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The period covered by this Edition of the Colour Group Journal is that of the Group's activities from October 1971 to May 1975. During this period two Symposia were held as well as the usual Group meetings. The subject for the first was 'Standard Conditions for Viewing' and the second was entitled 'Colour in Education'. Papers from both are presented in this Journal.

In the face of ever increasing production costs typewriter setting has again been adopted, but publication has been delayed by the necessary dependence on 'voluntary labour'.

It is our hope that, in spite of the delays, you will enjoy reading this edition of the Journal.

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Structuring Colour in Painting

Alan Cuthbert

A paper given to the Group on 6th December 1972

This is not an account of methodical research. As a painter, it is an account of involvements in colour, some aspects of which I have found to be of intense interest, others with which, so far, I have had no more than a casual flirtation. As a teacher, I have been closely concerned with a Foundation colour course at Wimbledon School of Art. In this capacity one naturally encounters problems and possibilities that one may not have the opportunity to explore in depth. I mention this to explain a tendency to meander between the general and the particular.

First I would like to attempt to define a number of stages in the process between the palette and the finished painting. They are the palette, the series, the process and the final colour structure.

The Palette one can think of as the artist's individual choice of tubes of paint, before any selection has taken place in preparing for a particular painting. This palette represents the potential of unit colour possibilities: A limited palette presents limited possibilities (black plus white less than 100), a broad palette of highly saturated paints plus white, presents perhaps millions of discern-able units.

The Series of colours can be thought of as the units of colours used in a painting seen not in their relative positions in the painting but assembled in their appropriate positions in the colour solid. A series can be complex, dispersed or compact, two or three dimensional, of a recognisable geometric order or amorphous.

The Process of assembling the painting although interrelated with the final structure of the painting can be seen to have its own structure in terms of the process of decision-making, the order of which may not necessarily be apparent in the completed painting. By the term 'Colour Structure' I mean the final network of interrelationships in terms of the actual differences between juxtaposed units of colour. In fact the 'Network of differences' would perhaps be an equally expressive form of explanation. In addition to the colour relationships themselves, such aspects as relative quantities (proportion of areas) or the apparent forms or space created can be a major part of the consideration, or an incidental by-product.

To put my own painting in some sort of context I would like first to mention work by painters who have used colour as a primary, or at least, major consideration in their work. As they have used colour for a variety of reasons it is also perhaps interesting to suggest categories within which it seems possible to classify them.

A number of artists have taken their starting point directly from a consideration of scientific discoveries and theories about the nature of light. Seurat's early attempts at pointillism are well known. Delauney and Moholy Nagy are two others who have concerned themselves with the behaviour of, or the manipulation of light. This tradition has continued into more recent kinetic work.

A second group of artists has been concerned with developing the range of visual phenomena of an optical/psychological nature. Op Art often explores the range of effects rising from retinal saturation of one kind or another. Examples can be found in the work of Albers, Vasarely and Bridget Riley. The series and the structure are often amazingly simple (the repetition of two or three hues or values) but extremely effective.

The constructivist tradition in the context of colour has been concerned with 'Constructing' arrangements and combinations of colours which derive from simple scales and colour mapping systems. The Ostwald system has probably been most influential in this connection through the interest of Bauhaus artists in his work in the 1920s. Artists who have worked in this direction are Max Bill, Richard Lhose and Vasarely. The series in this case are often simple scales (the spectrum, a monochromatic series or a desaturation series) and the structures evolved from a permutation or composition from these.

The three groups I have mentioned so far are usually concerned to remove any extraneous aesthetic considerations. The works are also often contrived to simulate one simple response. This means that they are normally non figurative - abstract or structurist. For the rest one could divide artists who have a major interest in colour into two further groups:

Those who are concerned with the observation and analysis of colour in natural forms or in works of art and who then use the knowledge and experience, perhaps with the addition of some theories of colour, to refine their colour. Many artists both past and present would fall into this category which in any case should include Delacroix who for a period structured his paintings round pairs of complementaries. Van Gogh and Gauguin, who in their later work although working to some extent from observation, often appear to have confined their colour series to those obtainable from the surface of the colour solid, were also much concerned with the effects of structuring their paintings round multiple pairs of complementaries.

Painters in the final category take their standpoint from theory and speculation about the emotional effects of colour. A great deal of theorising about the supposed effects of colour on the emotions - and speculation related to colour meaning, colour language and colour symbolism has provided the motivation behind this category of colourists' usage. Much of the theory may be now considered either inaccurate or at least over-ambitious. Nonetheless this tradition has produced a great deal of fascinating work, for example that by Kandinsky and Klee. It is interesting that colour in this context with Klee has produced some of the most lyrical and inventive colour in European painting.

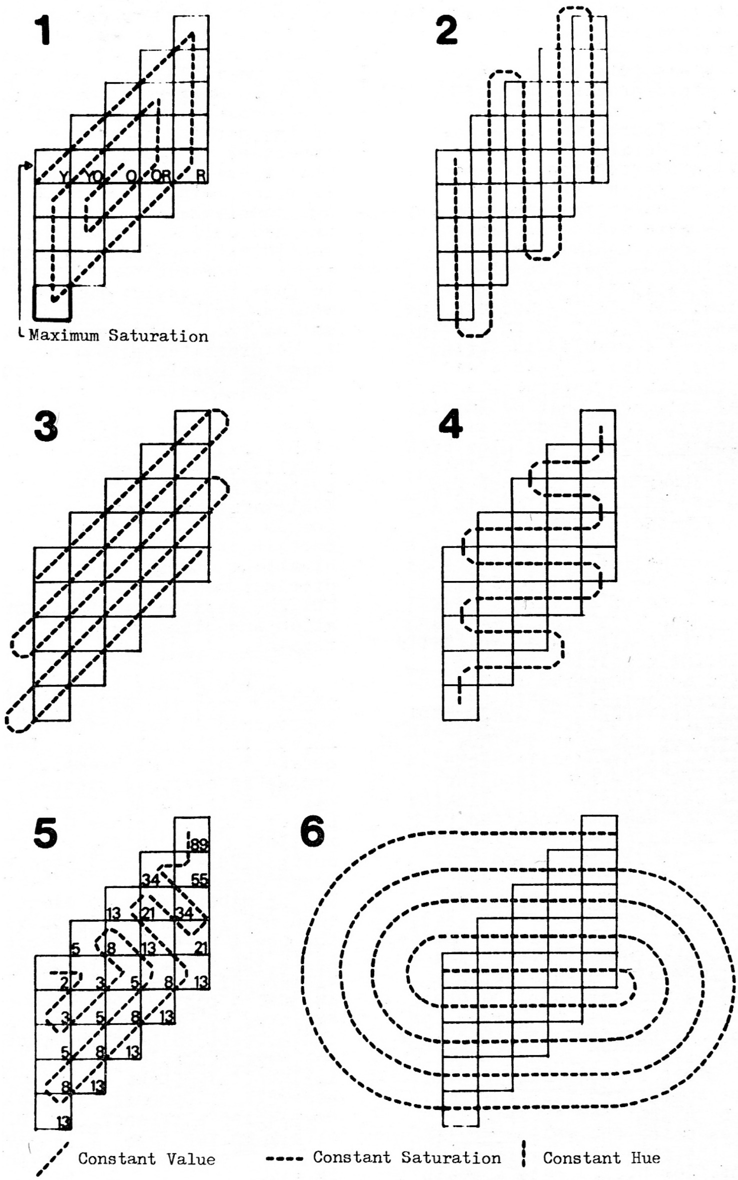
Inevitably these classifications are not precise, for artists tend to follow their noses. Vasarely, in recent years for instance, seems to have moved from the optical to the constructivist and has a tendency at times to combine both. Likewise Gauguin who relied to a large extent on observation and also appears to have had a fairly rational approach to colour usage, was also concerned with colour symbolism.

In addition to those I have mentioned there are other ways of colour, such as limiting one's palette to the use of the maximum saturation colour circle, the close value equal saturation series as often used by Morandi. There is a studio folklore to do with warm and cool colours and colour space: that oranges project and blues recede, or, reduce light contrast, or reduce colour contrast, or reduce saturation, to obtain space. One can even use colour not as colour at all but merely as light. Using the fact that the colour circle can be used as a value scale with yellow being the lightest and purple being the darkest.

My own painting however is closest to the constructivist tradition. An interest in light and light modulators; finding ways of exploiting the possibilities of light shadow and reflected light, and grey scales, seemed to lead naturally to a curiosity about colour.

The simplest paintings were those related directly to the spectrum series. They were exploratory in a Chevreulesque way but with personal criteria rather than a number of observers behind the decision as to what was interesting or satisfactory and what was not. There were problems in finding suitable paints with which to paint the spectrum, decisions on how and why to divide the spectrum into a particular number of units, and later on how to adjust proportions in order to obtain modularity. At this stage I was thinking of colour in a negative way: white as total reflectance, colour as partial absorbtion, these paintings therefore were related to a white ground. The paintings explored the effect of different numbers of hues from a spectrum series. Some were selected on a measurement basis e.g. the two extremities plus the hue appearing on the Golden Mean, others on a number basis (there were 14 steps in the spectrum series used). The colours were kept in their normal relative positions, rather like a spectrum with certain hues removed.

A further group of paintings was concerned with exploring monchromatic possibilities, particularly of yellow. Here one encountered the problem of constructing yellow scales (about which I have talked to the Colour Group). In these paintings I was also involved with developing a way of relating desaturation to proportion so that one would feel that the areas, whether highly saturated and small, or less saturated and larger, contained the same amount of reflective pigment, in the one case closely packed, in the other, dispersed. In fact four different proportional series were used in attempts to achieve this form of colour balance. In the first two the yellow series was a simple desaturation scale obtained by cross mixing the red and green sides of the spectrum, both structures are readable being merely a methodical exhaustive sampling of the sequence. The third came from a series obtained from desaturating the primary yellow but maintaining a constant value by the addition of white. Here the series was related to a predetermined proportional grid.



The fourth was an almost complete desaturation series, (yellow de-saturating towards the grey scale) except that values lighter than the primary yellow were excluded. In this the process behind the final structure was more complex, partly because of the number of yellows (36), partly because the triangular format of the series presented a problem in stringing the series in such a way and finding an interval to the final sequence, that would give variety in value and/or saturation to each of the nine sets of four. In addition to this, every other group of four was reversed in order to obtain a counterpoint effect.

Another group of paintings evolved from a yellow to red series made up of five scales containing five steps, making 25 units in all. When initially exploring possibilities the series were numbered in different ways: spiralling in to orange (l) (the mean of the series) up and down the hue scales (2), diagonally backwards and forwards along the equal value groups (3), linking groups of equal saturation (4 & 6) and as a contour linking sets of equal proportion (5). With the latter the maximum saturation hues having been allocated proportions of 2,3,5, 8,13 from red to yellow respectively, this number series was continued with de-saturation. I used a similar sampling process to that just mentioned, no sample being used more than once.

Other simpler series were later abstracted from this main series of 25: for example a series using the yellow scale plus the remaining maximum saturation hues. Here I again used a similar sampling process and schematically the series provided the shape motif. In this case an L shape, but square shaped (3 x 3) zigzag, cross, parallel etc. were explored. Numbering possibilities depended on the complexity of the motif. It may be important to emphasise here that these were all abstracted from the main series of 25, in the configuration illustrated. One had only to change the configuration, for example to shunt the monochromatic scales to form the series into a square, or to construct the series from hexagonal samples, to be presented with a new range of possibilities through hot only abstracting similar structures but being able to recognise other patterns which might present interesting possibilities as a series. The process has a lot to do with familiarity for after a while one is able to predict to a certain extent (particular combinations and sequences have distinct moods or associations) but the excitement of exploration and discovery still remains.

I would hate to have it implied that the way that I have approached an exploration of colour is the only way. The phrase 'Colour Programming for use as an everyday language' was used in the Royal College poster for the Colour Group meeting. This phrase was abstracted from some notes Peter Lloyd Jones wrote on an exhibition of mine. What he meant by this was that such a process as the one I have described contains the important language element of repeatability. It is just a part of the language explored by Chevreul, Ostwald and Albers, to name the three who have probably been the most influential. Like any language however, it depends first on developing a fluency, but ultimately on the form it is given and on whether one has anything to say.

Colour Vision Defective Artists & Art Students

R.W. Pickford

A paper given to the Group on 3rd November 1971

HISTORICAL INTRODUCTION

Goethe first raised the problems of colour vision defects in artists in his Farbenlehre (1810). He mentions two young men who compared green with orange, red with brown, rose with pale blue and pink with the colour of the sky. He believed they had a defect of blue sensitivity, but we should now call them protanopes with confidence.

He made a landscape painting with most of the colours of an autumnal brown and a rose-coloured sky to illustrate what they saw. He also speculated about the possible colour vision defects of the painter Uccello.

In 1872 Liebreich gave an account of the changes in Turner's paintings after 1830, when he had reached the age of 55 and the crystalline lenses of his eyes became rather dim and dispersed a bluish mist over illuminated objects. He mentioned the painter Mulready, whose paintings showed a marked change towards blueness after he was about 50 years of age. Liebreich also suggested that painters who had a moderate red/green defect, and had diminished red sensitivity, might see desaturated reds as green. He instanced a painter who showed roofs as red on their sunny side but green in shadow, and oxen also as red in sunlight but green when shadowed. This was afterwards called "Liebreich's Sign" by Angelucci, in 1908, and he argued that red/green defective artists should confine themselves to white, black, yellow and blue, as indeed, some of them do.

Edridge-Green reported in 1920 on the work of a Royal Academician who was a red/green defective, but there was no sign of abnormality because his wife used to give him the correct colours to use. Raehlmann (1901) studied the influence of colour vision defects in copying paintings. Strebel (1933) mentioned a German-Polish painter whose colour vision he tested in 1916, and who was a red/green defective. This painter used largely loam-grey, sulphur-yellow and dark blue. The case of El Greco was also mentioned by Strebel, who thought this painter had a yellow/blue defect arising from pigmentation of the optical system due to age. According to Strebel, El Greco painted increasingly in yellow and blue/violet colours as he grew older.

Trevor-Roper (1916 and 1970) gave an exceptionally good account of the problems. He mentioned that Constable may have had a defect of red vision, because, in spite of the predominantly brown colours of his paintings, when challenged by Sir George Beaumont, "Do you not consider it very difficult to determine where to place your brown tree?", he replied, "Not in the least, for I never put such a thing into a picture". Trevor-Roper also gave an excellent pair of pictures illustrating the marked change from yellow towards greenish-blue in a scene painted before removal of cataracts and again afterwards.

The present writer (1964) has mentioned the work of a Canadian artist, Thoreau MacDonald, who knew he was red/green blind and whose father, also a painter, had to put these colours in for him if they were used.

RACIAL DIFFERENCES IN COLOUR VISION IN RELATION TO ART

Myers (1925) set forth the data of Rivers who had shown that many non-white peoples he tested, and, in particular, the modern Egyptians, had diminished sensitivity to blue and also to some extent to yellow, in comparison with white races. Myers dismissed the possibility that weakness of blue vision might account for the absence of a definite word for blue among many non-white peoples. A people who used the same generic name for green and blue, as in Gaelic for instance, might, however, be just as sensitive to these colours as white people who do have different words for them. In any case, the slight differences reported by Rivers would not be great enough to account for the absence of a definite name for blue. The fact that there is no decisive word for blue or brown in the Iliad does not necessarily lead us to believe that the Ancient Greeks had inferior vision to ourselves.

Myers points out that the ancient Egyptians "frequently used blue pigment on their pottery, on their stone figures, and - excentrically it is true - in colouring the surface of their reliefs and their sculptures". He adds that, "We have yet to discover the origin of the extraordinary schemes of colouration which were employed among ancient civilisations, and resulted in blue bulls, green men.and the like".

Red/green colour vision defects are less frequent in non-white than in white peoples. It is therefore less likely that an Indian, Chinese, Egyptian, Negro, American Indian or Australian artist's colouring would have been influenced by red/green colour vision defects, than that of a Caucasian artist.

Summing up, therefore, it is more likely that peculiarities ox colouring in the art of non-white and so-called primitive peoples have been due to colour vision defects than to the influence of the availability of certain pigments and by social conventions and traditions of artistic expression.

COLOUR DEFECTIVE ARTISTS TESTED BY THE WRITER

An American Artist, Mr. Donald R. Purdy, of New Haven, Conn., was kind enough to allow the writer to test him and discuss his paintings (1964). He was simple deuteranomalous, and his paintings were mainly woodland scenes. In his earliest phase he had liked dull colours, and later became attracted to what he called "Barbizon" colouring, with a predominance of browns and greys. Later, because of the interest of buyers of paintings in bright colours, he developed a more colourful art. Few of his paintings, however, include both red and green, and, if one of these colours is used much, there is a "framework" based on yellows and blues. The "Barbizon" kind of colouring remained his favourite, and he complained of the dazzling effect of red and green when they were present together. He thought that his colour vision defect, of which he was quite aware, had led him to study values of light and shade carefully in order to distinguish colours better.

The writer studied two protan artists, both of whom were amateurs (1965). The first, Dr. P. A. Ray, an Indian artist, was simple protanomalous, and the second, a pupil of his, was extreme protanomalous. Dr. Ray used saturated reds, blues, golden yellow and black very freely, and green to some extent. He liked green, but his knowledge of his defect, which he had as a student of psychology, led him to avoid greens and red/green contrasts. His pupil also used blues, yellows and browns very freely, with little red or green. He had very poor red/green discrimination and had learned for himself to avoid these colours in painting, and how to save himself from making disturbing mistakes.

