one single uniform color.[2]

The first stage of this investigation was to select a field site that allowed for an uninterrupted viewing of the whole sky vault from the horizon in all directions and to the zenith. Direct studies from the sky were painted within a circular format (diameter 37 cm) with artists' grade oil paints at specific times of the day. The circular format was seen as a two-dimensional equivalent of the total observable sky vault, with the position of the sun within this space carefully noted, the top of the image indicating north. Colors were mixed on a palette and matched against individual sections of the sky from the zenith downwards. Minnaert tells the observer to stand with your back to the sun and let it fully illuminate the color samples that constitute the cyanometer, a procedure that was followed as closely as possible throughout this study. To further assist in gauging the accuracy of the mixed colors against sections of the sky they were applied to strips of cardboard that were themselves covered with a previously painted black and white chequer-board pattern. When held up against the sky this combination of high contrast base pattern and color sample was found to be useful in assessing comparative lightness and saturation values between the paint samples and the appropriate sections of the sky. For the sky is so radiant with light that it is easy to underestimate its relative darkness, therefore visually comparing a region of the sky against the extreme contrast of black and white made it easier to find a mixed paint sample of the correct tonal value. These carefully mixed samples were then applied to the corresponding equivalent section of the sky in the circular format and the image built up progressively (Fig 1).

PIGMENTS

Alongside these direct observational studies a survey was undertaken of the pigments currently available in artists' painting systems. Because of significant variations in sky color, temporally, spatially and atmospherically, it is difficult to isolate one pigment capable of representing this complete range. Yet traditionally and out of necessity artists did just that, for until the Industrial Revolution the number of pigments available for use by artists was limited and especially so in the blue range. Until the invention of Prussian Blue in 1704, the first modern synthetic pigment, artists had to rely on naturally occurring mineral colorants that were rendered useful by processes of crushing, levigation and grading,[3] or on simply processed materials that produced pigments of restricted application (Egyptian Blue).[4]

In describing his device for measuring sky color Minnaert proposed that a number of pigments be used to increase the range of colors by their generation through mixture: Zinc White, Bister (Bistre), Prussian or Cobalt Blue. However this selection of colorants is at the very least unclear and indeed may not be the most effective for the task. During Minnaert's lifetime Zinc White was not the only white pigment available. Still in use was the historically important Lead White, as well as the more recently developed Titanium White. For the purposes of this study only Titanium White (Colour Index Pigment White 6) was used, both for its stability and scattering power (measure of whiteness).[5] Bister is an unstable, unrefined carbon black that varies considerably in its colour depending upon the source and processing of the raw material used in its manufacture.[6] Prussian Blue (C. I. Pigment Blue 27) is a stable and inexpensive blue pigment but has hue characteristics that limit its ability to represent the full range of sky colours. Finally there are at least four separately classified variations of Cobalt Blue used in artists' paints, from green influenced (C.I. Pigment Blue 35 and Pigment Blue 36) to red influenced (C.I. Pigment Blue 28 and Pigment Blue 74), Minnaert did not specific which Cobalt Blue to use.

The problem then was where to begin the search for the most suitable pigments to realize the concept of the cyanometer. The issue was exacerbated by the existence of the bewildering array of choices that is currently available in artists' paints, with manufacturer's catalogues often having listings numbering well over one hundred. The range of blue pigments, the most obvious starting point, is itself extensive, for as well as Prussian Blue and the four variations of Cobalt Blue previously stated, there are four other principle chemical types with many variations in a number of these classifications. In total there are in common usage at least twenty modern synthetic blue pigments as well as the historically important naturally occurring mineral pigments including azurite and lapis lazuli. As the sky presents a diversity of colour that is not able to be reproduced by one blue pigment alone it was logical then to investigate those pigments that in mixture with others would generate the greatest possible range of colours. It is here that the concept of tintorial strength provided the solution. Tintorial strength is a set of internationally defined standards based on a pigment's light absorbing or scattering characteristics[7] but for artists it is most clearly demonstrated by the relative ability of one pigment to confer color to another through mixture. A blue pigment of high tintorial strength will produce more shades or tints when mixed with white than will a blue of lesser strength mixed with the same white.

Prussian Blue, suggested by Minnaert, does exhibit strong tintorial properties, however it is an unsaturated blue; that is a blue with violet and black influences. So from Prussian Blue it is not possible to mix a more saturated and purer blue further back along the spectrum towards green. It is similarly not possible to mix a clean violet from a strongly green influenced blue when combined with a blue red (magenta). Therefore a pigment close to the concept of the psychologically unique blue (that is a blue color that most would regard as neither green nor red influenced) and of high tintorial strength seemed to offer the best hope of being a useful starting point in the search for those pigments most capable of representing the colours of the sky.

