Sky Blue, But What Blue? A New Evaluation of the Colors of the Sky for Artists and Designers

Ken Smith*

Faculty of Art and Design, Monash University, Melbourne, Victoria, Australia

Received 28 April 2006; accepted 21 June 2006

Abstract: This study describes a process of relating the perceptual analysis of the colors of the terrestrial atmosphere to currently available pigments used in artists' painting systems. This process sought to discover how the colors of the sky could be defined and simulated by these pigments. The author also describes how confusion over the bewildering choice of suitable pigments on offer in the market place can be clarified. © 2006 Wiley Periodicals, Inc. Col Res Appl, 32, 249–255, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/col.20291

Key words: art; design; sky color; perceived color; environment; pigments; painting systems

INTRODUCTION

In his influential book, *Light and Color in the Outdoors,* the biologist and astronomer Marcel Minnaert (1893–1970) describes how the mixing of; "**...** zinc white and bister with prussian blue or cobalt blue in different proportions" can be used to create a cyanometer for analyzing the variable blueness of the sky.[1] A cyanometer so made is a series of painted cards, each numbered with the varying proportions of the pigments used to create their colors that can be held up against the sky to evaluate its color. While Minnaert was an incomparable observer of the multifarious phenomena of light and color, his knowledge of pigments and their consequent representational qualities was probably limited. By again analyzing the sky color and correlating this study with the range of currently available pigments in artists' paints, Minnaert's concept of cyanometry is now more realizable. A color solid that is capable of representing most of the colors of the sky using four of these pigments is proposed.

AN EMPIRICAL METHOD FOR ANALYZING SKY COLOR

Science can explain why the earth's atmosphere appears blue, the preferential scattering by air molecules of short wavelength light photons emitted from the sun.[2] For artists the consequential questions are often more likely to be not why, but rather what; what are the blue colors that are perceived in the sky? These were the fundamental questions that lead to a reappraisal of how the colors of the sky can be represented by the pigments used in contemporary painting systems. Before attempting to answer this question, a number of parameters had to be created. Firstly to make possible such a study, a control of only using cloudless skies was established, the variability of highlights and shadows in cloudy skies makes the reproducible analysis of sky color difficult. Secondly the observational analysis of the sky could not include the extreme, but for artists often highly engaging aerial phenomena of sunrise and sunset, for these involve other variables such as atmospheric water content, dust, and other pollutants that are difficult to quantify. Thirdly the color of the illuminating light, the sun, had to be as constant as possible. As the sun rises above the horizon in the morning and sets in the evening, the changing thickness of the atmosphere through which its light must pass to reach the earth's surface changes the apparent color of sunlight. At dawn it changes from red to orange, yellow and white and then again in reverse order at dusk. Therefore, all the observations had to be made when the sun was at least 20° above the horizon. Fourthly as sky color changes with terrestrial altitude,[2](p23) the location from where the observations were made must be defined, in this case, Melbourne, Australia (37° 45′ south, 144° 50′ east), at sea

*Correspondence to: Ken Smith (e-mail: ken.smith@artdes.monash.edu.au).

level and over the 2002/2003 southern hemisphere summer.

One fact that quickly became apparent throughout this study was the range of colors that can exist even within these controlling parameters. The colloquial "sky blue" quickly becomes a meaningless term when the total vault of the sky is observed from a location that affords a relatively uninterrupted viewing of the horizon in a 360° radius. From here, even the most casual observer will notice significant changes in the color of the sky from its zenith region down to the horizon and in any direction, so which of these colors is then to be classified as sky blue? The whole language for the description of sky color needs clarification.

Both our evolutionary biology and perception of the world mediated through art may be partly responsible for this simplification. A survey of skies represented in the Western tradition of landscape painting reveals that generally the sky was observed and painted across a relatively restricted range of angles of inclination, from 0° at the horizon, to approximately 50° of elevation. Rarely represented is the full 90° of elevation from the horizon to the zenith of the sky vault. This may in part be due to the limits of the eyes' visual field, for when looking straight ahead the upper limit for eye movement is approximately 55°.[3] As the sky approaches the horizon it becomes lighter in color,[2](p24,25) and it is the blues within this region that most would associate with the term "sky blue." However, this is not the whole sky and therefore not the complete range of its colors.