Another protan artist was a professional painter, and he was a complete protanope. He had been through a school of art successfully without any defect being suspected. He gave up colour work altogether for 15 years, but said it was because black-and-white work was more paying. Later he took up painting in colour again and became a successful artist. He was very skilful, knowing that reds had a different scale of values for him than for most people, and generally used yellows, ochres, oranges, blues and black, with very little red or green. After the tests he still did not believe he was a colour vision defective, although his wife sat by him and discussed the anomaloscope settings with him as he made them, and it was clear that he had no red/ green discrimination at all.

COLOUR DEFECTIVE COLOUR WORKERS AND ART STUDENTS

Heine and Lenz (1907) compared 18 normal artists with normal people other than artists, and showed that the artists had better colour vision on the average, as did good colour workers. Pierce (1909) found that, among 54 members of the staff and students in a school of art, the best colour workers had better colour vision on the average than ordinary colour workers of equal experience. The writer (1951) showed that 16 art students with normal colour vision were more sensitive to red and green than the general population.

Art teachers who used the Ishihara Test found red/ green defective students in four schools of art for the writer and he then met the students and tested them with the Pickford-Nicolson anomaloscope. The art schools were at Croydon, Nottingham, Aberdeen and Glasgow, and nine red/green defective men students were found, three from Croydon, two from Nottingham, two from Aberdeen and two from Glasgow, where one woman had also been found in a previous research. The frequency distribution of types of defect did not differ in statistical significance from that in the population at large, and, since the schools were widely separated, there was apparently no tendency for the defectives to be found in a school of art in one place more than in another.

In another research the writer (1969) was assisted by Mr. Donald I.A. MacLeod, who tested almost the whole intake of students in a school of art in two years, namely 112 men and 111 women, with the Ishihara Test. Six men and one woman defectives were found, and these were then seen by the writer and tested with the Pickford-Nicolson anomaloscope. Again the frequencies of men and women defectives in these samples did not differ to a statistically significant extent from those in the population of the same area, and the distribution of types was the same as for the general population.

In these samples three men and one woman did not know of their defects beforehand, nine were tested by a medical officer before going to the school of art, two found their defects by tests done by friends at the art school, and two were tested first by art school teachers.

The writer's pupil, Stephen R. Cobb, found little difference between school of art students and a comparable group of non-art students.

GENERAL OBSERVATIONS

An art student who has simple deuteranomaly or protanomaly may not be much affected in his colour work, because he will have quite good hue discrimination although on a scale of hues different from the normal. All the same such people usually avoid reds and greens.

If he has extreme deuteranomaly or extreme protanomaly, his hue discrimination in the red/yellow/green and in the blue/violet/purple regions will be seriously affected, and he will have to learn to avoid noticeable errors. The darkening of reds for a protan gives some advantage since he can learn that dark colours have a good chance of being what other people call red.

In dichromatic deuteranopes and protanopes there is complete red/yellow/green and complete blue/violet/purple confusion. Art students or artists with these defects will have to learn either consciously or unconsciously, how to avoid downright errors, and may have to get their relatives or friends to help them. They will have to satisfy the colour harmony expectations of normal people within their own colour vision limits, or to use hues they do not see, under guidance, in ways other people would expect, if their art is to be acceptable. When their art is realistic confusions and mistakes of colour will have to be avoided. If it is not realistic then colour schemes satisfying their own perception will have to satisfy those of other people too.

The colour defective artist therefore has a double problem, namely to use such colours as he can correctly to produce colour schemes satisfactory to him, and also to satisfy the different colour expectations of his clients who are normal. However, some persons who have major colour vision defects may have very good artistic ability, and it seems that it would be better to help them to understand their own defects and to take advantage of guidance by others than to exclude them altogether from art.

REFERENCES

References to most of the works mentioned in this article will be found in the following:-

Myers, C.S. (1925). *An Introduction to Experimental Psychology* Camb. Univ. Press., (3rd ed. reprinted).

Pickford, R.W. (1964). *A Deuteranomalous Artist.* Brit. J. Psychol**.** 55, 469-474.

Pickford, R.W. (1965). *Two Artists with Protan Colour Vision Defects*. Brit. J. Psychol**.**, 56, 421-430.

Pickford, R.W. (1969). *The Frequency of Colour Vision Defective Students in a School of Art and the Influence of their Defects.* J. Biosocial Science, 1, 3-13.

Trevor-Roper, P.D. (1959). *The Influence of Eye Disease on Pictorial Art.* Proc. Roy. Soc. Med. (Ophthal.). 52, 721-744;

Book Reviews

Presented to the Group on 3rd November 1971

THE WORLD THROUGH BLUNTED SIGHT

by Patrick Trevor Roper: Thomas & Hudson 1970

This book is an attempt by an eye surgeon to find the effects of abnormal vision on the personality and art of man. The book is well-presented and lavishly illustrated with 29 colour photos, 78 in monochrome and with 5 line drawings.

The first chapter entitled "The Unfocused Image" deals with refractive errors and discusses the effects of myopia on writers, poets, musicians, painters and even horses. Some discussion is given as to whether the impressionist painters painted in their particular style because of their myopia. There is next an interesting section on the effects of astigmatism, and whether the elongated style of El Greco and the squashed style of Hans Holbein the Younger could be attributed to ocular astigmatism. This is now generally accepted as fallacious.

The next chapter is on "The Acceptance of Colours" and deals with artistry in birds and mammals and man. It is suggested that Goya's deafness after the age of 47 was responsible for the subsequent loss of gaiety and colour from his paintings, and that Van Gogh's later paintings reflected his depression.

Chapter three on "The Withdrawal of Colour" discusses the effect of defective colour vision on art, and enquires whether Constable, Whistler and Carriere were colour defective. Artists of course used conventions, and the "drab brown" style was one. The possible effect of cataract is also discussed and it is suggested that Turner's later rather blurred diffuse orangy-red pictures were due to cataract, or were just due to the normal course of the development of the painter's art. There is apparently no medical evidence of cataract in this case. The interesting case is quoted of a locomotive paint used by railway companies called "Stroudley's improved engine green". This was in fact a golden yellow, since the superintendent Stroudley was a colour defective.

The next chapter on "Retinal Rivalry and Unbalanced Eyes" deals with squint in art. Although we now think a squint is unsightly, in earlier societies it was a mark of godliness or even beauty.

Either consciously or unconsciously most portrait painters gave their subjects a slightly divergent squint to convey a rather spiritual expression.

Then follows a chapter on the encroachments in the field of vision, and it deals with the effects of ocular capacities, damage to the visual pathways and of schizophrenia. There is an interesting sequence of paintings of a cat by Louis Wain which develop into strange and horrific patterns as a schizophrenic illness developed.

The last chapter deals with total blindness in which is discussed various aspects of blindness, including the psychology and art of the blind, and also the recovery of sight.

There are copious notes on the text and nearly 200 references.

The book certainly contains some fascinating subject matter, is very provocative of thought, and poses many questions which one had either ignored or not really thought about very much. It is however disappointing if one hoped to find answers to the questions, or much help in formulating one's own opinions. Many topics are of course too controversial or too speculative for definite conclusions, but one would have liked to have had the advantage of the author's expert opinion expressed more often. It is true that in the preface he states that "by constantly retreating behind the theories and experiments of others, I have tried to let these speak for themselves and only rarely presumed myself to arbitrate". Such abdication of responsibility on the part of the author to state his views and convictions naturally detracts from the value and authority of the book. Nevertheless it will I hope inspire others to pursue these fascinating questions further.

C. A. Padgham 17.11.71

TWO BOOKS FROM PAKISTAN

Hamdard Pharmacopoeia of Eastern Medicine.

The Times Press, Karachi, 1969 pp. 500 + xiv.

Ibn al-Haitham. Proceedings of the celebration of the 1000th anniversary.

The Times Press, Karachi, 1970 bp. 346

These books were sent to me as Vice Chairman of the Colour Group, following a message of goodwill which I sent to the Hamdard National Foundation in Karachi on behalf of the Group. We were Wishing them well in a celebration of the millenary (•within a few years) of the birth of Ibn al-Haitham, or Alhazen, the Arab scientist from Basra whose writings had a great influence on the development of mathematics and optics in the middle ages, Snd which we can still read with profit. The celebration took place in Pakistan in November 1969, and the proceedings were received here in 1971; they were edited by Hakim Mohammed Said, President of the Hamdard National Foundation, a state-sponsored concern promoting the study of Eastern medicine.

Somewhat earlier a related organisation, the Institute of Hsalth and Tibbi research, published the Pharmacopoeia mentioned above, also edited by Hakim Mohammed Said. This impressive book was also received; it is essentially a Herbal, based on the great mass of Greco-Arab medical information available in the Eastern world, and contains some hundreds of recipes for external and internal application in most human diseases. Many recipes have several very different applications, and most of them have many constituents (up to 150 in one case). This main section of the book is preceded by a survey of many hundreds of drugs used, particularly vegetable, but also animal and mineral ones. It is followed by a section on preparative techniques, and a codex which gives detailed illustrations of about 100 plants, and botanical information on their occurrence and use. The book ends with some pharmacological and chemical studies of medical plants and their active ingredients.

The Western reader can easily understand the use of vegetable drugs, but it is difficult to appreciate the use of parts of mammals, birds, reptiles and insects, and still more so the many mineral substances, including powdered gemstones and toxic metallic compounds, even if taken internally in small proportions only. The codification and study of these remedies are to be welcomed, for they represent an important part of ancient Eastern culture, but it seems doubtful whether the use of these recipes could compete for long with Western pharmacology, with its great advances and spectacular achievements during this century.

The Alhazen celebrations recorded in the second book were also a demonstration of Muslim enthusiasms for the achievements of early Arab culture, personified not only by Alhazen, but by Geber, Avicenna and many known in the West, lived from 965 to 1039, the last part in Cairo where he passed on his knowledge to students as well as teaching calligraphy. A temporary retirement from public life followed his inevitable failure to carry out a promise to the Caliph al-Hakim to dam the Nile for irrigation purposes at Aswan, where this has only recently been accomplished. He emerged when the Caliph died, but not much more seems to be known about his life. His many manuscripts, often derived from the rewriting of Greek treatises as his own ideas developed, form an impressive memorial. They are to be found in several libraries as originals or copies, especially in Cairo and Istanbul. The work of most interest to medieval philosophers and modern scientists is the Kitab ul Manazir, now known as 'Treasury of Optics', published in a Latin translation in Basel in 1572.

The published Proceedings begin with accounts of the meetings at Karachi, Rawalpindi, Lahore, Peshawar and Dacca. Speeches were made on the life and work of Alhazen, his philosophy and standing in the scientific world both ancient and modern, and there were some longer expositions of parts of his work. The following section gives the text of all the messages sent to the conference by individuals and societies from most parts of the world.

The book then provides valuable texts of seven of Alhazen's shorter treatises on light and geometry, translated from the Arabic via Urdu, though one on light is repeated in a different translation via German. Some of these make difficult, but worthwhile reading, and it is a matter of regret that so little of Alhazen's output is available to the West in authentic translations. His achievements in the theory of light (including 'Alhazen's problem' to determine the point of reflection of a light ray from a spherical surface, such that the ray proceeds to a given point), in the anatomical and functional description of the eye, and in the astronomical and geometrical discussions (including the determination of the side of a regular heptagon in a circle), as well as the writings on logic and philosophy, assure his eminence in the history of science, though perhaps some of his ideas have been over-enthusiastically assessed in the light of later knowledge.

His contributions in the field of colour are small. Perhaps the most definite statement attributed to him is that the blue of the sky is a mixture of the darkness of the sky and the sunlight reflected from dust particles in the air; but this discovery, according to another writer in the book, comes from a ninth century Arab, Al-Kindi.

More general articles on Alhazen and commentaries on particular parts of his work, with bibliographies, end this book devoted to the 'Father of Optics'. It is very largely in English, with many quotations in Arabic. It is well produced, and reflects great credit on Hakim Mohammed Said and his colleagues who organised the celebrations.

S.T. Henderson

The Newton lecture

In 1970, when the Committee of the Colour Group invited Dr. Deane B. Judd to deliver the next Newton Lecture, it was suggested that he might like to link it with the AIC meeting to be held in York in 1973. In accepting the invitation, Dr. Judd welcomed this suggestion, as he had not planned to travel abroad during 1972.

He continued:

"My topic will most likely be some aspect of the problem of sampling the pigment-color solid with the closest possible approach to perceptually uniform spacing. The OSA Committee on Uniform Color Scales has been studying this problem under my chairmanship since 1948, and the study is nearing completion."

"A part of the support that we have received for this project comes from those whose main interest is in color coordination or color harmony. It has long been recognized that the effectiveness of a design depends importantly on the perceptual sizes of the differences between the colors making up the design. Perhaps by 1973 I will have developed some' worthwhile material to present along this line." *Letter of 19 February 1971*

Later in 1971, when it appeared that Dr. Judd's illness was making it difficult for him to keep to his programme of work, we made some further suggestions, so that he might not feel in any way burdened by a commitment.

Dr. Judd replied:

"It strikes me as very courteous of the Colour Group to offer to hold a Group meeting in Washington, D. C. so as to minimize the effort required of me to deliver the Newton Lecture. I have delayed answering your letter until it has become clear that I can put up a fairly protracted fight against the cancer of the pancreas threatening to reduce drastically my life expectancy. I prefer therefore that the original plan of presenting the Lecture as a part of the meeting in York be adhered to. I will make every effort to prepare a creditable Newton Lecture on the subject, Size Perception of Color Differences, and to present it at that time. I have good hope that I can fulfill this commitment."

". . . . I have near to completion the written version of a talk, Color in Visual Signaling, that I gave 28 May 1971 before a meeting of the Armed Forces - NHC Vision Committee. It will be offered for inclusion in the minutes of that Committee, but it will not be available in the open literature. If at any time in the future it should appear that I will be unable to prepare a suitable lecture on Size Perception of Color Differences, I might rewrite this material as the Newton Lecture, although it is somewhat more of engineering interest, and less of scientific interest, than I think befits a' Newton Lecture. This material might be presented for me at York, or elsewhere, in England during the summer of 1973. Please let me know if you consider this procedure suitable as a stopgap measure." (Letter of 6 January 1972)

Dr. Judd sent the script bf this talk, which he had corrected by hand, if not completely rewritten as he might have wished. Although his good hope sustained him througn that summer, Dr. Judd was not able to continue his work on colour differences. He died on 15 October 1972.

Owing to his forethought in providing a stopgap, we were able to present a Newton Lecture in accordance with his wishes. The paper on Color in Visual Signalling was put to the Group on 9 May 1973; it has subsequently been published, along with the rest of the Vision Committee symposium, in the book *Color Vision* (National Academy of Sciences, Washington, D. C, 1973).

The Newton Medal, engraved with the name of Deane B. Judd, was presented to Mrs. Judd on 4 July 1973 at the York meeting, following tributes from Dorothy Nickerson and David Wright.

Throughout his career in the field of colour studies, Deane Judd exemplified the process of applying mathematical and numerical methods to problems that had previously lacked such applications - a process that was initiated in this field by Isaac Newton. Judd's work puts him worthily in the company of his forerunner. May his spirit continue to enlighten and encourage us.

R.W.B

The following five papers were presented at the Group's Symposium on 'Standard Conditions for Viewing' held at the City University on 5th April 1972.
Papers were also presented fcy F. Malkin and K. McLaren.

Viewing of Artwork & Proofs

Leslie Hubble

a - b = see

This may seem an odd subtitle, but it epitomises a most remarkable and valuable British achievement in standardisation, that is, B.S. 950 (Artificial Daylight for the assessment of colour) which is in two parts:

Part 1. 1967 (Artificial daylight for colour matching and appraisal)

Part 2. 1968 (Viewing conditions for the graphic arts industry)

The implementation of B.S.950 in its two parts has already had a profoundly beneficial effect upon the productivity of the British colour using industry and the graphic arts, and its influence is now spreading to many other countries since it is based upon international standards of daylight and does not contravene any other national standards, of which there are in fact none truly comparable. The true value of such standards lies in their adoption and the object of this paper is to appraise all those in the graphic arts industry with a brief summary of the work that has gone into drafting and implementation of these standards and the benefits to be derived from the standardisation of visual colour appraisal.

The equation

The equation **a - b = see** is an oversimplification of the phenomenon of human colour vision and states that if (b) the absorption characteristics of the pigmentation be subtracted from (a) the spectrum of radiated power of the light source, what is left will stimulate the sensation of a particular colour in the mind of the average human observer. However, amend either (a) or (b) or the controlled viewing conditions, such as background colour, and the resultant colour sensation will inevitably change. Consider therefore the astounding fact that until the implementation of B.S.950 in its two parts, neither (a) in the equation **a - b = see** nor the viewing conditions have ever been constants. It follows therefore that throughout colour using industries, trades, professions and the whole of the graphic arts, no matter what effort was put into repeating (b) accurately, the resultant sensation of colour remained indefinite.

The equation **a - b = see** cannot better be demonstrated than by a photographic colour transparency which has to be viewed against a luminous background and will visibly change as it is moved from one aspect to another, be it white cloud, blue sky, red brick, green field and so on. Thus a transparency viewed under anything other than standardised viewing conditions is virtually meaningless colour-wise. Two almost incredible facts emerge from this:

1. There has never before the introduction and implementation of B.S.950 Pt. 2 been any standard for the viewing of transparencies.

2. As the transparency is the one and only visual link between subject matter and its final reproduction in print, the success or otherwise of the printer has been controversial and unpredictable in regard to colour.

The B.S.950 committee was reconstituted in 1960. It was just ten years before it became possible to purchase a standard transparency viewer (other than a small number of prototype models), with the introduction of the VeriVide Printers' Range of apparatus for the visual assessment of colour.