Firstly the investigation examined the range of Ultramarine Blue pigments (C.I. Pigment Blue 29). Ultramarine was the name given to the pigment derived from the naturally occurring mineral lapis lazuli and is historically very important in the Western tradition of painting. These natural occurring mineral pigments have now been almost completely replaced by totally synthesized products of the same chemical constitution. Like their natural counterparts modern synthetic Ultramarine Blues are available in a number of subtle variations of hue, again between the red and green polarities, with most orientated towards the former. This inherent hue bias is one discounting factor in their potential application to the task at hand though it is not as significant a factor as it is with Prussian Blue, for Ultramarine Blues are generally more saturated or purer colors. However in comparison with other similarly colored pigments they have very low tintorial strengths and are therefore less effective in mixture. Manganese Blue (C.I. Pigment Blue 33) another metal derived blue pigment has similar properties.

In consideration of Minnaert's recommendation to use Cobalt Blue, the investigation looked at one in particular, Colour Index Pigment Blue 35, which is often labelled by paint manufacturers as Cerulean Blue, and sometimes as Sky Blue. Yet its color characteristics; a green influenced blue, of relative lightness and of low saturation make it of limited use in representing the total sky vault, it certainly had restricted application to the skies evaluated in this study. Another Cobalt Blue, (C.I. Pigment Blue 36), is even more green influenced and can be very easily described as turquoise. The two remaining pigments in this category, (C.I. Pigment Blue 28 and Pigment Blue 74), respectively light and deep red blue shades do offer real promise. All cobalt pigments are very stable, of low to medium tintorial strength but in comparison with other pigments they are also very expensive, the cost differential between Prussian Blue and Cerulean Blue can be by many times. Throughout this survey cost effectiveness was a considering issue in determining the best pigments for the task, for the aim has been to provide practical options for the range of painters, from students through to professionals.

The last remaining major category of blue pigments is the Phthalocyanine range. These are amongst the most important synthetic pigments produced today with a wide range of commercial applications including artists' paints. They are stable, lightfast, especially in reduction with white and of high tintorial strength.[8] They are also within the medium range of the price scale. These blue pigments are produced in a number of shade variations from green to red influenced including; Colour Index Pigment Blue 15:3, Pigment Blue 15:1 and Pigment Blue 15:6 respectively, and it is the latter that became the single most important pigment used in this investigation.

However to complete the sequence and to extend the range of colors achievable through mixture two more pigments were added. The field studies, where the pigments where mixed to most closely match perceived sky color revealed the necessity to include a violet pigment in the sky colour mixtures. For in all the skies that were studied there was an easily perceived progression of dark to light colors from the general zenith region down to the horizon. As well there was a more subtle and variable progression from strongly red influenced blues around the zenith to more green influenced blues approaching the horizon. Color Index Pigment Blue 15:6 alone in mixture with white does not cover this range nor do any of the other major blue pigment types. The most effective pigment for this supporting role was found to be Dioxazine Violet (C.I. Pigment Violet 23), a pigment of uncommonly strong tintorial strength and its blue violet shade makes it a natural mixing companion with the range of Phthalocyanine Blues to represent the red influenced blues observed in areas of the sky. The final pigment found to be necessary to mix with the paint on the matching swatches to most closely approximate observed sky colour was at first so counter intuitive that a procedural error was considered. Minnaert's listing of colorants was also perplexing on this issue, for mixing black (Bister) into something that appears so light and luminous initially appeared incorrect. However in the full intensity of a midsummer's day it was found to be necessary to add Carbon Black (C.I. Pigment Black 7) to the mixture of white, blue and violet to match the very dark blues observed in parts of the sky.

PIGMENTS FOR A NEW CYANOMETRY

The four selected pigments (C.I. Pigments: White 6, Blue 15:6, Violet 23, Black 7) are, it is proposed, the simplest, most effective and economical set capable of generating through mixture a very large number of the blue colors observed in a variety of skies (Fig.1). Figure 1 contains a sample one hundred of these mixtures from within a color space created by these four pigments. These one hundred mixtures are only a fraction of the total number of possible discernable variations that can be mixed by these four pigments. These four pigments in mixture are also able to simulate the broad color characteristics of all the other blue pigments previously discussed, for with a little practice in color mixing almost exact matches can be made. It is important to note that none of the other blue pigments could be mixed together to match the color creating characteristics of Pigment Blue 15:6 and Pigment Violet 23. For it is the tintorial strength of these two pigments relative to all the others that enables their considerably larger color generating capacity.