This fresh appraisal of the color of the sky was commenced by first selecting an observational site that provided the widest range of viewing angles, in this case within a flat zone of open farmland that was previously an extensive tidal and estuarial floodplain. 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. This is crucial for the correct gauging of the perceived color of the sky, but it also constitutes one of the paradoxes of the whole procedure. To 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 these extreme contrasts made it easier to find a mixed paint sample of the correct tonal value. As full illumination is critical to this process the cards were held up against a section of sky at an angle as close as possible to perpendicular to the sun. At the same time care was taken to avoid the distortion of the color by the gloss of the freshly mixed and wet paint. 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. It is possible to use this method of color matching to evaluate approximately two-thirds of the total sky space but impossible to use when looking into the regions of maximum luminance approaching the solar aureole and downwards from here to the horizon, for the color swatches are always in shadow. Attempts were made to illuminate these samples by mirrors, but it was found that they always appeared darker than the area of the sky against which they were viewed for mirrors reflect only a fraction of the full intensity of sunlight. As well, it is of course dangerous to look directly at the sun, so to complete the circular image in these areas a method of extrapolation by eye, using comparative evaluation between these areas and those already established had to be used.

THE RANGE OF AVAILABLE BLUE PIGMENTS

Parallel with 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 have done just this, 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,[4] or on simply processed materials that produced pigments of restricted application (Egyptian Blue).[5] The fact that artists of stature were able to achieve by such limited means works of spectacular evocation is further evidence of their brilliance.

In describing his cyanometer, 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).[6] Bister is an unstable, unrefined carbon black that varies considerably in its color depending upon the source and processing of the raw material used in its manufacture.[5](p97) 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 colors. 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 100. 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. The principle criterion for the selection of the pigments used in this study had to be effectiveness and this included cost effectiveness for ultimately the aim was to select a group of pigments that could be used by the widest range of artists from students through to professionals. Therefore while the historical pigments are still available, by comparison with most others they are extremely expensive and so were not included in these tests.

As the sky presents a diversity of colors that are 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 colors. 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[6](p42) 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. However, there is another factor here that has to be considered when mixing colors and that is what may be called the hue polarity of a pigment, its place relative to other pigments of similar color when compared to the spectrum of refracted white light. The region of the spectrum of most interest for this study is that between wavelengths 400 and 490 nm, namely violet, indigo, blue (Fig. 1). The hue polarities here are red and green, with violet at the one extreme being perceived as red influenced, and at the other end of this range, turquoise, a green blue. The purest blue, the psychologically unique blue is at approximately 470 nm.[7] and without a red or green influence.

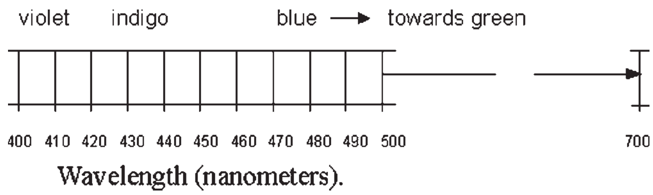

FIG. 1. The violet to blue component of the visible spectrum. The total visible spectrum of light extending from approximately 400–700 nm of wavelength.

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. One of the characteristics of mixing colors with pigments is that while it is called a subtractive process, in comparison to the additive process of mixing color by light,[8] in the practical reality of the artist's studio it is actually a process that involves augmentation. In the case of Prussian Blue its violet and black influence is not subtracted when it is mixed with another color, this influence is always part of any mixture, it cannot be taken out, and it can be masked but not eliminated. 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 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 colors 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 pigments derived from the naturally occurring mineral lapis lazuli. These natural pigments have now been almost completely replaced by totally synthesized products of the same chemical constitution. Like the natural pigments, 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, Color Index Pigment Blue 35, which is often labeled by paint manufacturers as Cerulean Blue, or indeed 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