In search of (a)

By the mid 1950s the use of colour in consumer goods, print and most other products had grown to such an extent that industrial colour control had become a major function of productivity, and the need for standardisation of colour rendering had assumed serious, and, in certain fields such as dyeing and colour printing, vital proportions. For instance, take a range of garments for a mail order firm. Firstly the colours have to be chosen, and progressively maintained by the dyer. They then have to be accurately reproduced by the printer in the catalogue. Variation in the one and deviation in the other inevitably lead to heavy trading losses.

The situation was much aggravated by the increased use of fluorescent dyes, inks and brightening agents. The first attempt at standardisation was when, in 1931, the Commission Internationale de l'Eclairage (C. I.E.) established an 'Artificial Daylight' in the form of an actual illuminant consisting of light from a tungsten filament lamp passing through two filters, solutions of salts of copper (blue) and cobalt (pink). The resultant colour rendering was similar to that vaguely known as North sky daylight. It was designated **Standard Illuminant C**. Quite apart from its instability, this subtraction from an already inefficient light source rendered it impractical for industrial colour control.

In 1941, the spectrum radiated power of Illuminant C was recorded as the British Standard for colour matching lamps when these became technically possible. Various methods and combinations of illuminants were subsequently used to simulate Illuminant C, the most successful being a mixture of special light-blue fluorescent and tungsten filament lamps, as used in the now obsolete Siemens Ediswan colour matching cabinet and the current VeriVide LAB type C cabinet, supplied to certain American owned companies operating in the U.K. and their suppliers.

The absence of ultra violet radiation rendered Illuminant C unsuitable even as a basis of a new British Standard, so when in 1960 the B.S.I. Technical Committee LGE/9 was reconstituted, an entirely new approach had to be adopted.

Starting from scratch

Briefly, it was argued that the human visual mechanism has evolved under the environmental stimulus of daylight, and since daylight is constantly changing within certain limits, the mean or average of all normal phases of daylight should be the obvious choice for the new British Standard.

Very little reliable data regarding the spectral distribution of daylight had been recorded at that time and the first task was to take a series of readings. This took nearly two years but by early 1963 a large volume of data from three independent laboratories in England became available to the B.S.I, technical committee. Concurrently, similar readings were being taken in America and Canada and by fortunate chance, the CLE. 1.063 convention in Vienna was shortly to be held enabling all five sets of readings, amounting to some 640 in total, to be collated.

From this mass of accurate data, a series of spectral curves were evolved, each typical of a phase of daylight and distinguished by their correlated colour temperature: and designated as Standards of preferred daylight D - followed by its colour temperature, the mean being in the order of D6500, similar to the old illuminant C but with certain significant differences, the most important being the inclusion of the ultra violet component of daylight in order to activate the now very important fluorescent content in modern dyestuffs, pigments and brighteners.

D6500 was thus chosen as the spectrum of radiated power for BS.950 Pt.l. (Artificial Daylight for colour matching and colour appraisal) and is the standard used in all cases of industrial colour control, such as the printers' machine room.

The Standard of preferred daylight for the graphic arts

B.S.950 Pt.2. (Viewing conditions for the graphic arts industry), published a year later than Pt.l, has for its standard D5000 - a much warmer phase of daylight than D6500 - and the obvious question is "Why two standards?" Unlike straightforward colour matching, photo-reproduction involves the use of a colour transparency as a frequently employed link from subiect to print. Thus the B.S.I, technical sub-committee PHC/14, responsible for Ft.2, was faced with problems which do not apply to Pt.l. Transparencies can be manufactured and processed to suit a wide Variety of illuminants both for exposure, projection or surface luminance. It is obvious however that manufacturers would wish to avoid such diversity. Furthermore, we in Britain could not establish a standard arbitrarily owing to the International character of the maior manufacturers of colour film.

World film makers decided they could not accept D6500, many favouring 3500K, which is that of a tungsten filament projector lamp. So bearing in mind that transrarenci.es would have to be compared with reflectance proofs under controlled conditions and that better colour discrimination is obtained at D6500[1]. D5000 was the compromise ultimately chosen internationally, and B.S.950 Pt.2. is based on this spectrum of radiated power.

As recently as August 1971 the ISO issued the following:
the illumination for comparison viewing of photographic colour transparencies with reflection colour prints - in controlled surround - should be CIE illuminant D5000, representing a phase of daylight with correlated colour temperature o 5000 K.

The words 'in controlled surround[1] were inserted at the behest of France and they lead the way to the adoption of B.S.950 in its entirety, not only in the Common Market but throughout the World, for B.S. 950 not only specifies 'controlled surround' but covers the following:

1. Spectral power distributions of D6500 and D5000 in l0nm bands.
2. Spectral distribution of both illuminants in the Crawford six visual band system and two ultra violet bands, with tolerances.
3. The chromaticity coordinates with tolerances.
4. Levels of illumination and luminance with tolerances.
5. Background colour and brightness by reference to the I.E.S. Code.
6. Warning against glare and extraneous light and environmental guidance.
7. Warning against specular reflections.
8. Provision for testing for metamerism.
9. The recording of hours during which apparatus may be expected to conform.

The Total Implementation of BS950, Pts 1 & 2 for the Graphic Arts Industry

A study of the Graphic reproduction industry reveals five well defined stages in reproducing subject matter in print.

1. The illumination of the subject.
   This is largely dictated by the type of film but care must be exercised that

[1] Of the CIE 1931 Sources A, B & C, having correlated CT.s of 2850, 4880 & 6740 K respectively, C was chosen and was always preferred, as the standard for colour matching and appraisal. Standards in America have hitherto been 6800 and 7400, the latter for cotton grading and other 'white' industries.

extra lighting used for modeling, etc. has similar colour rendering properties.

2. The making of the colour transparency and its approval as a true reproduction colourwise.
When the transparency is submitted for approval it must henceforth be illuminated by a British standard viewer and until such times as all those involved have such viewers, it is essential for printer and studio to have portable viewers, as from now on the transparency and viewer are components of a luminous reproduction. Furthermore the original subiect matter must also be illuminated by D5000 if a true comparison is to be made. A side-by-side proofing cabinet would give optimum conditions for such comparisons. Uncontrolled comparisons are meaningless.

3 The making of plates and cylinders and passing of repro proofs against transparency.
The graphic reproduction trade house or department has to be satisfied that his plates are capable of producing satisfactory colour reproductions and to prescribe the inks. This must done in a side-by-proofing cabinet giving comparable luminance.

At this stage there is another diversity to be taken into account, that is the stock on which the printing is to be done, Quite apart from surface finishes, paper manufacturers use a number of fluorescent brighteners which, the inks being transparent, can make a significant difference to rendering.

This can best be guarded against by examining the stock first by D6500 and then under ultra violet radiation. For this, a Laboratory colour matching cabinet is available giving D6500,.three levels of ultra violet radiation to reveal the strength and nature of the fluorescence, if any, and alternative filament lighting as test for metamerism. For those not fully acquainted with the phenomenon of metamerism, it should be explained that metamers are different spectral energy distributions capable of evoking identical colour sensations in foveal vision. A metameric match therefore is visual equivalence of physically different stimuli. In the equation **a - b = see**, **b1**in the case of a metameric match, is equated to **b2** which though having different absorption characteristics nonetheless produces the same colour sensation. But if (a), the spectrum of radiated power of the light source, be changed, then **b2** will produce a different colour sensation from **b1**. To reveal metamerism it is advisable to use a light source having a spectral distribution widely different from that under which the match is being judged, which is why the filament lamp is recommended for this purpose in B.S.950.

4. Proofing or obtaining pass sheet against repro by printer.
Before printing can begin the printer must ensure that the colour balances are correct by comparing his proof or pass sheet with the repro. proof.

This can only be done in a side-by-side proofing cabinet where the repro. , pass sheet and, where necessary, the transparency can be seen simultaneously under the controlled conditions interpreting B.S. 950 Pt.2. Cabinets are available with reflectance decks 30" x 44" and 40" x 50" and even larger if necessary.

These reflectance decks, known as C.I.P.D.s (concave ironclad proofing decks) are concave to eliminate specular reflection, to maintain, as far as possible, the same luminance from top to bottom and to present the prints more or less at right angles to the line of vision. Ironclad, to permit the use of magnets to support print in any convenient position.

5. Machine room colour control against printers pass sheet. The proof and then pass sheet having been found satisfactory it then becomes the criterion of colour control in the machine room. This last stage is a matter of simple colour matching and therefore comes under B.S.950 Pt.l. and the colour control cabinet, having a full width C.I.P.D. is normally supplied with D6500 (Artificial Daylight) lamps.

Conclusion

From the foregoing guide lines there has emerged a range of equipment expressly designed to meet the specific requirements of colour using industries and the graphic arts in particular.

Though this range of apparatus represents years of research into the needs of colour using industry, it would be of no avail had it not been for the technical ability and willingness of the lamp industry to develop and market lamps to conform to D6500 and D5000 within the tolerances set out in B.S.950. Both the Thorn 'Artificial Daylight' (D6500) and the Philips Graphic A47 (D5000) must be unique in their advanced technology and stringent quality control. No paper on this subject should be without a tribute to these lamp manufacturers for doing something very difficult and costly to develop, expressly to assist the productivity of many branches of the colour using industry.

Finally, there are many highly sophisticated and costly pieces of equipment which undoubtedly assist the printer and other colourists to get results more quickly, more consistently and at less cost, but in the end the question remains 'does it match?' to which only the average acceptably normal human visual mechanism can give the answer and only then when the means of illumination and the viewing conditions conforms appropriately to B.S. 950 Parts 1 & 2.

The Reliability of Visual Decision in the Hosiery Industry

S.M. Jaeckel

1. INTRODUCTION

Three investigations were described. The first concerned pass-fail decisions in a quality control scheme (1), the I.W.S. (International Wool Secretariat) Woolmark light-fastness specification; the second the assessment and grading of unwanted barriness, especially in false-twist nylon knitted fabric, by means of the HATHA Barriness Scale (2); the third the variations in severity and consistency amongst industrial assessors experienced in making pass-fail decisions about repeat dyeings of knitted fabric in many different colours and their probability of making wrong decisions. The third topic formed part of a much larger investigation (3) still In progress that involved correlation of visual and instrumental pass-fail decisions concerning colour, which extended well beyond the scope of the symposium. All three investigations involved teamwork by many HATHA staff members. The third would have been impossible without the help of technical staff of many textile dyeing and knitting firms and their customers.

2. A STATISTICAL EXAMINATION OF VARIATIONS IN ASSESSMENT OF LIGHT-FASTNESS ACCORDING TO THE WOOLMARK SPECIFICATION

2.1. The Problem

The Woolmark quality control scheme specifies minimum light-fastness ratings (4). Information was required on the reliability of the assessments. How likely was it that a sample that should be passed was failed, or vice versa? What was the effect on reliability of altering the number of assessors?

2.2. The Procedure

Test patterns and light-fastness standards are exposed to a specified xenon lamp until two exposed areas of the minimum acceptable standard show different defined degrees of contrast (Grey scale 4 and 3 (5)) to an unexposed area, the light-fastness standard similar in contrast to a test pattern is found by inspection under standard conditions. Half-grade assessments, falling between two standards, are possible. The mean of the assessments at the two degrees of contrast indicates whether the light-fastness of the test pattern is at or above (better than) or below the specified minimum.

2.3. The Data

373 assessments by each of three assessors of perceptible shade changes in terms of light-fastness grades showed the following distribution:

Assessment Range of Three Light-fastness Grades

Grade	0	½	1	1 ½
Observed (%)	20	61	18	1
Theoretical (%)	23	58	19	0

The mean range was 0.49 light-fastness grades, implying *A* standard deviation of 0.29, the theoretical for the associated normal distribution agreeing well with the observed.

2.4. **The Analysis**

The probability of a fade being rated half a grade too low equals that for a rating half a grade too high and, with that standard deviation, is 1 in 5, 1 in 14, and 1 in 33 with one, three and five assessors, i.e. 20%, 7%, and 3% respectively. Assessments at the two degrees of fade are twice the number of assessors, and each of the probabilities that a test pattern is passed or failed wrongly by rating half a grade too high or low respectively is 1 in 9, 1 in 50, and 1 in 200 with one, three and five assessors, i.e. 11%, 2% and ¼ % respectively.

The probability of error with a boarderline pattern in the unlikely event of three assessors differing systematcally by half a grade from the correct in rating light-fastness, i. e. too lenient or too severe, is 1 in 17, i. e. half that for one correct assessor with standard deviation 0.2%, and better therefore.

2.5. Conclusion

On the basis of the above within-laboratory findings, the use of three assessors, even if one of them is indifferent, is to be preferred to use of one assessor on the grounds of accuracy and to use of five assessors, except in special cases, on the grounds of productivity, economy and diminishing returns.

3. THE ASSESSMENT OF BARRINESS WITH THE HATRA BARRI-NESS SCALE AND THE EFFECT OF COMPARING UNEQUAL AREAS

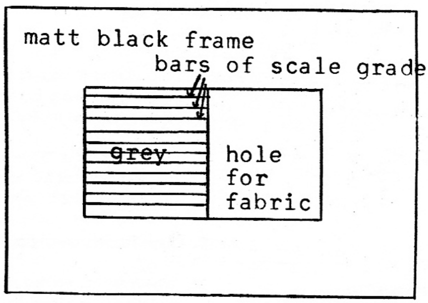
3.1. The Problem

Regularly repeating stripiness in fabrics or barriness can occur which is commercially undesirable. There are a variety of causes. If it is present, agreement is required as to whether it is or is not commercially acceptable. The prevailing situation in 1966 is illustrated by the results obtained from six commercial assessors for 45 fabrics deliberately knitted at HATRA to provide a wide spectrum of potential for barriness. When asked whether each fabric in turn was **A** bar free, **B** barry but commercially acceptable, or **C** barry but commercially unacceptable, 38% of fabrics were accepted by all six assessors (**A** or **B**), but the remaining 62% were disputed (**B** or **C**, or **A** or **B** or **C**): none were judged unanimously to be unacceptable. A means of numerical grading was desirable to provide a basis for quality control systems and a greater measure of industrial agreement.

3.2. The Solution

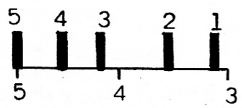
After many attempts involving various types of fabric and yarn and also printing processes, a photographically prepared barriness scale was developed at HATRA and introduced in 1967. This consists of five grades and makes it possible to grade fabrics easily, reliably, and quickly into any one of nine half-grades, from bar-free perfection (Grade 5) to very bad bars (Grade 1). The dimensions of a scale grade are indicated diagramatically.

HATRA Barriness Scale Grade



(2mm = 1cm) (1/5th actual size)

The bar-background contrasts of Barriness scale grades 5 to 1 are related to BS Grey Scale spacings as shownbelow -



since it was found that barriness objectively equivalent to Grade 1 or Grade 2 of the BS Grey Scale was felt to be so bad from a practical point of view that neither these grades nor the distinction between them were of interest for barry fabrics.

3.3. The Procedure

The following is a reproduction of the printed matter on the back of each scale grade.

READ CAREFULLY DO NOT TOUCH GREY CARDS

HATRA BARRINESS SCALE

(for grading numerically fabrics of all colours with bars of all widths and contrasts)

The Scale consists of five numbered black frames, in each a grey card and a hole of equal size. Grade 5 is bar-free, Grades 4 to 1 are progressively more barry.

Instructions Ratings may vary with conditions of use. What fellows gives maximum agreement between observers. If other conditions are used, agree, specify, and record these.

1. Light of at least 75 lumens/sq ft from "Artificial Day-light" fluorescent tubes should fall on the fabric at an angle of 45°. (Rough guide: 2 ft from 1, or 3½ ft from 2, such 65/80 W tubes)

2. View fabric perpendicularly from 1 ft (30 cm) away.

3. Rotate fabric, selling side uppermost, to find, and record, orientation of greatest apparent barriness.

4. Put scale frames in turn on fabric, with bars on card and fabric parallel, **and** compare bar/background contrasts.

5. The barriness rating of the fabric is the number of the grade with similar bar/background contrast, or the imaginary contrast mid-way between two scale grades, e.g. 3—4, if this is judged more like the fabric contrast Possible ratings: 5(no bars), 4—5,4,3—4,3,2—3, 2,1—2,1.

6. Place together fabrics identically rated: errors become prominent and fabrics differing in bar/background contrast from most in the group can be compared with adjacent groups and rechecked against the scale.

7. Store scale away from light.

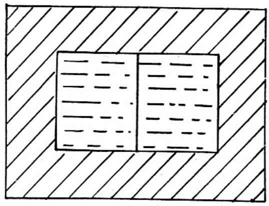
Interpretation No single rating, like 3, or 3—4, is an always valid limit of fabric suitability: such limits will vary with fabric construction, colour, end-use, end-use orientation, area visible in end-use, viewing conditions, and illumination. More barry (lower rating) fabrics may be acceptable for small end-use areas, particularly if not often viewed obliquely.

THE HOSIERY & ALLIED TRADES RESEARCH ASSOCIATION

3.4. The Data

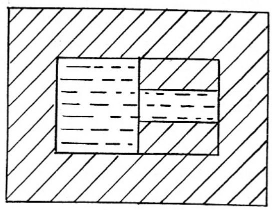
To validate the HATRA Barriness Scale, reproducibility and reliability ofassessments were investigated before the scale was made available generally. Five HATRA observers assessed nine fabrics using three different methods, four times by each method, i.e. twice with one scale, twice with anotherscale. This design, with a total of 540 assessments, permitted calculations about variations between fabrics, observers, methods, and replicate assessments. The fabrics included white, mustard, and various depths and hues of blue and green. The bar repeats ranged from 1.5 to 12 mm, and the ratings obtained from 1 to 4-5.

The methods differed in the areas available for cornparison, as illustrated.

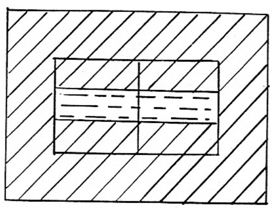


A

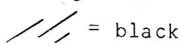
A is the standard method, **B** uses one-third of the area of fabric (unequal grey card and fabric areas), **C** uses one-third of the standard area both for grey card and for fabric.