For painters practical results are in the end usually more important than speculation and materials are the vehicles through visual ideas are expressed and therefore they have to function in ways envisaged by the creative artist. So the test for the effectiveness of these selected pigments is their practical application in actual paintings to the task of representing sky color. The investigation conducted throughout this project lead to knowledge of the existence of a previously unknown pigment in the phthalocyanine range, namely Colour Index Pigment Blue 15:6 and its availability in some brands of artists' quality paints. This is now the only blue pigment that is part of the author's palette when working outdoors. It has proved itself to be a most valuable mixing pigment and base color generator for the representation of sky color. It is unfortunate that it is only included in the catalogues of a few paint manufacturers, this is also the case for the second most important pigment revealed by this survey, namely Dioxazine Violet (C.I. PV23).

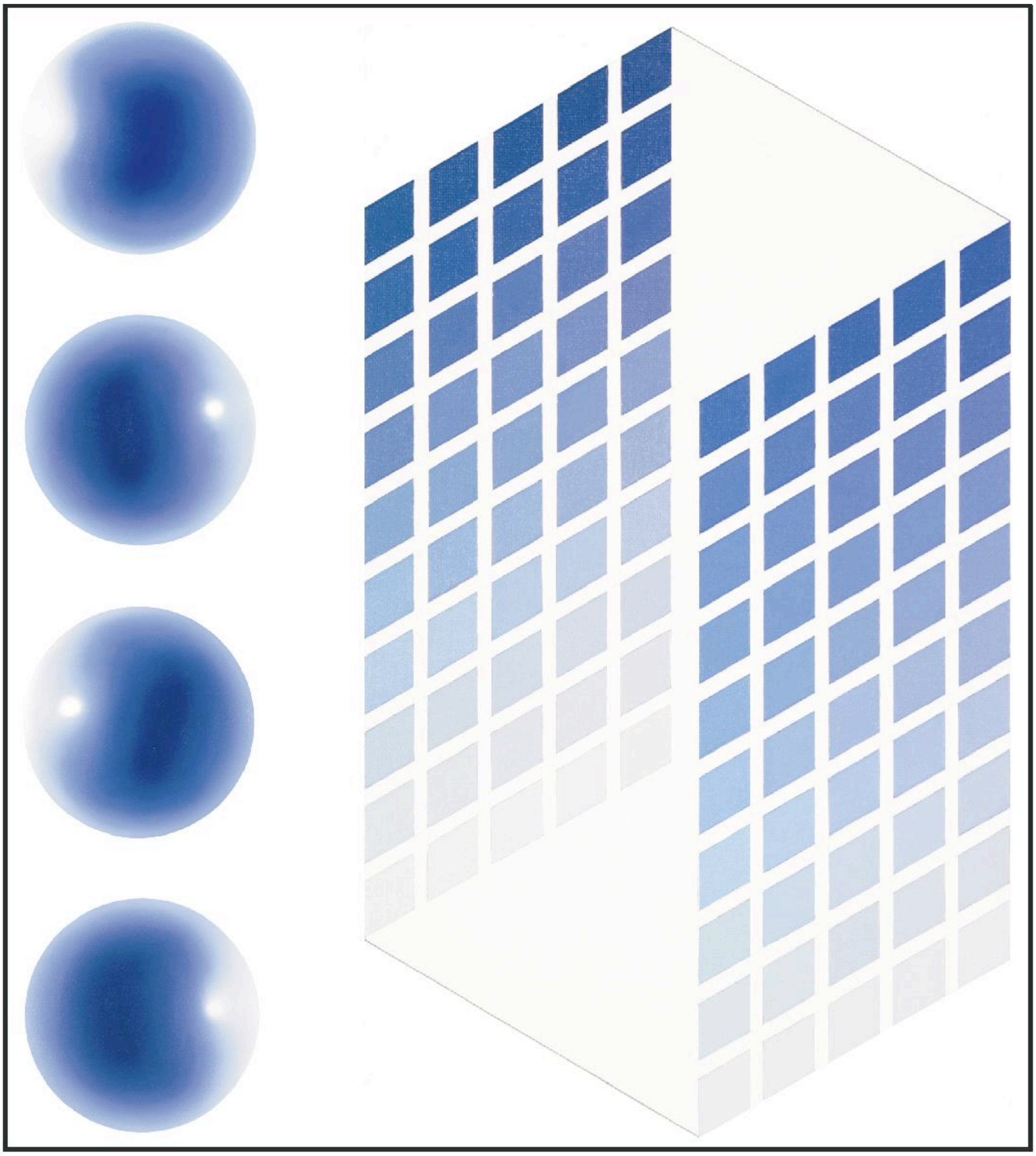

Fig. 1. *The total sky vault observed (top to bottom) on: 2/12/2002, 7.00 - 8.00 PM; 10/12/2002, 8.00 - 9.00 AM; 15/12/2002, 4.30 - 5.30 PM; 19/12/2002, 7.00 - 9.00 AM Oil on canvas, diameters 37cm.*

One hundred sky-blue colors within the color space created from Colour Index Pigments; White 6, Blue 15:6, Violet 23, Black 7. Oil on canvas 37 x 21.5cm. (© Ken Smith).