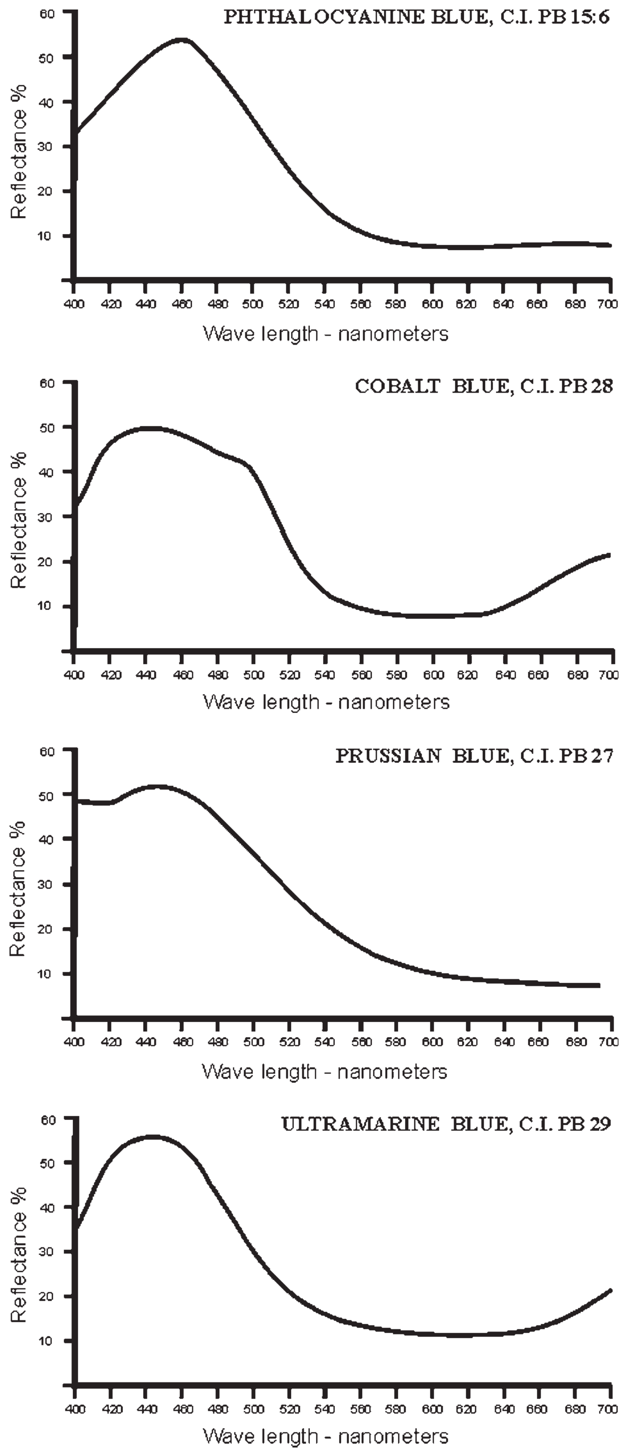

FIG. 2. Reflectance curves of the four major blue pigments analyzed. The more focused curve of Phthalocyanine Blue CI. PB 15:6 clearly indicate its greater saturation or purity of hue. Produced from pigment samples in artists' oil paints analyzed by a Macbeth spectrophotometer, Model 700A under CIE Standard Illuminant D65.

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 again in comparison with other pigments they are very expensive, and the cost differential between Prussian Blue and Cerulean Blue can be by a factor as high as six.

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.[9] 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: Color 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. The spectral reflectance curves of the four major blue pigment types analyzed in this study clearly reveals the unique hue and saturation qualities of Color Index Pigment Blue 15:6, its dominant and relatively narrow curve (Fig. 2).

However to complete the sequence and to extend the range of colors achievable through mixture two more pigments were added. Pigment Blue 15:6 is very close to the concept of a psychologically unique blue, slightly less red than the Cobalt Blues (C. I. Pigment Blues 28 and 74), but it is a considerably more powerful mixer especially in association with other similarly high tintorial strength pigments. The field studies, where the pigments where mixed to most closely match perceived sky color, first revealed the necessity to include a violet pigment in the sky color 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 is a more subtle and variable progression from strongly red influenced blues around the zenith to more green influenced blues approaching the horizon,[10] (Fig. 3). 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). Also referred to as Carbazole Violet,[9](p518–520) Pigment Violet 23 is 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 color 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. Science explains the existence in the sky of zones of maximally polarized sunlight, most significantly in an area at around 90 degrees of angle from the sun on the solar vertical circle