B



C



3.5. The Analysis

The means of the ratings for the three methods were A 2.6, B 2.8, C 2.6. There was no difference between the two equal-area methods A and C. With Method B the averages of 20 assessments on each fabric were half a grade higher for four of the nine fabrics. Therefore sometimes too lenient, too high a rating, by one half grade, may be given if fabric areas very much smaller than scale-grade areas are assessed with the whole of the scale-grade area. Method B should be avoided and, when necessary, Method C should be used.

The standard deviation based on the range of duplicates is a measure of the consistency and repeatability of assessments by any one observer under the same conditions. It ranged from 0.08 to 0.20 for the five observers for Method A, with a mean of 0.15, so any one observer is always likely to be within half a grade of his own average assessment for any one fabric (95% confidence limits + 0.3). The corresponding standard deviation based on the range of observers is a measure of the agreement between observers. For the nine fabrics it ranged from 0.0 to 0.5 with a mean of

0.35. The reproducibility of HATHA Barriness Scale ratings is at least of the same order as that of British Standard Grey Scale ratings. There can be systematic differences between observers. At worst their average criteria of rating differed by half a grade. Accuracy of assessment increases with number of observers making one assessment each, the 95% confidence limits of the mean for 1, 2, 3 and 5 being + 0.69, + 0.49, + 0.40, + 0.31 barriness grades. The percentage of cases found out of 360 are compared with the theoretical for agreement of two observers -

Rating difference	0	½	1	1½
Experimental	41	40	17	2
Calculated	37	48	13	2

3.6. Conclusion

Any two observers are likely to agree completely or within half a grade on the rating of fabrics in 81% of all cases. For any group of fabrics with the same true rating, any observer with a standard deviation of 0.35 about the true mean for the group is likely to rate 52% of the fabrics in the group correctly, 24% of them high and 24% of them low. Therefore, for the fabric group for which the true rating is the agreed borderline one, he is likely to accept 76% of the borderline group (52% rated correctly and 24% rated too high) and reject 24% of them (because he will rate these too low on one assessment). In this general case, he will also accept 24% of the group truly half a grade below the borderline (because he rates these too high) but he will reject 76% of this group.

4. VARIATIONS OF ASSESSORS IN MAKING PASS-FAIL DECISIONS ON COLOUR-MATCH ACCEPTABILITY (3)

4.1. Patterns

Three groups of knitted false-twist nylon patterns were studied. There were 200 plain-knit ones in red, blue and yellow dyed at HATRA, 265 single pique, skinny rib or Miralon ones (different knitted structures or yarns) in pink, pale blue, light fuchsia, deep fuchsia, and navy from industry, and 560 plain-knit and ripple (a different knitted structure) ones in red and blue at each of two depths and in yellow, green, and brown dyed at HATRA. Most attention was devoted to those patterns in the three groups accepted on 5% to 95% of assessment occasions, referred to as HATRA-185, Industrial-234 (or Ind.-234) and HATRA-435. There were standard patterns for comparison, three for the first group (one for each colour), ten for the second group (one for each colour in each structure), thirteen for the third group (one for each colour at each concentration and in each structure).

4.2. The Assessors

For the first group, in 1967, there were 32 from 10 firms, 13 of whom made repeat assessments. For the industrial group, in 969, there were 24 assessors from 7 firms (8 from, and average or'standard' for, the 32 in 5 of the 10 firms, 10 from the supplying firm, and 6 from the buying retail organisation) all of whom made repeat assessments. For the third group, in 1970 and 1971, there were also 24 assessors, all of whom made repeat assessments, from 12 firms (6 each 'standard' knitters and dyers, 'other' knitters and dyers, suppliers - of the 234 - and buyers; 14 had also assessed the industrial group and 5 of these the first group; 3 had also assessed the first group but not the industrial group).

4.3. The Assessments

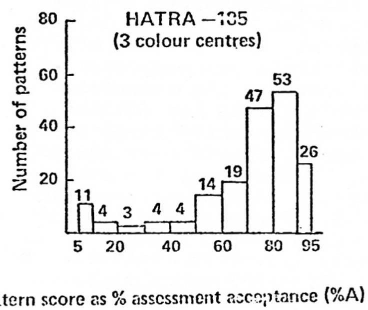
The assessors were asked to compare each pattern in turn with the relevant standard pattern and to answer with YES or NO the question "Would you accept this pattern as a commercial match to this standard pattern?" All patterns were 80 mm wide, the industrial ones were square, the others 95mm long. Average viewing distances of 53cm correspond to 8° to 1O^0 subtended at the eye. The assessors' customary viewing conditions varied and included daylight as well as BS950, 1Q67, Part I fluorescent tubes. For the HATRA-435 group, 7 assessors used North daylight (2 of whom held the patterns) and 17 Verivide cabinets (7 of whom held the patterns), so 12 each had oblique incidence and normal viewing (5 daylight flat, 7 Verivide held) and the reverse situation, normal incidence and oblique viewing.

4.4. The Acceptability of Patterns

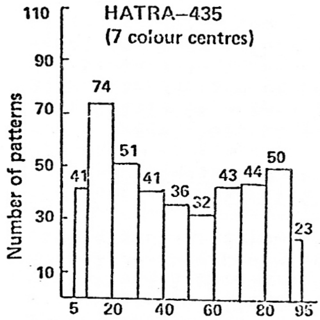
The histograms illustrate the distributions found, based on 100% A equalling 32, 48 and 48 'YES' replies per pattern respectively for the HATRA-185, Ind.-234 and HATRA-435 groups. Mean % A values were 70.8, 41.2 and 45.9.

4.5. The Severity of Assessors

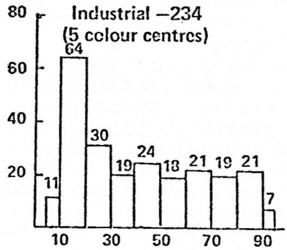
This was determined in slightly different ways for the different pattern groups. Thus for the Ind.-234 group, patterns were grouped into acceptable heptiles: the second heptile contained all patterns passed 7 to 13 times out of 48, the fourth heptile all patterns passed 21 to 27 times out of 48, etc.



For each assessor, the patterns in each heptile were classified into three groups according to the assessor's duplicate decisions: ✓✓2YES, ✗✗ 2 NO, ✓✗1 YES, 1 NO. The heptile was found in which, or at the boundary of which the assessor switched form more ✗✗ to more ✓✓ decisions. This was defined as the assessor 's severity level.

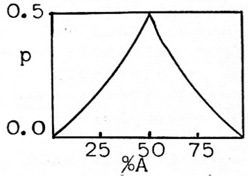


Severity variations were found not only between firms, but also within each of several firms. One and the same firm for this Ind.-234 group contained both lenient (14% severity) and severe (86% severity) experienced assessors, i.e. their "switch-over" level from failing to passing was for patterns accepted by more than 14% or more than 86% respectively on all the assessments. That is, different assessors tend to be systematically different in severity. Whereas the severity range for the Ind.-234 group was 72%, that for the HATRA-435 group was 10D%, i.e. from assessors tending to accept to assessors tending to reject everything. The different sub-populations of assessors - "standards", suppliers, buyers - differed markedly in mean severity for one, but not for another, group of patterns. Of the 14 assessors common to the HATRA-435 and Industrial-234 groups, some were similar in severity on the respective %A scales for the two groups, some were more severe for the one group and some for the other, so at least some of the assessors changed their severity for different pattern groups. Those that changed most and mainly in one direction all assessed in daylight and it is just possible, but by no means certain, that this viewing detail may be relevant, but other factors are involved as well and the data may not permit statistical proof of the suggestion.



4.6. The Consistency of Assessors

A completely consistent assessor would pass half and fail half the patterns at his severity level: his inconsistency or proportion, p, of wrong decisions would be 0.5. He would pass all more acceptable patterns and fail all less acceptable patterns: his p would be 0.0. There are no such assessors. By pooling pattern groups equidistant on pass and fail sides of the severity level, p can be found as the proportion of fail and pass decisions, i.e. inconsistent with the severity level, to total decisions. This can be done for different distances from the severity level. This pooling can be extended to all assessors regardless of their severity levels, on the basis of equal distances from the severity levels, whatever these are, and a mean p or inconsistency for all assessors obtained. The mean curve of p against *%A* is shown in both directions for an assessor of average severity, i.e. centred on 50%A. Individual curves are broader or narrower, but of similar shape, ending in a cusp. Individual values of p found 20%A away from the severity level ranged from 0.09 (9% inconsistent decisions for such patterns) to 0.34 with an average of 0.22. the values further away from the severity levels were of course smaller. There was no correlation between severity and inconsistency, and, in contrast to severity changes, consistency changes for assessors common to two pattern groups were very slight.



4.7. The Probability of Wrong Visual "Pass-Fail" Decisions

Unlike inconsistency, which is the proportion p, the actual errors made depend very much on the acceptability distribution for the particular patterns. The product of inconsistency and number of patterns, in the acceptability group a particular distance from the severity level of the assessor, summed over all the groups, indicates his errors relative to his own severity level. These ranged from 6% for an assessor with 10%A level, i.e. very lenient, for the HATRA-185 group containing very few patterns in that acceptability region to 30% for the same group for an assessor with 80%A level, i.e. very severe, there being a cluster of patterns in this region. The median - and mode - errors found for the three groups for assessors ranging in severity from 10%A to 90% were 19% wrong decisions.

If the firm's aim severity differs from the assessor's severity level, then for the acceptability groups between the two severities what is wrong for the assessor is right for his firm and in these the remainder of the product defined above must be substituted for the product in the sum. This was done for aim severities of 40% to 70%, a range relevant in the light of the potential need for tolerance-limit variation for different colours, end uses, fabrics, structures, and customers on the one hand and different balances aimed at between cost of production with tighter limits (higher severities) and cost of complaints with wider limits (lower severities) on the other hand. The lowest errors were often found where assessor and firm's aim severities coincided with one another in a region away from the mean acceptability of the patterns: 8% was found, but 18% was more typical both for this and for assessors with the aim severity near the mean acceptability. The highest errors exceeded 50% and, except in the HATRA-185 group, were associated with lenient (10%A) assessors when the firm desired a critical standard (70%A). The data provide a basis for comparison with instrumental decisions, but this is beyond the scope of this symposium. Further refinements in analysis are under consideration: average, not individual, inconsistencies were used in the above calculations.

4.8. Conclusions

Assessors in one firm can differ very widely in severity from one another, from the average for the firm, from the firm's aim, and, sometimes for different pattern groups at different times. The mean differences between firms are often less. Assessors also differ in consistency, but this is less than and not related to the severity variation. Percentages of wrong decisions depend on pattern acceptability distribution as well as on actual and aim severities. They can range from better than 1 in 13 (8%) to worse than 1 in 2 (50%), but are often nearer 1 in 4.5 (18%).

5. Acknowledgments

To the Director and Council of HATRA for permission to lecture and publish and, with gratitude, to many present and past co-workers on HATRA's staff.

6. References

1 Internal HATRA Report "A Statistical Examination of Variations in Assessment of Light Fastness According to the Woolmark Specification", September 1967

2 S.M. Jaeckel, HATRA Production Note No. 17, "The HATRA Barriness Scale", November 1967

3 S.M. Jaeckel, "The Utility of Colour-difference Formulae for Match-acceptability Decisions", Helmholtz Memorial Symposium on Color Metrics (A.I.C.), Drieberoen, 1971

4 WSS98 Woolmark Specification 3," 1st May, 1967

5 B.S.2662: 1961, see 'Standard Methods for the Determination of the Colour Fastness of Textiles', 3rd. ed. Bradford, Society of Dyers and Colourists, 1962.

The Food Manufacturer's Point-of-View

H Goodall

The talk was based on information received from members of the B.F.M.I.R.A. in response to a letter of enquiry and represented a wide range of interests in food manufacturers. It was primarily concerned with the difficulties facing food manufacturers when attempting assessment, rather than viewing conditions as such.

Food manufacturers recognise the desirability of assessing the colour of their products in some standardised, and if possible, objective way. It must be remembered, however, that with foods it is not only the colour which is important, but the combination of colour with other factors such as visual texture, gloss and translucence which modify the colour and give the final appearance. Frequently the colour is not uniform, but is a composite of lighter and darker shades as in pastry and biscuits, or even a mixture of completely different colours as in a slice of corned beef.

Even with relatively simple commodities, such as sugar, colour assessment is not always straight forward - with liquid or dissolved sugars instrumental readings can be used as reference standards, but colour assessment of sugar in crystal form is complicated by the effects of crystal size and distribution.

When the sugar is converted to sugar confectionery, the difficulties of evaluating colour and appearance are much, greater. Sweets and toffees tend to be heterogeneous in colour, contour, reflectance and translucence, and these factors all have an effect on the apparent colour. Even with fondant, which is more uniform in colour, the crystal size and gloss are important factors. Chocolate is similar to fondant in that gloss and crystal size are important, and it also has its own characteristic setting properties, so that it is quite possible to mould portions of the same melted sample and produce blocks which are satisfactorily tempered, but which are different in colour. It is for this reason that a manufacturer of couverture, which is sold for re-use, assesses the colour on the freshly melted sample. This procedure, however, is not much help to the manufacturer wishing to standardise the colour of the finished article, or of dessert chocolate.

Flour confectionery is also heterogeneous in colour, intensity of colour, surface texture, and reflectance, and in some cases - jam tarts for example - there are two completely different components, each with its own parameters, and each contributing to the over-all colour and acceptability of the product.

Soft drinks, particularly comminuted products, constitute another field in which particle size, translucence and reflectance have an effect on colour. Also, if a synthetic colour is added, it must be such that not only the drink as a whole, but also the two strata into which it may unfortunately separate, are of realistic colour.

When one comes to pickles and vegetable products such as soups, colour, form and visual texture are indeed heterogeneous, whereas in sauces and salad creams the colour is uniform, but is again affected by consistency, particle or emulsion size, and reflectance, In meat products such as corned beef, luncheon meat and sausage, not only is the proportion of fat to lean an important factor in assessing the over-all colour, but the extent of heterogeneity - the degree of mincing - also has an effect.

These considerations give some idea of what might be termed the basic factors to be taken into account when assessing the colour of foods, but it must also be realised that in many foods the colour does not remain constant. The fact that the pink colour of freshly cut cured meats can change to brown and even to grey is probably well-known; perhaps not so apparent is the change in the colour of jams, which alter more slowly, but quite definitely, over a period of months, usually becoming browner. Biscuits and cakes also lose their freshly baked warm colour and become much less attractive in appearance.

In view of all these factors, it would obviously be a great help if manufacturers had some objective reference standard, and many firms have gone to considerable lengths with this aim in view. They have experimented with a wide range of the instruments available, tried colour chips or cards, painted standards, and even colour photographs, but in many cases found little improvement on visual assessment.

For some products, instrumental assessments are available, and in some cases manufacturers have been able to establish their own such standards, but probably much routine colour assessment of food products is carried out on the factory floor, and often without any standard other than memory. Provided production is under good control, this can on most occasions work quite satisfactorily, but in shift work, and particularly at night, difficulties are encountered. One member of the R.A. made the point very forcibly that in these circumstances it is vital to have a control sample available, otherwise the night production (biscuits were the case in point) would appear over-baked when seen by daylight. Apparently the public is quite vocal on such matters, and not always with condemnation - the over-baked samples may be declared delicious, and the request be made for this type of product as a general rule. This difference in public taste is, incidentally, sometimes taken into account - water biscuits of two degrees of bake are available, and instant coffee of four or five flavour-types.

In addition to routine colour assessment in the factory, most firms institute some kind of periodical colour checks away from the production area, and it is on these occasions that a control sample of some sort would be available. It might often be an acceptable sample of a previous production, or use could be made of established standards, or published specifications. On these occasions too, some form of standardised viewing conditions would be used - north daylight at a particular time of day, artificial lighting of some type, viewing cabinets, etc. Some products would be assessed for colour from their surface appearance only - for example biscuits - but products such as jam must be satisfactory both in the jar, and when spread in a thin layer, as on bread, while soft drinks would be assessed both as sold, and diluted as for drinking.

Not only does the food manufacturer assess the colour of his own products, but he also monitors his supplies of raw materials, and it was surprising to the writer to learn that wide variations in the colouring of labelling and packaging materials had been encountered by more than one member of the R.A. from whom enquiries were made.

The foregoing should convey some ides of the problems facing food manufacturers when monitoring the colour of their products, and their awareness of the desirability of this type of control. The letters received from members show clearly that they would welcome any improvement in the standardisation and simplification of colour assessment, and a sound objective technique would be very valuable. There is need too for an efficient in-line colour sorter which is cheap enough to be installed on all production lines.

Standardisation of Conditions for Colour Vision Testing

W. O. G. Taylor

THE PURPOSE OF A COLOUR VISION TEST

It is impossible to discuss usefully the standards which should be adopted, before considering the purpose for which the tests are being carried out. There appear to be five main categories, which, given in the order of rigour of standards are:

A. Trade Testing.
B. School Children.
C. As Genetic Markers.
D. Detection of Disease
E. Scientific Investigations.

A- TRADE TESTING:

It is perfectly legitimate to give a trade test in which the appointee is asked to perform operations similar to those he would have to carry out in practice (Wright, 1964). An excellent example is the American ***FAA colour signal light gun test*** (Lewis & Steen 1971, 1972).

1. The conditions of the test should be similar to those encountered in the works: thus, if (say) wiring of colour coded cables sometimes has to be checked when the cables are dirty or the lighting is poor, then the tests should also be made under these conditions.