THE LABELLING OF ARTISTS' PAINTS

An essential component of painting practice is skill in color mixing. This in turn requires clarity by artists in their choice of pigments for they need to know what colors can be consistently generated by mixture. They also need to know what pigments are included in the paints that they purchase. This project revealed considerable confusion in the naming and labelling of artists' paints. A non-inclusive survey of manufacturer's listings of blue paints using phthalocyanine pigments reveals the use of numerous trade and proprietary as well as historical names that have little connection to the actual pigments used in the contemporary paints. The practice by manufacturers of mixing a number of pigments together to make particular exotic and trade name colors only adds to this confusion (Fig.2).

This situation prompts a plea for greater clarity in the labelling of artists' paints and a more assertive use of the Colour Index International system of pigment classification. This system of certification is increasingly being added to the containers of artists' paint but often in an inconspicuous section of the brand label and usually in very small print size. This often has the appearance of merely being the fulfilment of a regulatory requirement rather than a confident statement of the product's capability. However artists also need to become aware of the value of this system and to use it to help them make informed choices about the best pigments available to achieve their expressive ambitions. There are wonderfully powerful pigments available to artists today and this project has endeavoured to reveal a small number of them.

COLOR NAME	COLOUR INDEX GENERIC NAME	COLOR NAME	COLOUR INDEX GENERIC NAME
Azure Blue Hue	PB15:3, PG7	Primary Blue Cyan	PB15:3, PB16
Blue Lake	PB15	Scheveningen Blue Deep	PB15
Caribbean Blue	PB16	Sèvres Blue	PB15:3, PB29, PW4
Cerulean Blue Hue	PB15:1, PB16, PW4	Sky Blue	PB15:3, PW4
Cyan Blue Primary	PB15:3, PW4	Space Blue	PB15, PW4
Hortansia Blue	PB15	Spectrum Blue	PB15:3, PB29, PW6
Manganese Blue Hue	PB15:3, PW4, PBk7	Spectrum Cerulean	PB15, PW4, PW6
Monestial Blue	PB15	Tasman Blue	PB15:3, PV23, PW6
Ocean Blue	PB15:3, PW6	Thaline Blue	PB15:1
Old Holland Blue	PB15:6	Touareg Blue	PB15:3, PG7
Pacific Blue	PB15:3, PV23, PW6	Translucent Cyan	PB15:3
Phthalo Blue	PB15:3, PW4	Transparent Oriental Blue	PB15:6
Phthalo Blue Green	PB15:4	Turquoise Blue	PB15:3, PG7, PW6
Phthalo Blue Red	PB15:6	Winsor Blue (Red Shade)	PB15
Phthalocyanine Blue Lake	PB15:3	Zinc Blue	PB15:1, PW4

Fig.2 *Sample color names of artists' oil paints made by a range of manufacturers and all using phthalocyanine blue pigments as their prime colorant with their corresponding Colour Index International Generic Names displayed on the manufacturers labels, catalogues or web-sites.*

1 M.G.J. Minnaert, *Light and Color in the Outdoors*, Springer-Verlag : New York, p. 267, 1992.

2 K, Smith "Sky Blue, But What Blue? A New Evaluation of the Colors of the Sky for Artists and Designers". *Color Research and Application*, Vol. 32, No. 4 pp. 249-255, August 2007.

3 M.Price, "A Renaissance of Color: Particle Separation of Azurite for Use in Oil Painting", *Leonardo*, Vol. 33, No. 4, pp. 281-288, 2000.

4 R.J.Gettens, G.L. Stout , *Painting Materials, A Short Encyclopedia*, Dover : New York, p. 112, 1966.

5 G. Buxbaum, ed. *Industrial Inorganic Pigments*, Wiley-VCH: Weinheim, p. 43, 1998.

6 R.J. Gettens, G.L. Stout, p. 97.

7 G. Buxbaum, p. 42.

8 W. Herbst , K. Hunger, *Industrial Organic Pigments*, VCH: Weinheim, pp. 418-443, 1993.