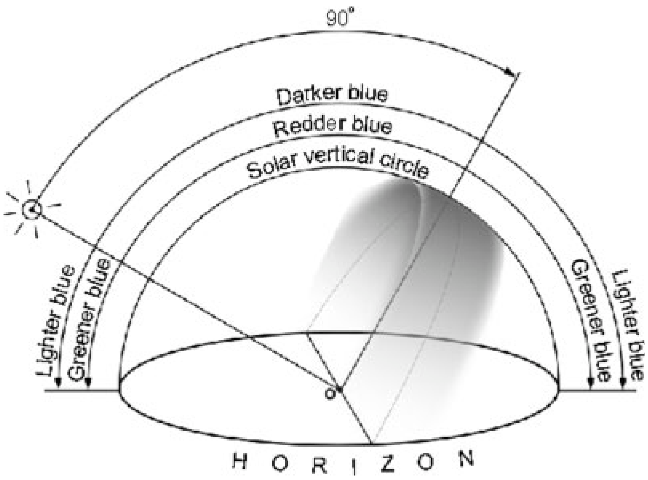

FIG. 3. Sky vault, zone of maximum polarization of skylight, and progressive gradations of sky color as seen by an observer at O. The darkest blues of the sky are within the zone of maximum polarization. (Reproduced from Ref 2, with permission of Cambridge University Press).

(Fig. 3). These are the darkest parts of the sky and they can be very dark indeed.[2](p26,27) Painted colors that simulated these regions recorded *L*a*b** tri-stimulus values as dark as *L* 37.27; *a* −2.10; *b* −12.30 (samples evaluated under CIE Standard Illuminant D65 with a 10° aperture). As well another set of causative factors may need to be considered in this particular investigation for the intensity of summer sunlight in parts of Australia is notable for a number of reasons. On the edge of the vast expanse of the Southern Ocean the atmosphere over the continent can at times be exceptionally clear of aerosols in the form of dusts and man-made pollutants. During the summer the air over the land can also be very dry and low in water vapor. It is probable that all these factors influenced the presence of the very dark sky colors that were observed. Yet Minnaert did include black in his selection of pigments so it is possible that what was experienced throughout this study was only a more extreme example of what can be seen elsewhere around the globe.

One other, often overlooked blue pigment that should be mentioned as having some application in the description of sky colors is Indanthrene Blue (C.I. Pigment Blue 60). This is a red influenced blue, somewhere between Prussian and Ultramarine Blue in color, of high stability and which in mixture with white gives a quick approximation to deep sky color. However its red influenced and unsaturated qualities make it less useful for the lighter sky blue colors and on this basis it was not considered a primary mixing blue for the purposes of this study.

A COLOR SPACE FOR THE COLORS OF THE SKY

The four selected pigments (C.I. Pigments: White 6, Blue 15.6, Violet 23, Black 7) then constitute the four directions of a color space (Fig. 4). They 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. Figure 4 also contains the relative positioning of a sample one hundred of these mixtures within the color space, with the percentages of colored paints used to create the mixtures of the eight corner colors noted. These 100 mixtures (Fig. 5) are only a fraction of the total number of possible discernable variations. 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 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. The only discrepancy in the whole system is in the slight variation of color found in trying to achieve a match with Cobalt Pigment Blue 36 (Cerulean). It is not possible to achieve an exact match to this color with a mixture of Phthalocyanine Pigment Blue 15:6, Pigment Black 7 and Pigment White 6. However, changing Pig-

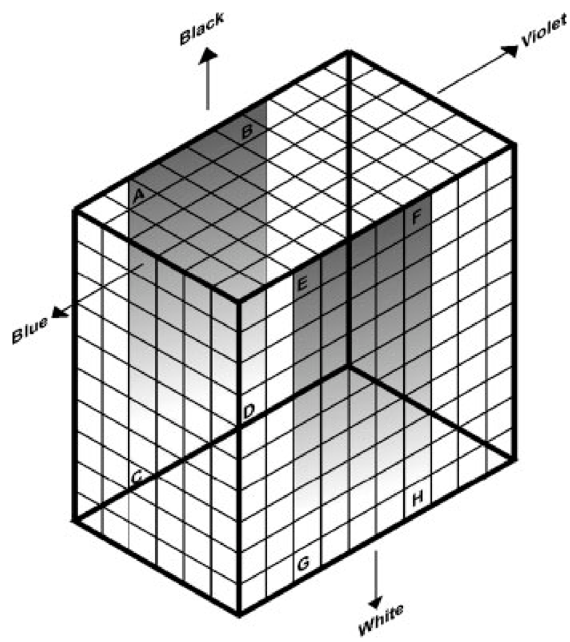

FIG. 4. Color space created from Color Index Pigments; White 6, Blue 15:6, Violet 23, and Black 7. Approximated percentages of pigments by weight in each nominated position of the color space. Plus their *L*a*b** color space co-ordinates produced by a Gretag Macbeth spectrophotometer; Model 700A under CIE Standard Illuminant D65 with a 10° aperture. (© Ken Smith)