2. It must be recognised that such a test does not necessarily indicate whether a man is or is not 'colourblind' - only that he can perform such and such a job safely. Other tests and other conditions might decide otherwise. Sloan and Habel (1955 a,b.), found that a colour code suggested by Judd for aircraft instrument panels such that not only the normal but also 75% of the colour blind could discriminate them was unsuitable for point sources of light such as airfield beacons at a distance. Some colour defectives who could identify the signals on the instrument panel unfortunately failed to discriminate the airfield beacons, even when restricted to only two of the three colours, hence though fit for air-crew on one criterion, they failed when a different task was attempted.

3. It is a <u>Trade</u> test and does not permit of any latitude in scoring. If the subject makes any mistakes that the normal operator would not, <u>then he has failed</u>.

4. If an objective measure is required, then his results should be compared with the mean of a sufficient (about l00) normal persons. Failure may be set at the 5% (2 x SD) or 1% (3 x SD) level.

5. The effect of age must be considered (Lakowski, 1958 a.b, 1962).

It may be asked whether a more objective type of test is required in the industrial field: this depends on how demanding the task is in a colour sense. If the task is one of accurately discriminating colours close to each other in hue (the 'isomeric' colours) - as in dyeing, bleaching, paper-making, then this is probably true, but the exact test must be carefully chosen for this particular purpose. Farnsworth's l00-hue test is an example of this kind of test (Farnsworth 1943). The standard of performance should be that appropriate to the amount of information required. It is essential to remember the strong age-effect in this (and some other tests) - Lakowski (1Q62), Verriest *et al* (1962 & 1963) and Ruddock (1965). The colour aptitude test is a similar test but I have no personal experience of it.

Where the task is one of discriminating between colours far apart on the hue circle, but known to be confused by the colour blind, the various lantern tests (Martin's, Board of Trade, Edridge-Green's) are in fact Trade tests in that they imitate conditions not otherwise easily reproducible, such as signals on the railway or ship's lamps at sea, (Wright, 1964). The pseudo-isochromatic plates are not a satisfactory substitute, since they eliminate with certainty only the congenitally colour blind and may miss - for example - the early case of tobacco blindness in a middle-aged signalman, since the stimulus he receives at work is one of small angular subtense ('point-source') and the P. I.C. tests normally are used at large angles. The l00-hue test and the anomaloscope would however detect his colour loss and should be used where there is suspicion that a worker has previously had normal colour vision.

B. SCHOOL CHILDREN

In spite of strong recommendations over a long time, notably in the 1946 report from the Physical Society and a symposium at the Royal Society of Medicine (Riddell, 1949), it is only fairly recently (Scottish Home and Health Department 1962) that, in this country, school children have been routinely tested. No directive, however, has been made as to the age at which this should be done. There are broadly three significant points in the school career:-

1. School Entrants.

2. Prior to entering Secondary School.

3. School Leavers.

There is something to be said for each of these times.

1. School Entrants:

With the functional use of colour in the initial teaching of both reading and the use of numbers (Gattegno, 1962: Cusenaire) colour blind children may be substantially handicapped (letter to Editor, 'Where', 1965). But the problems involved in detecting and accurately measuring a colour defect in children of this age are considerable. Sloan (1962) uses P.I.C. tests as a screening test, particularly "dual-response" plates (Ishihara 2-9) but discarding plates of the 'hidden response' type (Ishihara plates 18 -21) as being liable to cause confusion. (This is probably because many children at this age have ultra-sensitive colour perception.) For qualitative analysis she used the D-15 test of Farnsworth (developed from his l00-hue test) and some of the plates of the American Optical (H.R.R.) and Tokyo Medical College tests but found the discrepancies between them disturbing. An anomaloscope does not appear to have been used.

Unlike Verriest, who in his report on the 100-hue test published in 1962 apparently did not use it under the age of ten, Lumbroso (1963) gives the results of testing children with it, in forty-six under this age, twelve of whom were between five and six years old. In the latter the (partial error) scores varied from 100 to 335, with a mean of 177 and an S.D. of 65.7. This is clearly much above the standard of normality adopted by Farnsworth (from tests on an older age group) but agrees with the kind of results I found in Edinburgh, (Taylor, 1966). Lumbruso does not say in this paper whether the results found helped in the detection of colour blindness. It is possible that the concept of a 'spectral' type of arrangement as in the lOO-hue test is not usually grasped by a child until somewhat later. I have suggested that in the children tested by me this was about the age of eight (Taylor 1966), and that the American Optical (H.R.R.) test with its shapes rather than letters or figures was a good one. The innumerate plates (snake-like patterns) of the Ishihara test can be used, but it is not always easy to be sure that the five year old child understands and is following the pattern as seen by him.

Gallagher (1964) and Sassoon (1970) tested children at very young ages and recommend the D-15 test. Taylor (1970) pointed out that Terman and Merrill found that colour appreciation developed later than that of shape, probably not before the age of three. Lakowski (1958 a,b) tested over 500 subjects from five years of age to ninety by various methods including an anomaloscope. Of these 50 were between 5 and 10, and 50 between 11 and 15 years of age. He found fewer 'normal' or best subjects in these two groups than in the ages of best colour vision (between ages 16 and 35). He found that the very young differ from the best age group in one interesting aspect. Their average mid-matching point (on the Pickford anomaloscope) is shifted slightly towards red end in the R. G. equation, towards yellow in the Y-B equation, and towards the violet in the V/B/G equation. This indicates that colour discrimination improves throughout childhood, and warns us to be on our guard about applying to this age group standards of normality derived from a population in the 16-25 age group as is generally done (for the understandable reason that such a 'normal' population is usually most readily available in Universities or Colleges).

It does suggest that conclusions from tests at the age of five should be tentative and a retest done at a later date - probably pre-vocational. In my opinion too, no school child should be given a simple 'Trade Test'. They should be regarded as multi-potential so that all possible avenues are kept open to them.

2. <u>Test prior to Entering Secondary School</u>:

At this age (about 11) the problems of comprehension are few, a colour order (for 100-hue test) is accepted, and on the other hand some choice of future career is being made, with selection of courses in, e.g. science, art or geography, in which colour blindness may be important. (Taylor 1971).

A simple screening test of high efficiency should be used for every child. Taylor (1970), showed that where the Ishihara T.M.F. , A. 0. (H.R.H.) and Farnsworth's F. 2 tests are considered purely as screening tests and carried out according to their published instructions, a high order of accuracy is obtained; varying from 98^ to 9°.*5%* if there is no objection to including an odd person subsequently found to be not colour blind, (as is reasonable where the test is purely to select for further examination). These tests were carried out on 365 school children (mostly 11 - 14) and 234 of their adult escorts. The subsequent diagnostic test should include a colour discrimination test such as the 100-hue test and also a test on an anomaloscope under conditions of some rigour. Advice based on these findings should not be dogmatic unless the defect is clearly extreme and the suggested career one where a colour confusion may be dangerous. There are many instances of intelligence or observation overcoming the handicap that a colour defect may be: awareness of the nature and extent of the difficulty may well be an important step in learning to circumvent it.

3. School Leavers:

This is now really a prevocational test and can be more specifically directed towards the particular career, but, as Lakowski (1966) points out, his printers' entrants sometimes change their minds after the selection process has taken place and instead of spending their time in black and white work as compositors, change over to colour printing. It may also happen that promotion to supervisory or managerial standing in a firm may entail responsibility for accuracy of colour matching, so that the above-mentioned desirability of keeping all avenues open suggests that it would be better to carry out the more objective procedures, and thus give a fuller analysis than a simple 'trade test'.

In the author's opinion the most cost-effective method for school children at present is to test all school entrants about whom their teachers express doubt about their colour-coded responses; but to reserve a full survey until the last year in primary school when a reliable screening test should be performed on every child, following which all failing the test (including border-line cases) and also those tested at school entrance should be referred to a suitably equipped laboratory for colour discrimination and anomaloscope tests. For the screening survey I recommend Farnsworth's F.2 test (Taylor 1970 a,b) an improved form of which has undergone extensive study, on which a report is at present in course of preparation.

C. AS GENETIC MARKERS

Congenital colour blindness of the red-green type, being carried on the X-chromo-some is of profound importance to the geneticist, and whereas in the school child (Sloan 1962) the exact type is of secondary importance, in genetics it is of vital significance. Apart from the interest of the transmission of the colour blindness itself, linkage with other sex-linked characters has permitted the identification of the position on the chromosome of these genes, in measurements ('centi-Morgans') of some accuracy, allowing predictions of inheritance to be made (Kalmus 1965). It follows that P. I.C. tests will seldom give results with the requisite accuracy of discrimination as to type of defect or as to severity. For this an anomaloscope (Nagel, Pickford) is desirable. However circumstances will have to decide the method used: it is obviously more important to get <u>some</u> information even if incomplete, when, as so often in a genetic survey, relatives have to be interviewed in their Own homes scattered over a wide area, or native population studied in the bush. (A good example was recently published by Brody (1971) on inhabitants of the Pingelap Islands.) The advantage of carrying a portable form of acceptable lighting (e.g. Veri-Vide) is to be remembered. This is also one of the outstanding advantages of Pickford's anomaloscope (Pickford and Lakowski I960: Pickford 1967): it can be used with a car battery and is therefore recommended for population surveys in primitive conditions.

Warburg (1964) has lamented the limitations of colour defect in some linkage studies. An important possibility for the use of colour vision as a genetic marker on the X-Chromo-some has been opened up by recent papers from the "evergreen" Professor Georg Waaler (1967, 1968, 1969) where he gives strong support to the possibility that the 'unique green' point for different observers may be bimodal Gl and G2 for males, Gl/Gl, G1/G2, and G2/G2 for females. If confirmed this will constitute an invaluable inheritable differentiation of the X-Chromosome, easily detected and widely represented.

D. DETECTION OF DISEASE

Throughout the nineteenth century isolated reports were made, mainly by German physiologists, of cases of colour blindness apparently due to disease. This was not rationalised until about 1912 when Kolner systematised the information published until then. On this is based Kolner's Law - that lesions in the outer layer of the retina lead to yellow/blue defects, whereas lesions in the rest of the visual pathway result in defect of re/green vision.

Little more until 1950, but since then , revived interest, and particularly large-scale surveys, carefully controlled, of groups of patients (e.g. Lakowski 1962, Kinnear 1965, Chisholm 1969), have thrown much new light on this factor and revealed the great value such tests as the 100-Hue and the anomaloscope can have in the diagnosis and control of treatment of disease. Lakowski (1958, a, b) emphasises the importance of allowing for age factor in these patterns, which until recently was overlooked.

The P. I.C. tests will fail in many cases because they are too insensitive, and the Ishihara test has plates only for red/green deficiencies. It is also to be remembered that disease may be patchy in its incidence and hence some parts of the retina may be normal, and some abnormal; one eye may be affected and not the other. Hence, for any kind of test, the eyes must be tested separately, and in anomaloscope tests, the size of target varied to detect differences as the area of stimulation of the retina is increased or reduced. The direction of gaze may also be significant: but this gets into the realm of colour perimetry - testing of the field of vision for colours -a little explored field in scientifically acceptable terms.

E. SCIENTIFIC INVESTIGATION

Here standards are absolute - in other words, as high as can reasonably be achieved. Great attention to detail is necessary if unexpected errors are not to be introduced and a familiarity with work already published on the subject of the investigation will enable the investigator to avoid many of the pitfalls. It is necessary to understand the scientific basis of the measures employed. Lakowski (1966, 1969) explains by colorimetric and photometric analysis just what is being tested in various P.I.C. tests (Ishihara, T.M.C., A. O. , H.R.R.) Dvorine, Farnsworth's F2 and F5, Willmer W2 and Wll, tests of colour aptitude, F. 100-hue and the I.S.C. C. "C. A. T." test, and the Nagel and Pickford anomaloscope by a comparison of the location on the colour triangle.

More elaborate apparatus may also be devised which utilise high quality prisms or diffraction gratings and special lamps to produce exceptionally bright and large spectra, so that matching of narrow-band wavelengths may be done, and even use of the secondary and tertiary spectra produced, as in Shirley's (1966) instrument. The latter uses the phenomenon of Flicker Fusion which has different thresholds for luminosity and for colour matching, but this type of investigation is outside my field of experience.

REFERENCES

Brody, J.A., Hussels, I., Brink, E. , and Torres, J., (1970), Lancet I, June 13, 1253-1257.

Chisholm, I.A., (1969), Trans. Ophth. Soc. U.K., 89., 243-250.

Farnsworth, D. , (1943). J. Opt. Soc.Amer. , 33, Oct., 568-578.

Gallagher, J. R. , (1964), Arch. Ophthal., 72, 200.

Gattegno, C., (1962), *Words in Colour*, Education Explorers Ltd, England.

Kinnear, P. R. (1965), Proc. Internat. Colour Utg. Luzern, I, 267-270. (Munsterschmidt-Verlag, Gottingen).

Lakowski, R., (1958a), World Science Review, 70, Nov.

Lakowski, R., (1958b), Adv. of Science, 15, 231-236.

Lakowski, R. , (1962), Die Farbe, JJL, 69-86.

Lakowski, R. , (1966a), Brit. J. Physiol. Opt., 22, 10-32.

Lakowski, R. , (1966b), Brit. J. Physiol. Opt., 23, 186-209.

Lakowski, R. , (1969), Brit. J. Indust. Med., 26, 173-189, 265-288.

Lewis, M. F. , & Steen, J.A. , (1971), Report FAA-AM-71-27, June, 1-7. (U.S. Fed. Aviation).

Lumbroso, B.D. , and Proto, F. , f1963), Boll. Oculist, 42, 794.

Physical Society (Colour Group Committee), (1946), The Physical Society, London.

Pickford, R W & Lakowski, R, (1960) Brit J Physiol Optics, 17, 131-150
Pickford, R. W., (1967), Internat. J. Neurol., 6, 210-221.
Riddell, W. J.B., (et al.), (1949), Proc. Roy. Soc Med., 42,145-150.
Ruddock, K.H., (1965), Vision Res., 5, 37-8.
Sassoon, H. F., & Wise, J.B., (1970), Lancet, I, Feb., 419-420.
Scottish Home and Health Department, (1962), Circular 58/1962.
Shirley, A. W., (1966), Brit. J. Physiol. Opt., 23, 254-257.
Sloan, L. L., &, Habel, A., (1955a), J. Opt. Soc. Amer., 45, 592-598.
Sloan, L. L., & Habel, A., (1955b), J. Opt. oc. Amer., 45, 599-601.
Sloan, L.L., (1963), Int. Ophth. Clinics III, Chap. 4, 697-705.
Steen. J.A. & Lewis, M. F. (1972), Report Aerospace Med 43 (1) 34-36.
Taylor, W. O. G., (1966), Trans. Ophth. Soc. U.K.. 86, 591-605.
Taylor, W.O.G., (1970a), Ann. Ophthal. (Chicago) 2, 186-192.
Taylor, W.O.G., (1970b), Ann. Ophthal. (Chicago) 2, 625.
Taylor, W.O.G., (1971), Brit J. Ophthal., 55, 753-760. Verriest, Vandevyvere, R, & Vanderdonck R, (1962) Rev Opt. 41, 499-509.
Verriest, G., Buyssens, A., & Vanderdonck, R., (1963), Rev. Opt., 42, 105-119.
Waaler, G. H. M., (1967), Norske Videnskaps-Akademi, Oslo, I.M.-N. Klasse (New Series) No. 9.
Waaler, G. H. M., (1968), Norske Videnskaps-Akademi, Oslo, I.M.- No, Kl. (New Series) No. 11.
Waaler, G. H. M., (1969), Norske Videnskaps-Akademi, Oslo, I.M.-N. Kl. (New Series) No. 12.
Warburg, M., (1964), Acta Ophthal. 42, 444-451. Where? (1966). Letter to Editor, 20, 650.
Wright, W.D., (1964), "The Measurement of Colour", 3rd Ed. (now a 4th Ed., 1969), Routledge 8. Kegan Paul, London.

Standard Conditions for Viewing in Colour TV Broadcasting

I. H. Teear *Television Service of the BBC in London*

I should like to limit the scope of this paper to the consideration of the conditions in which colour television pictures are viewed during the quality control processes in a television transmission chain, and to closely allied problems.

A television broadcasting organisation must ensure that the pictures that it sends to its transmitters are of a consistent and high technical standard. In order to fulfill this requirement the pictures must be monitored in viewing conditions that are the best achievable in practical operation. The viewing public, in their turn, can then be assured of receiving a picture of similar quality, if they, too, are able to control the viewing environment in their own homes.

The suite of Control Areas which form the technical complex of each Television Studio usually consists of a Production Control Area, a Sound Control Area, a Vision Apparatus Area and a Lighting and Vision Control Area. It is at the Control Desk in the latter area that detailed adjustments to lighting and to the colour balance of the pictures are carried out, and thus the quality of the outgoing pictures determined.

The test pattern that is used for the initial colour balance of the camera is a neutral step It is set up in the studio and is illuminated at a standard level of 150 ft.c. incident at the colour temperature equal to that which is used for the illumination of the studio sets. This is usually 2950K. The peak white of the test chart is of 60% reflectance, this being the maximum permissable value in the television system. The contrast ratio of the step wedge is 38:1.

The mathematics of the colour television system is such that the colour signals equate to zero when no colour is present in the viewed scene, such as a neutral step-wedge. In this condition the tristimulus values of the camera signals are equal, and are unity at peak white. The camera is initially adjusted until this condition is met. This adjustment is carried out in the Vision Apparatus Area and once made, providing that the analysis, and other optical and electronic parameters in a group of cameras are matched, should give a similar analysis of the colours of any scene.

Inevitably, small discrepancies do arise in camera balance and matching due to several causes. There are bound to be slight differences in the analysis of the coloured scene made by the optical splitting block in the camera. There are small differences in the colour responses of the camera tubes and lenses and also slight differences in the optical flare characteristics of these components. During studio operation it is inevitable that matching of the pictures from one camera to another will be affected by unavoidable differences in lighting level and direction of lighting, and perhaps by reflection of unwanted coloured light onto the subject matter as seen by one camera and not by another. Thus, it is necessary to provide trimming adjustments to the initial colour balance in order to take account of practical operational conditions. These adjustments, together with those of the camera lens iris and masterblack level controls are carried out in the Lighting and Vision Control Area.

Once the initial engineering camera line-up has been carried out in the Vision Apparatus Area, control of the cameras is handed over to the staff of the Lighting and Vision Control Area, for the final critical adjustment using the bank of picture monitors with which this area is equipped. The subject matter for this final adjustment is the most critical to reproduce accurately on a group of cameras, that is the gamut of human flesh tones. A live model, seated in front of the neutral step-wedge chart is televised.

Trimming adjustments to both lighting and cameras during rehearsal, recordings or transmissions, are made as required by the occupants of the Lighting and the Vision Control Desks. The adjustments are made in rehearsed cooperation, by visual assessment of the pictures, on the bank of monitors in front of the desks. The colour monitors in this stack therefore must be precisely set up, in order that they give as faithful a reproduction as possible of the pictures being transmitted. It is with these monitors in mind that we can now discuss the many facets of colour monitor line-up and colour television picture viewing in controlled conditions.

The colour reproduced on a colour television picture monitor can be influenced by two factors, associated with the monitor itself. They are

a) the coordinates of the phosphors used
b) the normalising illuminant to which the colour monitor is set.

The coordinates of the phosphors used in the colour television display form the starting point of the colori-metric calculation from which the camera analysis curves are derived. Thus, once the phosphor coordinates have been decided upon, they should in an ideal situation remain for all time. Differences in phosphors from one manufacturer's shadow mask tubes to another, and changes made in the course of development, have caused colour television broadcasters particular concern. The coordinates laid down in the Specification of the Pal System I Television System, to which this country works, are as follows:-

	R	G	B
X	0.64	0.29	0.15
y	0.33	0. 60	0.06

Acceptance of these coordinates, in Shadow Mask Tube Manufacture, would be a major step towards standardisation of viewing conditions both from the broadcaster's and the home viewer's points of view.

The normalising illuminant of the colour monitors, i.e. the colour of the screen when a neutral shade is being viewed by the colour camera, is also laid down in the Specification of our Television System, and is of vital importance for the correct rendition of colour. It must be a visual match to, and thus have the same coordinates as, the Standard Illuminant D/6500.

During the past few years many methods have been devised by which colour monitors can be adjusted to produce this illuminant at peak white, through the grey scale to black, a process referred to as the grey scale tracking of the monitor. In the field of television broadcasting, operational pressures require that time spent in engineering line-up and adjustment, be kept to a minimum. But at the same time a high standard of performance is expected from all picture producing equipment and of line-up and matching of all picture monitors. At the same time the more experienced the studio technical staff become in picture appraisal, then the more critical becomes their acuity to colour imperfections and differences, and again a higher standard of performance is demanded from the apparatus. The method used for colour monitor grey scale balance must be speedy, yet accurate, and ideally must be able to be brought into instant use, say during a transmission, in order to check the balance of a monitor which is suspected of having drifted from its initial line-up. It must be possible to do this of course, without affecting the outgoing pictures. To this end, the trend in the BBC has been towards the provision of reference light sources of the correct brightness and colour temperature either built into monitor stacks, or adjacent to single monitors, rather than to use measuring or other line-up devices which have to be brought up to the monitors. When one considers that the colour monitors are used to make visual assessments of picture quality, it seems reasonable to balance those monitors by that same critical visual assessment, by comparison with a known reference.

Many types of reference source have been designed and appraised since the commencement of colour television. Some devices are better suited for use with single picture monitors rather than with a stack of monitors, as is used in the technical area of a large production studio.

A brief account of the evolution of these references is given, leading up to the present preferred technique of Colour Picture Monitor line-up.

The first reference source used was a Colour Matching Fluorescent Lamp. The case on which it was mounted was lined with suitable white plastic sheeting, to diffuse and evenly distribute the light across the area of the step-wedge. The step-wedge is manufactured photographically, on neutral film base. The brightness of the display was controlled by a mechanical shutter arrangement around the lamp. An electronically generated step-wedge was switched to the colour monitor. Visual comparisons with appropriate correcting adjustments to the colour monitor were made, until a satisfactory visual match was achieved. The difficulty experienced with this arrangement was that the eye had to move from a colour monitor screen to a much smaller reference source, in order to make a comparison. In so doing, it lost the required fine degree of comparison. A second disadvantage was the close proximity of uncorrected monochrome monitors, which surround the colour monitors in a stack, and which have a correlated colour temperature around 10,000°K. The presence of the large area of incorrect illuminant affected the adaptation of the operators to the correct reference. Also, difficulty was experienced in using a test pattern which filled the raster of the colour monitor. Even with the best combination of picture tube, scanning coils, and associated circuitry that is found in today's professional colour monitors, it is not possible to obtain a raster that is completely free of colour shading. The presence of this colour shading around the edges of the raster tends to confuse one's finer sense of critical colour comparison with the reference.

The use of the above type of reference light source is however still used to line-up single colour monitors.

It was realised that where stacks of mixed monochrome and colour monitors were concerned, a reference source of larger area was required, together with a test signal that did not fill the raster of the picture monitor, and it was decided to make an attempt to use filters to colour correct the monochrome monitors in the monitor stacks, in order to provide the large area of reference illuminant at the preferred brightness of 21 ft. lamberts peak white, and at as close to the required colour temperature of 6500K as as practically possible.

A suitable test signal was generated, by means of a simple modification to an existing test signal generator. This generator, the Picture Line-up Signal Generator, usually called PLUGE, originally produced a pattern as shown in **fig. 1**.

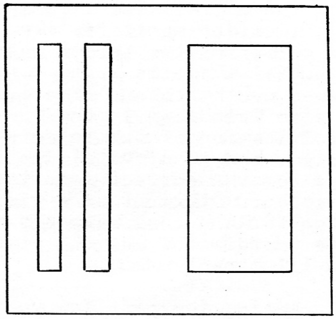


Fig. 1

This pattern was developed for use with monochrome television to enable the correct brightness setting of the monochrome picture monitors to be obtained. The brightness control was adjusted for extinction of the left hand bar of the pair of bars on the left, and threshold visibility of the right hand bar of the pair. The size of the large pattern was arrived at after much experiment, and is arranged to enable the iris of the'eye to stop down by the same amount as it would do on an average television picture. In this way the eye is in the desired condition to enable it to judge correct black level, set as described.

This test signal generator has been modified to enable it to be switched to a four step pattern as shown in **fig. 2**. The signal amplitudes (brightness) of the components of the patterns in the above figures are as follows:-

(l) Picture Black 0%

(2) 4% above Picture Black

(3) Background at 2% above Picture Black

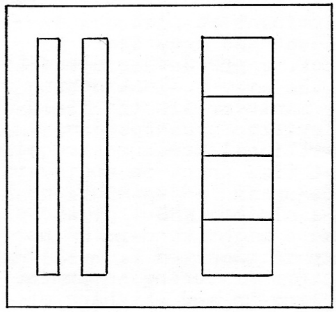


Fig. 2

(4) Peak White 100%
(5) Mid Grey Approx. 50%
(6) Four approximately equally spaced

It has been found that this four step pattern provides all the necessary information to enable the grey scale of a colour monitor to be set accurately. The one test signal generator thus provides both the test signals that are required for colour picture monitor tracking, and monochrome and colour picture brightness and contrast setting.

Many experimental colour filters for colour temperature correction of the monochrome monitors were tried before a suitable and repeatable item was made. The filters finally used were made by spraying a film of transparent lacquer of defined colour quality, onto either glass or perspex sheets. These filters were then clipped into the fronts of the monochrome monitors, or in some cases the implosion guards were removed, sprayed and then replaced. The combination of mono- chrome monitor tube and filter are matched to provide a consistent standard throughout our television operation. This was made possible by using the small differences in the colour of the monochrome picture tubes and small differences in filtering due to variations in the thickness of the film of lacquer. A measuring procedure was established, using a modified Tintometer, in order to facilitate the task of matching the large numbers of monochrome tubes and monitors. The colour coordinates of the corrected monitors fell into two close groups which are shown in **fig. 3** as A and B.

The diagram is an approximate uniform chromaticity presentation, with *x* and ***y*** coordinates.

This presentation may be a little unusual. It is believed that it arose from the work of F.T. Simon and W.J. Goodwin of the Union Carbide Company. Their paper, entitled *Rapid Graphical Computation of Small Colour Differences*, was published in the American Dyestuff Reporter Vol. 47. P.105 (1958). The work was based in turn on a paper by D. L. MacAdatn in J. Opt Soc Am. Vol 33 P. 18 (1943). The

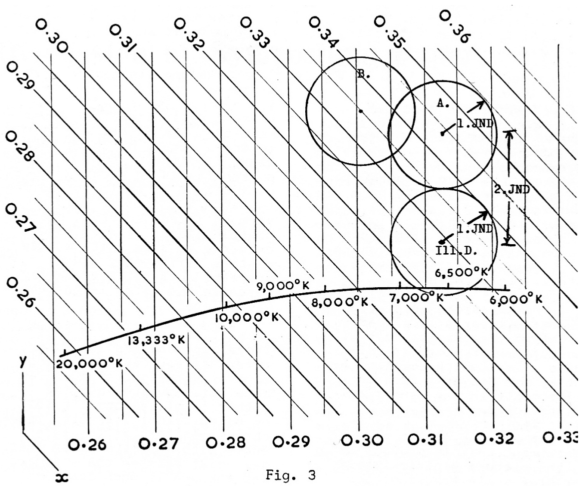


Fig. 3

Illuminant D point is marked in fig. 3, together with circles indicating 1 and 2; Just Noticeable Differences. One JND is taken as an increment of 0.004 in U or V on the 1960 UCS CIE Diagram, and is transposed onto the ***x*** and ***y*** scales, of the above figure. It can be seen that the corrected monochrome monitors are not a precise absolute standard of colour temperature. The economics of producing such a standard would have been prohibitive. The monochrome monitors, however, give a consistent visual reference which, it is suggested, is adequate in absolute terms.

One television picture tube manufacturer is already marketing monochrome tubes with phosphors that given an adequate visual match to Illuminant D, for use as reference illuminants in the manner described above.

An example of the type of instrument that is brought up to the picture monitor itself, for grey scale tracking, Is the "Graphicon". The prototype of this device was developed by Messrs. Thames Television Ltd. as a solution to the colour monitor line-up problem. The cylindrical part of the body contains a filament lamp, the current through which is stabilised at a value to give a source which, in conjunction with a calibrated correcting filter of Chance 0B8 Glass, produces in the viewing aperture at the top of the instrument, an area of 6500 K reference illuminant. The brightness of this illuminant can be adjusted over a wide range of values by an iris diaphragm in the light-path. The head of the instrument contains a Lummer-Brodin Cube which is used to compare light from a colour monitor screen at the entrance port, with the inbuilt reference illuminant. The monitor is made to display a step-wedge pattern, and the light intensity of the Graphicon instrument is adjusted to enable a comparison to be made at any point in the grey scale.

Some uneasiness has been expressed regarding the use of fluorescent tubes, such as those used In the first instrument that was described, for making a direct match against light from the mixture of three phosphors, as in a colour television tube. One is attempting to match two stimuli that have very different spectral energy distributions. There is some evidence to show that because of this difference, one operator does not necessarily perceive the match in the same way as another.

It is appreciated that there are many conditions when reference sources containing fluorescent light sources can be of great value, but the author is of the opinion that by using colour corrected monochrome monitors as the reference , then any metamerism that may exist between the standard and unknown is much less, as the two spectral distributions concerned bear some similarity to each other.

As a closing topic, a brief mention is made of the ambient viewing conditions in the Lighting and Vision Control Rooms. The decor of the control room is arranged to give a matt neutral impression. The arrangement of the working lights should be such as to keep reflected light onto the monitor stack to a minimum. All working lights should be as near a visual match to D. 6500 K as possible. Working surfaces are normally covered with near neutral, matt, laminated plastic material. Ideally the reflected light level from these surfaces, and that from white script sheets, should not exceed say 10 ft. lamberts, that is approximately half the level of peak white from the monitor screens, which are set to 21 ft. lamberts. The immediate surround to the monitor stack is again covered with a light neutral matt plastic material, spill light onto this light surround is such as to reduce the eye fatigue which is experienced when television monitors are viewed in dark surrounds.

In conclusion, I should like to thank the Director of Engineering of the British Broadcasting Corporation for giving his permission to read this paper. I should like also, to acknowledge that many of the points herein mentioned have arisen from the many interesting discussions that the author has enjoyed with friends and colleagues in all parts of the television manufacturing and broadcasting industries.

Discussion of Symposium Papers

The Chairman for the final session, Mr. F. Malkin, now opened the meeting to a general discussion on all the topics raised, and on any others which seemed relevant. Mr. S.M. Jaeckel asked if there had been a systematic investigation, using the same panel of assessors, or whether the 16-tile or 25-tile array used by some ceramics manufacturers gave different results from the 3-tile array used at B.Ceram.R.A. Mr. Malkin replied that this had not been properly checked; it was possible that boundary contrast mattered more in the small array, and that the 16-tile array might be more sensitive to showing up differences of overall colour in two batches of production, but there was no conclusive evidence. Mr. Jaeckel commented that under practical conditions it was probably boundary contrast that mattered in customer acceptance rather than averaged contrast. Both Mr. I.T. Pitt and Mr. H.G. Mackenzie-Wintle enquired whether the white grouting normally found between adjacent wall tiles had any significant effect on the perceptibility of lightness or chromatic differences. Mr. Malkin replied that the grouting probably did not have much effect as even if the tiles were mounted with no gap between their edges, there would still be an obvious discontinuity due to the curved edge; if there was any effect it would mainly be to reduce lightness difference sensitivity. Mr. G.J.

Chamberlin took up this point, which had been elaborated in Malkin's lecture, and drew attention to the remarks which Deane B. Judd had written in to ASTM Specification D1500 (1965) on lubricating oils, that the two viewing fields should be slightly separated to emphasise chromatic differences and reduce the noticeability of lightness differences.

Mrs. D.I. Morley commented that in the printing industry, and probably others, pairs of samples were habitually compared, and the samples were switched left-to-right several times over to minimise the effects of asymmetry which Malkin had described. Did tile manufacturers always use "walls" of tiles? Mr. Malkin replied that for critical viewing for batch acceptance, a "wall" array was used. However, for trials and at the beginning of a batch, a pair of samples would be intercompared for speed.

Mr. M.B. Lloyd commented on the textural difficulties in food colour assessment, and said it was essential to prepare specimens in such a way as to eliminate differences in texture. If this could be done, instrumental assessment could be very successful. Miss Goodall replied that in many cases it was not possible to eliminate texture differences and then only visual judgement was reliable. Mr. D.B. MacDougall asked how the non-colour attributes of surface structure were dealt with in the different colour industries. From answers, it appeared that in textiles this matter was not considered too important, in ceramics the assessments were made quite separately from colour assessment, in leather finishing difficulties arose with irregular glossy surfaces which gave goniophoto-metric plots which did not correlate well with appearance, and in meat products a similar problem arose.

On the subject of colour atlases, Mr. K. McLaren remarked that neither the Munsell nor any other system really spaced out the colours in a way most suited to the needs of designers; equal perceptibility of sample intervals was not what they needed. He himself was constructing a personal atlas (naturally using L, C, T coordinates) from the samples he met with in everyday problems of work. After several years of additions this would give a distribution of samples well related to practical problems in industry. Mr. R.W. Brockle-bank took up McLaren's point that the four unitary hues were not exactly opposite each other in pairs in an equal-perceptibility colour space. Friele had claimed that the four unitary hues were equally spaced round the hue circle for constant-lightness low saturation stimuli, but that if maximally saturated samples are available (and with lightness differences) the situation is different. Mr. McLaren replied that in textiles the full range of colour gamut was of interest, and that even if Friele were correct for pastel shades this would not. be important in practice; there were relatively too many "dull" colours in the Munsell Atlas, from a commercial point of view, which was why he himself had started his own personal do-it-yourself atlas.

The subject of colour atlases inevitably led to the question of backgrounds against which samples should be viewed. Mr. F. Malkin expressed his disagreement with the CLE. recommendation to use a neutral grey background of average lightness when examining surface colour samples for colour difference; in his view the background should be as similar to the samples as possible and this probably constituted the main advantage of viewing large samples. (Earlier he had expressed reservations about the validity of large-field standard observer data, but that point related to the importance of the boundary region in colour matching or colour difference assessment.) Mr. K. McLaren pointed out that some in the textile field would present a pair of cloth samples for quick appraisal against a trouser-leg for convenience; this trouser-leg was usually dark and fairly neutral. Mr. D.J. McConnell wondered whether a black box well below the level of the samples would be a better controlled method of acheiving a dark background. Miss B.K.A. Battersby pointed out that with light samples a black background would make them look less saturated and would reduce discrimination due to a "glare" effect, the converse of looking at dark samples against a white background which also gives reduced discrimination. However many textile people like a dark background, and she thought a series of dark greys would be helpful with the darker colours and patterned material. Mr. D.B. MacDougall stated that white backgrounds are used in viewing meat, but the general room environment is a neutral grey and the illumination is D65 to BS950 Part I. Dr. F.J.J. Clarke pointed out that the after-images provided a compelling reason for wanting the background to be as much like the samples as possible. Finally Mr. R.W. Brocklebank remarked that an average natural background, representative of indoor and outdoor environments, has a reflectance of around 15%, equivalent roughly to Munsell Value 4. However the average chromaticity is not neutral but a low-purity greenish-yellow.