	White (%)	Blue (%)	Violet (%)	Black (%)	*L*	*a*	*b*
A	55.35	36.17	5.90	2.58	44.64	−2.51	−32.79
B	55.35	24.35	17.72	2.58	40.12	2.24	−30.49
C	99.60	0.34	0.04	0.02	86.63	−5.04	−9.53
D	99.60	0.20	0.18	0.02	84.39	−2.98	−10.88
E	56.82	37.12	6.06		45.59	1.27	−41.09
F	56.82	25.00	18.18		41.21	7.77	−38.98
G	99.43	0.54	0.03		85.51	−5.48	−11.75
H	99.70	0.25	0.05		84.74	−2.10	−12.30

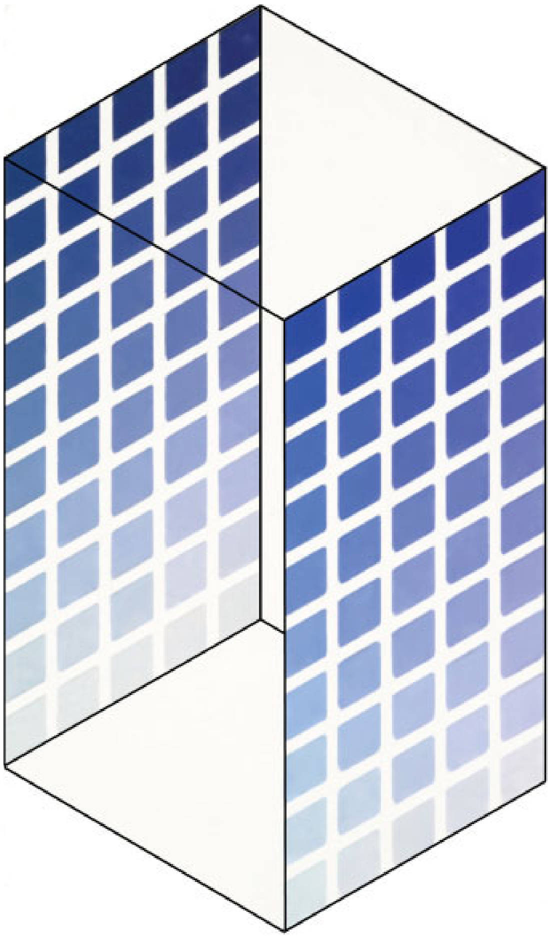

FIG. 5. One hundred sky blues from with in the color space created from Color Index Pigments: White 6; Blue 15:6; Violet 23; Black 7. Oil on canvas, 37 × 21.5 cm. (© Ken Smith)

ment Blue 15:6 to the greener influenced Phthalocyanine Pigment Blue 15:3, and keeping all the other pigments the same, an exact simulation is possible. In fact the whole system can be re-biased by adjustment of the Phthalocyanine Blue component, using one or other of the three main classifications. Pigment Blue 15:6 was chosen because of the red influenced blue skies that were observed throughout this study.

PROCEDURAL ANOMALIES

The four chosen pigments then form an optimum mixing set for the generation of most colors observed in a cloudless sky within the established daytime parameters. The described procedures that lead to their selection attempted to be as accurate as possible to the direct perceptual experience of looking at sky color. To minimize the possibility of subjective color distortion the observer's color aptitude was evaluated and defined as normal.[a] However the process of sky color evaluation that was used in this project does of itself introduce a number of distortions and paradoxes that must be acknowledged and at least partially explained.

Firstly all the observations were performed outdoors in sunlight, its full intensity illuminating the color samples, yet most pictorial art objects are mostly viewed indoors under considerably lower levels of illumination. Therefore what may be perceptually true in an outdoors environment might not always be visually correct in a pictorial composition that is viewed indoors. Secondly evaluating sky color by this procedure instigates processes of adaptation in the eyes of the observer due to the extremely bright and color influenced test environment. Adaptation, a characteristic of all sensory systems is defined as; reduced responsive reactions in these systems because of prolonged stimulation.[11] In this test procedure this involves in the eye both light adaptation; closing of the iris aperture as well as retinal desensitization, and chromatic adaptation; the reduction of retinal sensitivity to short wavelength (blue) light. While these processes are generally understood by perceptual psychologists, the degree of effect that each has, singularly and collectively in influencing the perception of color is less clear.[11](p94–142) Another factor that may have to be considered is the Bezold-Brucke Phenomenon.[12] This phenomenon describes how the perception of a hue changes when the relative intensity of the light by which it is illuminated changes. As light intensity increases the perceived hue quality of a blue moves further along the visible spectrum towards the shorter wavelengths, effectively becoming more violet. It is possible then that the described method of color evaluation used in this project causes the sky colors to appear darker and less saturated. Therefore adding a greater amount of white and less black to the color mixtures would make them appear lighter and more saturated, more as the sky would appear to a less light and color adapted eye.