F.J.J.Clarke

Colour Therapy

Theo Gimbie

Art is applied in the Hygeia Studios to give therapeutic benefit. In art Seminars movement, rhythm, sound and form, as well as colour, are given special consideration.

One finds that certain images stay fixed in the participants' minds as if held by a grid. Such images can become obsessional and are re-inforced by repetition. In a few instances the image breaks up and sinks as it were to a lower grid on which it is not so significant in one's everyday pattern of behaviour.

When lack of skill prevents the working through of an image, the images themselves become another block. Because of this, I have found it better to disallow the making of representational pictures. Working with difficult teenagers, for example, one almost invariably finds a negative attitude related to fear or hate. However, in making non-representational pictures it is not possible to rely on *brain* memory, so a certain freeing of mental activity is experienced during art lessons.

In teaching the technique it is important to start in the following way. Anything may be drawn, the only restriction being that it must never have been seen before. The drawing is now 'detached' and a deep involvement is experienced. What could be termed as *cell* memory is drawn upon.

Each picture demonstrates three basic principles:-

1. Momentary forms. The drawing can change quite drastically and overshadow the other two stages.
2. Period forms. There is a gradual evolving of forms, which go from one stage to another working out some inner often incommunicable problem.
3. Basic or permanent forms. These can be detected as being almost permanent, recurring again and again like a signature tune.

The significance of colour should be interpreted only over a long period. The more intellectual person, for example, changes from one colour another, settling for a colour preference more gradually than the person with a direct and less intellectual approach.

A diagnosis can be made of trends in personality tendencies and patterns of health, from an analysis of attitudes towards form, colour, and the rhythmical recurrence of forms. It is very important to pursue this diagnosing with great restraint, as one will discover that it takes a long time - and at least eight to twelve pictures - before a true picture emerges. However, a first division in this approach to image-making can soon be made. Two groups are recognised as being basically either extrovert or intraverted. The next step is to find repeating forms which show regularity, system and habit. Then, see the proportion between some forms and others in the picture, the basic fullness or the linear lace-like quality. Not only thought, feeling and will, but also race characteristics underlies these patterns.

The technique has proved most successful with emotionally disturbed though intelligent people as well as with growing children suffering from ordinary developmental problems. Lastly, it is also a wonderful way of relaxing when one is tense and needing to switch off an over-active mind (see also Theo Gimble's article on this in *Child and Man* 1973).

The course is taught in ten sessions held from time to time at the Hygeia Studios -which also design schemes for hospitals, schools, conference centres, and so on.

The above Paper, and the following five papers, were presented at the Group's Symposium on ***Colour in Education***. The Symposium was held jointly with the Society for Education Through Art on 14th April 1972. A paper was also presented by C. A. Padgham.

Colour Therapy with Subnormal Children

Michael Wilson

Colour as a healing influence can work at several different levels of consciousness. As a constituent of a great work of art colour can work through the meaning and message of the total work. For this to happen some understanding of the picture is necessary. The Raphael cartoon of John and Peter healing the lame man at the gate of the Temple, which you can see downstairs in this building, has this quality.

At a lower level of consciousness the dynamic relationships of colour and form can have their effect on the beholder without 'meaning' or 'representing' anything other than what they are. We might call this the psychological or aesthetic level. At a still lower level of consciousness coloured surroundings can influence one's mood and behaviour in an instinctive and almost subconscious way. Only at this level can we speak of 'typical' reactions, or think of prescribing standard therapeutic treatment for standard types of illness.

I will now describe ways in which we use these two lower levels in a privately-run home-school near Birmingham where we have nearly 100 mentally subnormal, often severely subnormal, children.

We have built a small therapy pool, covered and heated, with level flooring at three different depths to suit even the smallest child. A novel feature is that the main illumination comes from lighting units housed in cavities in the side walls of the pool, situated just below water level so that most of the light is reflected downwards from the underside of the water surface. The pool is lined with grey tiles (Munsell Value 5) so that very little light escapes from the water. When human limbs enter the water they are at once brilliantly illuminated as they pass through the water surface. This effect is so striking that children who are otherwise hardly aware of their own limbs now begin to take notice of their feet and hands and to move more consciously and deliberately.

A further feature is that this lighting is coloured. We have two circuits of lights which can be dimmed at will and which are usually coloured with pink and blue stage lighting filters. A general observation is that the pink light stimulates activity whilst the blue induces more consciousness and control. Thus the pink is more useful for inhibited and spastic children, and the blue for the restless and excitable ones. This effect of colour is quite instinctive and there is no need to call the childrens' attention to it.

Another way of using colour has been devised for those children who cannot easily communicate and whose sense perception is evidently not normally developed. This method is highly individual and does not permit of generalised statements.

A long narrow room has been divided by a translucent back-projection screen measuring roughly 8 ft. wide by 6 ft. high. At the back of the room behind the screen is a set of small slide projectors fitted with pre-registered slide changing devices and continuously variable filters controlling the colour, brightness and degree of diffusion of the projected beams. The apparatus is remotely controlled from a small console in the viewing half of the room where the therapist sits near the child and can thus control the projections while watching the child's reactions. The console also controls coloured lighting in the viewing room.

The projected designs are made graphically, usually in two parts so as to permit of two-colour projection (often *figure-and-ground*). These are then photographed and projected as small black-and-white transparencies, the colour, brightness and sharpness being controlled as required by the therapist. The child is seated in front of the screen so that the screen occupies nearly the whole of its normal field of vision. The therapist is seated to one side and operates the controls in complete darkness and silence.

A typical sequence might be this: The room-lighting is slowly dimmed to a deep red. The screen is empty and looks grey. Gradually the screen becomes luminous and a warm-coloured cloud of light appears in the middle. Slowly this takes shape and a rounded form appears which might resemble a pair of wings, or lungs, or even two halves of the brain. The inside of this form is a cold blue, while the background is a fiery red. Slowly the colours deepen until the blue in the middle begins to take on a violet hue. At the same time the red in the surrounding has died away, and now the inside of the form begins to glow with red while the surrounding lightens to a cold blue.

The restless small headed boy who is watching gets very excited each time the inside of the form changes from blue to red. He sits quiet and contented at the glowing red shape in the blue surround. Now the whole picture melts into light, leaving the screen empty. The room light comes on once more and the light on the screen fades. Then the whole cycle is repeated.

These sessions usually last 15-20 minutes and may be repeated up to three or four times in the week, continuing for several months on end. In almost every case the child is only too eager to come back for more. The experience of letting one's imagination float out into a world of changing colour quite unrelated to the things of everyday life, at the same time being left entirely free, seems for many children to meet a need which is as real as the need for food and drink. One might describe it as a kind of inner 'massage' at the level of perceiving and feeling.

In the case of another child - this time a girl of nine who is very self-centred and suffers from epilepsy - a different design is used. Here a radiating star-like form appears in golden yellow against a blue background. The star then lightens from gold to white and the blue sky fades to a pale green. The green then changes to pink and back again, and continues to oscillate slowly but regularly between green and pink, while the star remains white. The girl, who took no interest in the golden star in the blue sky, now forgets about herself and becomes rivetted to the slowly swaying colours on the screen. This continues for some minutes while she remains quiet and concentrated. At no other time in the day does she achieve this mood of peace.

We find that many children develop a quite personal attachment to the form which has been designed for them. If the wrong form is shown to them or if the balance or sequence of the colours is not what they expect, then they register immediate disapproval. Occasionally they will give a name to their particular form, or, if their speech is fluent enough, even tell a story about it.

We made some colour transparencies of one or two of the more static design we have used, and these may give you some idea of the kind of organic though non-representational forms we are using.

1. In an onion-like design the yellow light from above is splitting open the round blue form and making it unfold like a flower. It could be compared to the light of intelligence taking hold of a lethargic physical organism.

2 . A curvilinear red-green design probably makes you feel that it works on the circulator dynamics of the body. The feeling you get from just looking uncritically at these designs will tell you more than any descriptions I can give you. A purple-and-gold design was for a thick-headed boy who had no reverence or respect for anything.

3. A curious design in red and blue was intended to give the most violent conflict that we could devise between the nature of red and the nature of blue. It was for a tough little boy whose behaviour seemed more animal

than human. He had no speech but would bite and scream when roused. Red light in the room would quieten him, but it was just one particular balance between red and blue in this projection that seemed to satisfy him. No other nuance would do. (Mr. Wilson showed a slide in which the colours were reversed just to show that if colour and form are not suitably matched, the whole effect is lost.)

You will see that the possibilities for treatment of this kind are unlimited and quite individual. These designs and sequences are worked out by a team of colleagues who know the child in question. The process is a mixture of imaginative diagnosis, artistic judgment and trial-and-error, tempered by the technical possibilities and limitations of the apparatus. Some cases have been more successful than others, but in no case has a child been disturbed or frightened by the strength of the colours or shown any disinclination to return for the next session. It is the sophisticated grownups who sometimes find it hard to bear.

In conclusion I would like to say two things. One is that colour used in this way works therapeutically only when the feeling and imagination of the patient is unhindered by any intellectual considerations. As soon as a child begins to want to rationalise about what it sees, we know that the therapy situation has come to an end and that the child needs school lessons. The other thing is that we have learnt that colour is not a thing or a quantity, but is more akin to a force, or process, or movement. In this respect we find Goethe's approach to colour eminently realistic.

Problems of Colour Education for Art & Design

J.Fish

To many people outside the present system of art education, it must seem surprising that there is no agreed framework of colour knowledge regarded as essential to courses in Fine Art or Design. Few would argue that the ability to manipulate colour with skill and understanding is not a professional requirement in most, though possibly not all, areas of fine art and design. Technically the artist or designer working with colour is interested in the 'colour sensation' which he controls by manipulating the 'colour stimulus'. (Colour Stimulus Synthesis: ref 1) Therefore it might be expected that the fascinating body of experimental fact about the colour stimulus, the colour sensation and the way that the one relates to the other, would be considered relevant to art education. However, only a few Colleges appear to teach colour at all seriously and factual knowledge of colour is not obligatory to obtain the Diploma in Art and Design. In other words it is possible for a student to obtain a 'degree level' qualification to practice design or to train as an art teacher without the most elementary knowledge of colour science.

Why is this?

It is possible to classify (very glibly) learnable knowledge of colour into two classes:

1 **Positive Knowledge** which is:

a Based on repeatable observation and experiment,

b Communal and impersonal,

c Valued (if at all) by art students as a *means* rather than an *ends*,

d Motivated by interest or applicability.

2 **Visual/Aesthetic Understanding** which is:

a Based on intuitive value judgements,

b Personal and only partially communal,

c Valued by art students as an '*ends*' as well as a '*means*',

d Motivated by desire to express or communicate.

Teachers and students who accept this classification argue that only the second class of colour knowledge is relevant to art education. They will point out that many of the greatest colorists of the past needed no colour science, but developed a private understanding from their own intuitive practice. The 'colour theory' which used to be taught rarely included experimental evidence and often contained vague or fanciful ideas which had to be taken on trust. Such teaching rightly fell into disrepute on the grounds that it could inhibit the development of visual sensitivity. It is true that Seurat was greatly influenced by Rood and Chevreul (ref 2). However, they would maintain, Seurat was exceptional and his type of 'scientific' approach has few adherents today. 'Colour Science' and 'Colour Art' are quite different, they argue, and should not interfere with each other.

That this divided attitude to colour really exists can be seen by anybody who peruses a library for books on colour. Scattered as they will be throughout the Dewey system of classification, the majority of the books will be found to fit into one or other of the two classes.

There are grounds for believing that this *laissez-faire* attitude to colour education is out of date. The classification upon which it rests is over simplified and misleading (ref 3). It reflects the damaging division which still exists in education between *science* and *art*. The difficulties of teaching colour and of finding staff qualified to teach colour, are rooted in an inappropriate structuring of the subject matter. Colour is not two subjects, it is one.

A detailed analysis, of the reasons for teaching colour as a factual subject open to experiment, as well as (not instead of) an intuitive subject, is beyond the scope of this paper. The arguments for Fine Art and Design are not exactly the same and would have to be stated independently. In this context it would be of immense help to the practising teacher if an authoritative body were to make specific recommendations. Here it will simply be stated that even a cursory examination of new directions in Fine Art or contemporary criteria for good Design would provide ample justification.

Useful objectives for an integrated colour course must be stated as far as possible in terms of observable behaviour (ref 4). The difficulty is that the most important objectives are unobservable. It is only possible to look for signs that they are being attained. The other great problem to be faced is the question of how such a course can be taught. Here the attitude of motivation of the student is all important. Ideal objectives frequently have to be rewritten to conform with the realities of present education. Therefore the objectives listed below are merely 'possible' objectives suggested as a framework for the discussion of methodology which follows.

General Objectives

1 To promote observable changes in behaviour likely to assist the student in attaining his own goals relevant to colour.

2 To achieve standards of ability in the use of colour which can meet appropriate professional responsibilities.

3 To foster a closer relationship between colour science and colour applied to fine art or design.

Next it is necessary to decide exactly what changes in behaviour should be taken as indications that the above goals are being realised. In suggesting these 'Specific Objectives' the following assumptions have been made:-

a That learning is more important than teaching.

b That first-hand experience is more likely to lead to learning than second-hand experience (ref 5).

c That learning by direct experiment is as essential to Art education as it is to Science education.

Unfortunately the third assumption is not universally accepted. It is intended to include both systematic or controlled experiment and discovery by accident or intuition. This distinction is important though it is not always made in art education.

Specific Objectives

1 To generate interest in colour as evidenced by:

a Reading Habits,
b Willingness to experiment,
c Curiosity,
d Persistence.

2 To develop the ability to design and conduct systematic experiments with colour including:

a Framing hypotheses,
b Using controlled experimental methods,
c Recognising legitimate conclusions.

3 To provide the student with an appropriate knowledge of colour as evidenced by:

a Written examinations with student consent,
b Verbal discussion,
c Descriptions of personal experiments,
d Studio Work.

4 To enable the student to perceive a relationship between colour Science and Art, and to apply a knowledge of colour to his studio work as seen by:-

a The generation of new ideas,
b Greater depth,
c Greater visual sensitivity,
d Problem solving ability.

One of the great difficulties in realising these objectives is the fact that many students come to colleges of Art with no great liking for analytical or 'convergent' subject matter. Frequently they are hostile to science or to attitudes that they think science represents. Few first year students see any advantage in systematic study involving observation and experiment, or (even worse) calculations and graphs. This is quite natural since the educational separatism to which they have been exposed has encouraged their belief that there is a fundamental difference between the working methods of scientists and artists. Close examination of good scientific research or original work in the arts reveals how superficial this attitude is (ref 6). The goals may be different but the creative processes are strikingly similar. Sometimes studio experience or a closer knowledge of the problems that they face in professional practice leads students to discover this for themselves. But it may be too late. Nothing is sadder than the sight of a student in his last term discovering that he cannot solve the problems that he wants to solve for lack of theoretical understanding or of experience of experimental methods.

One of the functions of Complementary Studies should be to bring about this change of attitude as early as possible in the student's education. In teaching colour, motivation and an interest in fundamentals with some perception of Its applicability have to be generated. Even the love of colour cannot be taken for granted. This task is almost impossible without:

a Adequate time-tabling.

b Term-teaching from staff with the appropriate disciplines.

c The provision of laboratory facilities for practical work.

In the past it has been difficult to meet these conditions. However, with the widening horizon of art education great opportunities now exist, especially within the new polytechnics.

A traditional approach is summarised below:

1 Lectures on Colour from several staff.

2 Set experiments relating to lectures.

3 Suggested reading.

4 Student finds application himself.

5 Student does applied experiments.

6 Special application to studio work.

7 General application to studio work.

This approach at least has the advantage that information can be presented in a logical, progressive sequence. Also it is open to the rigid structuring which may be necessary where a high student to staff ratio is forced.

Unfortunately these advantages are outweighed by the disadvantages. A logical presentation of information does not help the student to see the relevance of colour knowledge to his own work until late in the course. Therefore he is weakly motivated. Another disadvantage is that set experiments which follow lectures are not genuine. They do not develop curiosity, nor the ability to design genuine experiments. Lastly, recent research suggests that the lecture whilst it may be useful in conveying information and (with skill) ideas, is a poor technique for changing attitudes or generating interest (refs 7 &8).

Typical responses of students initiated on this type of course are, "Of course I am interested in colour but not in that kind of way" or "I hate laboratories because they are too much like school" (verbatim). Gone are the days when students could be told what they ought to be interested in. Art schools now operate in an atmosphere of almost total intellectual and creative freedom. The danger is that the self-discipline necessary to solve really difficult and worthwhile problems may not develop.

The following alternative approach has proved more successful in practice. It is intended to give priority to student motivation and to minimise the distinction between systematic and intuitive attitudes. The idea here is to 'seduce' the student by gradual stages into discovering Colour science for himself. It accepts the need to work backwards from the studio situation until interest is awakened.

1 Team teaching seminar on colour function and quality in Fine Art or Design.

2 Individual studio colour problems are discussed.

3 Each student performs personal experiments in an aspect of colour directly related to his studio work.

4 Student reads relevant literature on his selected colour topic, including original scientific papers.

5 The results of experiments are applied to studio work. New problems will arise and further development may be suggested.

6 A course of reading and experiments by consultation with the student and examination of his professional requirements.

7 General application to studio work.

This approach, and its variations, have the great advantage that the student can see at once how a study of colour can be related to his own studio interests. In addition it means that experiments need not be prejudiced by prior reading or lectures. Genuine experiments are essential to promote an understanding of research. They are also much more likely to bring about desired change of attitude.