CONCLUSION

The intention of this study was not to attempt to make a definitive statement on the nature of sky color, the phenomena is complex and that would require advanced understanding across a range of disciplines including physics, meteorology, optics, and perceptual psychology. Its more modest purpose was to describe the discoveries that dispassionate empirical observation of the sky could offer. Firstly that the colors of the sky cannot be defined by the simple and glib, "sky blue" for the total sky vault has four distinct zones of different types of blue color all blending imperceptibly one into the other. The lightest zone immediately surrounding the sun, the darkest zone opposite the sun, the graduated zone from the horizon upwards, and the rest of the sky colored between the darkest and horizon zones. Secondly that these various blues are from across the range of the short wavelength region of the visible spectrum, included green and violet influenced blues, however not all these colors are pure spectral colors for they exhibit considerable variations in

[a]The combined score from the Farnsworth-Munsell 100-Hue Test and The Inter-Society Colour Council, Colour Aptitude Test was at the 80th percentile.

lightness and saturation. Thirdly that the color characteristics of the blues observed in the sky can be effectively matched in artists' painting systems by a careful selection of mixing pigments. The exact selection is crucial and promotes a plea to manufacturers of artist's paints for clarity in the labeling of their products. The Colour Index International system of defining pigments by their chemical constitution, rather than by their accumulated historical and commercial names, gives artists greater certainty in their choice of colors and greater ability to repeat over time their color mixtures. Finally the plethora of pigment choices and consequent color options available to artists today creates real difficulties in knowing just where to begin the study of color in the visible world. This project by close and specific concentration on one aspect of the visible gives a practical starting point to those who themselves wish to explore further.

ACKNOWLEDGMENTS

The author wishes to acknowledge and thank the following for supporting this project: The Faculty of Art and Design, Monash University, Australia; The Australian Research Council, Small Grants Scheme; Mr. Dennis Whitely, Creanova Asia Pacific Pty Ltd; Dr. Peter McGinley, Manager, Color-Services, Dulux Australia; Mr. Derrick Kendrick, Visiting Research Fellow, School of Architecture, Landscape Architecture and Urban Design, Adelaide University, Australia. Mr. Derek Grantham, Cathay Pigments Australasia Pty Ltd.

1. Minnaert MGJ. Light and Color in the Outdoors. New York: Springer-Verlag; 1992. p267.
2. Lynch DK, Livingston W. Color and Light in Nature. Cambridge, UK: Cambridge University Press; 1995. p22–23.
3. Gerritsen F. Theory and Practice of Color. London: Studio Vista; 1989. p51.
4. Price M. A renaissance of color: Particle separation of azurite for use in oil painting. Leonardo 2000;33:281–288.
5. Gettens RJ, Stout GL. Painting Materials: A Short Encyclopedia. New York: Dover; 1966. p112.
6. Buxbaum G, editors. Industrial Inorganic Pigments. Weinheim: Wiley-VCH; 1998. p43.
7. Kaiser PK, Boynton RM. Human Color Vision. Washington DC: Optical Society of America; 1996. p66.
8. Chamberlain GJ, Chamberlain DG. Colour: Its Measurement, Computation and Application. London: Heyden; 1980. p18.
9. Herbst W, Hunger K. Industrial Organic Pigments. Weinheim: VCH; 1993. p418–443.
10. Shepard RN. The perceptual organization of colors: An adaptation to regularities of the terrestrial world. In: Byrne A, Hilbert DR, editors. Readings on Color, Vol. 2: The Science of Color. Cambridge, Massachusetts: Bradford; 1997. p331.
11. Palmer SE. Vision Science: Photons to Phenomenology. Cambridge Mass: MIT Press; 1999. p7.
12. Hurvich LM. Color Vision. Sunderland, Massachusetts: Sinauer Associates; 1981. p72–73.