On the other hand, this method involves an illogical sequence of study which may hinder the clear understanding of important principles. Also the student may get side-tracked and never obtain a complete coverage of the colour knowledge that might be useful to him later. Provided stage 6 is arrived at and followed through, these difficulties can be overcome. However, shortage of time and the slowness of natural 'self-discovery' may make this impracticable. For example, a student who wished to study interior design at another college, performed interesting experiments on the effects of tungsten illumination on metameric colours. However she could not read the literature on the subject because she had no time to properly understand the C.I.E. system of colour specification. In her case a traditional approach might have been more appropriate. Possibly an ideal system would be a flexible combination of both methods closely adapted to the needs and motivations of individual students. The difficulties of organising such a course are immense. However greater flexibility might be made practicable by the discriminating use of programmed learning and other new techniques. There is an urgent need for more research into this problem.

The questions posed here will never be answered until it is more generally recognised that some experimental sciences have a real relevance to the visual arts. The subject of colour is an excellent example of the need to break down the barriers between separated disciplines. Fine Art and Design still seem to be disorientated by the knowledge 'explosion' and the growth of technology. Students can hardly be blamed if they are bewildered and intimidated by the multiplicity of styles and media or the logarithmic increase in techniques and processes. Though it may have served in the past, 'rule of "thumb' knowledge is far too flimsy a foundation to meet the requirements of late twentieth century culture.

References

1 BURNHAM, HANES, and BARTLESON. *Color: A Guide to Basic Facts and Concepts*. 1963.
2 HOMER, William Innes. *Seurat and the Science of Painting*. 1964.
3 HELMHOLTZ, H. v. *On the Relation of Optics to Painting*. 1871 -1873. (Published in WARREN and WARREN *Helmholtz on Perception*, 1968).
4 MAGER, Robert F. *Preparing Instructional Objectives*. 1961.
5 DEWEY, John. *Experience and Education*. 1938.
6 VERNON, P. E. (Ed.) *Creativity.* Penguin Modern Psychology Readings
7 McLEISH, John. *The Lecture Method*, Cambridge Inst of Ed. 1968.
8 BLIGH, Donald A. *What's the Use of Lectures?* 1971.

Colour Awareness and the Environment

S. Donaldson-Walters

Art activities are at their best when incorporated in everyday affairs so that everyone is involved. (Miss Donaldson-Walters showed on a slide and described a great variety of Victorian children's toys, illustrating how an artist-designer can be engrossed in visualising through colour.)

In the west, particularly in this country the training of an artist has become polarised. Either he may through outward necessity decide to follow a design course; or he may wish to express his inner feelings through painting or sculpture in a fine art course.

This dichotomy does not occur in a primitive society, where the likelihood is that everyone will have painted at some time. Primarily to retain his spiritual heritage and the stability of his society the primitive usually follows an accepted system of teaching the younger members of his group the myths and legends of his own people. Painting is the graphic expression of this inherited knowledge. Anthropologists report that detribalised natives miss their traditional rituals which they are taught to enact as ceremonies as children,

If we think of the bark painting of New Guinea or Australia we can imagine the process as something like this. A search is made for a suitable tree offering bark that is both firm yet supple. One man will cut the tree trunk with an axe, and slowly and carefully peel a piece off. This piece will then be cleaned, unrolled and straightened over a fire. It is flattened over the knee, and weighted down with sand or stones. Having dried, it is rubbed down with a sticky juice, perhaps of a wild orchid.

This gives it the priming on which to paint. Sometimes colour is introduced at this stage to give a coloured ground, red or black. All colours used are of natural origin; such as the earth colours, the ochres, yellow, red and brown; white clay; and black made from crushed charcoal. It has been said than an aborigine will walk a hundred miles for a good ochre. Ochres of finest quality are a source of wealth and form of currency. Everyone becomes involved in the act of painting. If we think of a piece of decoration needed for ceremonial purposes, some eight men may be working together on it. An elder may outline in white, another add dots, and others add the ochre areas, the burnt ochre, the warm brown, and so on to the youngest who may prepare the paints, either by grinding the earth between stones, or chewing the burnt grounds from the bottom of a cooking utensil, adding leaf or chewed bark td his spit and making black dribble to become black paint. In having only a limited range of colours great care is taken that they are used in the right areas. The primitive uses a graphic means to express his people's iconography. In our society when we say someone is expressing themselves colourfully, we mean they are using an extremely vivid vocabulary!

Attempts are being made to increase the public's awareness of the necessity for the arts within daily life; and the Greater London Arts Association has organised Summer Art Courses especially for young people not necessarily going to pursue art as a career.

(Miss Donaldson Walters showed a very impressive and moving series of slides of young people's activities on a grand scale, demonstrating how these could be a spectacular success, given reasonable facilities.)

Colour Psychology in Art & Design

Don Pavey

The psychology of Colour for a designer is, more often than not, a matter of his having to ask himself 'Am I pitching my colours at the right level of expression, and in the right mood for the job in hand?' And if he has been brought up in the tradition of the Bauhaus he will be well aware of the notion of what we would call today the 'stimulus gradient'. The painter Paul Klee, for example, who lectured at the Bauhaus, described a range of expression from the explosive 'expression which tries convulsively to fly from the earth'; the effect of 'power', 'full-blooded strength'; and the 'severe'; to the 'relaxed', the 'serene' and the 'vague' (ref 1). A similar sequence of what would now be called environmental effects of colours was described over a hundred years earlier in Weimar, site of the first Bauhaus, by Goethe. These were the 'lucid', the 'mighty', the 'serious', the |serene' and 'melancholy' colour chords (ref 2). It was implied by the artists of the Bauhaus that all works of art might be placed on such a stimulus gradient. No doubt our Op and strobo effects of today would have been placed at the peak, and the most subtle atmospheric nuances at the foot of the gradient. Between the extremes of say, psychedelic disorientation on one hand and subliminal suggestion on the other, it is easy to visualise a gradient of effects that might well be compared with the range of expressions of the human voice, from a shriek, a shouted command, and modulated speech, to the barely audible whisper. It can be demonstrated that colours communicate similarly through levels of **1** maximum intensity and field contrast (the stimulant level), **2** high intensity and contrast, (the potent level), **3** moderate intensity and contrast, (the modulant), and **4** low intensity and contrast, (the tranquillant).

If one is prepared to make some generalisations, it does become possible to construct a serviceable frame of reference for the prediction of environmental effects on, for example, a statistically significant majority of observers. A first assumption one needs to make is that for all practical purposes, the more violent the field contrast - the stronger the impact will be of the colours received. A second assumption is that the lighter hues at full saturation are always likely to be punchy and stimulant whatever the field contrast. In most other circumstances it can be safely assumed that tonality (i.e. light/dark value and contrast) takes precedence over colour in determining level of impact. A tachistoscope shows that some tone-contrasts can be seen often several thousandths of a second before the hues. In my experience working with a tachistoscope rod vision is faster than cone vision. If this is so, it is not surprising that tone Contrast plays such a vital role in creating the precise character of an impact.

THE ACHROMATIC STIMULUS GRADIENT

At this point, a square frame of reference was shown giving sixteen tonal contrasts. Horizontal rows gave at the top four maximal contrasts, over four at high contrast, over four at moderate contrast, over four weak tonal contrasts. The first column gave four black backgrounds; the second, four dark greys; the third, four light greys; and the fourth column, four white grounds. Square motifs giving a tone contrast appropriate to the levels of impact were set into each background.

Given a very dark environment (see the black squares of the first column) it can be demonstrated that the most strongly contrasting tonal motif has to be white, the next is light grey, followed by a darker grey or black (!) against black, as in one of Malevich's paintings providing the whispered contrast. Similarly within a white or very light environment (see the white squares of the fourth column) the most violently contrasting motif has to be black; and motifs of succesively diminishing impact can be created by lightening the black motif in easy stages using, say, the Weber-Fechner (ref 3) concept. So far this is almost too obvious to need mentioning.

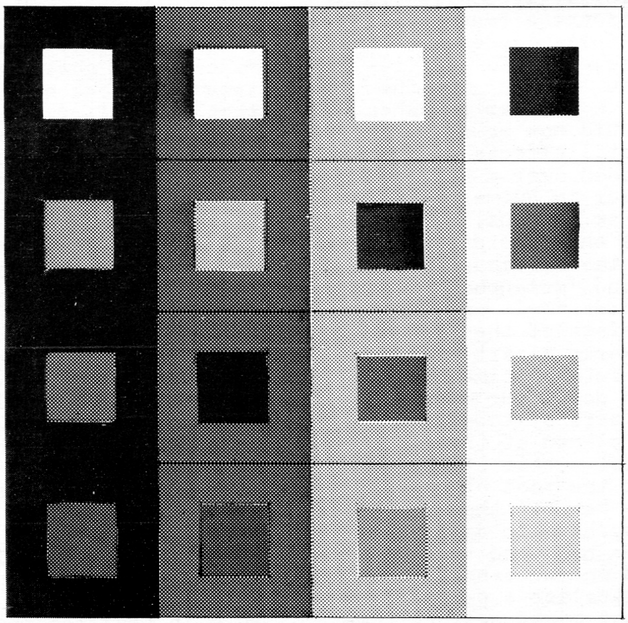


DIAGRAM OF A TONAL CONTRAST GRADIENT

But what happens when environments neither particularly light nor excessively dark become backgrounds for diminishing tonal contrasts? See, for example, the two columns of greys. At the top of the dark grey column, white again gives maximum contrast; and at the next level down the dark grey column, any light grey will still give quite a striking contrast. Complications arise, however, at the two lower levels. A black may very well be required now at moderate level, so that a new dark grey (lighter or darker than the ground) can be used at the lowest and 'quietest' level.

It may well be found that white gives yet again the strongest impact - at the top of the light grey column. This can be checked with a tachistoscope. But at second level down the frame of reference it can be seen that black or dark grey will give a strong, even very strong, contrast, though less of an impact than the previous one according to the tachistoscope. At third or moderate level it is easy to find a medium grey which will make an evenly descending step in stimulus intensity; while at the bottom of the column a light grey (slightly lighter - or darker! - than the ground) can be seen to give the required 'whisper' or subtlety of contrast.

The whole array of contrasts shows a diagonal of black motifs, illustrating that as an environment lightens so black becomes increasingly important as a stimulant motif. Moreover, the row of white motifs at the top of the frame of reference shows the importance of white as a stimulant even without excessively strong field contrast. Such concepts as these, obvious to the experienced designer, need to be stated and demonstrated before a research into the environmental effects of colours can be begun.

One rarely enters an ambient blackness of whiteness. Our normal environments tend to mid luminance, obviously. The squares on the grey back-grounds, then, are particularly significant, showing that each step of the stimulus gradient needs to be seen as a node rather than a simple arithmetical position in a Weber-Fechner gradient, each node carrying its own distinctive variations of possible effects at that level. Moreover, if the neutral greys, blacks and whites can evoke a whole constellation of effects, how much more so can the vast number of modulations of hues and hue contrasts.

THE CHROMATIC STIMULUS GRADIENT

As successive complexes of colour were mentioned the frame of reference was used to uncover, for example, a first column of four different blues a second column of four green variants, a third column of reds, and a column of four yellows. The columns had very high luminance hues (including the subtractive primaries) on the top row, less high luminance hues (including the additive primaries) on the second row, variants of moderate luminance and moderate intensity on the third row, and subdued gradations on the lowest.

The Stimulant level

At the climax of the stimulus gradient, yellow is used, for example, in the heavy-machine industries, together with black, for the most urgent warning of immediate danger. Closer to home it is a colour which many children use most in their paintings on their birthdays, to judge from the researches of Drs. Alschuler and Hattwick (ref 4). In fact, the Institute of Contemporary Arts discovered to their cost that the stimulant effect of yellow is so intense that it can incite children to vandalism. At an IGA exhibition of toys which were displayed in differently coloured rooms, all those in the yellow room were broken. The vivacious effect of yellow in many contexts makes it a peculiarly apt colour for the orgasmic expression of the discharge of impulse. The designer who wants a colour that will 'scream' in most contexts has no difficulty (ref 5). One can always get a violent effect with yellow if it is placed against black, purple, or any dark colour. It is the one hue that comes to its highest intensity at its highest tone value. Also, by contrast with many other colours, especially greys and blues, it seems (to those who are sensitive to illusions) to enlarge. This may be because it is received by two of the three sets of cones in the retina - the green and the red. In addition yellow usually contains a lot of white light which is picked up by the rods, so that yellow rays are received over a far larger area of the retina than the other colours.

Amongst the greens it is the lime greens that are the stimulants. Designers are usually aware that all greens, especially the yellow-greens, can be used to advantage in expressing different kinds of visceral sensation (ref 6). Lime green can easily create an 'edgy' effect - sharp and ascerbic as in so many of the spiney and prickly effects in Graham Sutherland's paintings. In unpleasant contexts it has been associated with nausea - sometimes used in the colouring of gas chambers as at San Quentin.

From a range of very different reds, few designers would hesitate to identify the subtractive primary Magenta as a 'screaming' stimulant.in many contexts - Shocking Pink, as it was called by Schaparelli in the '20s. The light bluish reds at full intensity are capable of expressing a whole ostentatious array of effects from a theatrical panache to the most convulsive of expressions. Ritual and sexual display sport these colours well. Tyrian purple, very like Magenta, was the colour of the robes of the Roman emperors, and much later the cassock of Roman Catholic priests. On the other hand, the same colour was set around the diaphanous garments of ancient Greek prostitutes. Magenta colours often seem to vacillate between red and blue, changing even as you watch them. Many designers have been conscious of this oscillant red-blue ambiguity and used it with piquancy in the expression of female coquetry and vacillation. Luscher associates it with naive desires for magical wish-fulfilment.

A stimulant amongst the blues is the subtractive primary Cyan (the greenish variety rather than the printer's cyan). This has a lightness and aerial quality. Its environmental effect is cool, fresh and bracing. It affects us, said Kandinsky, 'like a high cerulean sky' (ref 7). Sky blues have, not unexpectedly, been used by many to suggest freedom and escape - by association with the bright sky as of the Mediterranean. An intense light blue such as Giotto used in the St. Francis frescoes at Asissi is well capable of expressing feelings of liberation - freedom from the constrictions of dogma, for example, - or from convention, as in the lucid skies of the Surrealist, Magritte.

The Power level

The reds of the frame of reference provide, as it were, the heart of the system, in as much as they are, above all, colours which can be used to very special effect wherever positive and active confrontation has to tie made, especially in human and emotive contexts. The power red, Vermillion or Flame - the additive primary red, is the most forceful representative of the power level. It has a strength of impact that can be very appropriate in the expression of strong emotions such as love and hate. Even Mondrian in his non-figural Neoplasticism, attributed strong emotive values to his cloisons of red. As the psychomotor colour, the relation of red preferences to sexual potency has been described in clinical colour tests (ref 8). A special feature of the additive red is that it appears to be on a plane in advance of its actual position - though you may need the perceptive eye of an artist to appreciate this consciously, otherwise its effect is subliminal. Red rays normally focus 'behind' the retina, and in order to accommodate them the eye has to make the same change in its lens - it dilates it - as it does when looking at things nearer. This seems to be the reason why this red gives an impression of strength that under most conditions will appear to dominate and assert control over any other colours that are placed nearby.

Amongst the yellows at power level, deep orange yellows have most often been used for their environmental effect of expansive and 'energizing' radiance. In fact, the Bauhaus designer, Johannes Itten, saw red-orange as the colour of 'passionate physical love (ref 9). Orange has been an erotic and Bacchanalian emblem, as in Poussin's painting, since the Baroque era. The warm golden tone of much Renaissance cultural expression generally was more of a feast of delight for the flesh than the liturgical blues and purples of Gothic Art; and even in Victorian flower symbolism the marigold was a symbol of carnal lust. It reminds one that in the nursery world one research has shown that an over-emphasis on orange in children's painting can relate to auto-erotic activities and fantasies (ref 10). As the 'magically' heightened colour of Caucasian flesh, orange has a rich healthy and invigorating effect capable of reflecting a malestrom of interpersonal activities in the energetic working out of impulse, as Kandinsky said 'like a man convinced of his powers (ref 11).

The power greens, signal or grass have an orectic amplitude as the colours of, according to Itten, 'fruitful-ness' and 'incarnate sentience' (ref 12). Grass green, one of the oldest colour names, stands for a whole range of power greens, from the additive primary band. The sensation of exuberant fulness (ref 13) which many observers experience on seeing these greens, make them good colours to be used in the expression of all kinds of potentiality -fertility, pregnancy, puberty, growth and so on. As the medieval marriage colour it is worn by the famous Arnolfini bride in green painted by van Eyck.

The power blues are the additive-primary blues. Designers call this band of colours - ultramarine, blue-violet, or blue-purple.. They see these colours as being tinged with red. These 'charged' or 'electric' blues, together with the other two additive primaries, played a leading role in the structural colouring of paintings after the Neo-Impressionism of Seurat. Their vogue was brought to a climax in the strident mystical expressionism of the German painter Nolde, and later in the paintings of the Blaue Reiter group. The reddening of blue presents the spectator with the paradox of something brought forward which is much more, apt to recede. As such, the painter and designer, finds it an admirable colour in the promotion of 'the remote' - in, for example, idealistic militancy; though the darker one makes this blue, the more disciplinary and severe it can seem to become, especially when contrasted with light effects.

The Modulant level

Of the colours of moderate impact, the Viridian greens have very good focal acuity, appearing neither to advance nor recede from the surface they are on. Turquoise and Sea green colours are particularly useful to the designer in making for precision and equilibrium, as in diagrams, systematic flow patterns, indicator panels, monetary notes, and so on. Like black, these colours have the quality of incisiveness, but without black's static 'inertness'. By comparison, the intensity of some greens remind one that the retina is more sensitive to green than to the other additive primaries, and green occupies a central place in the spectrum. After all, it has been necessary over evolution to identify green especially clearly as a food signal, and it is presumably deeply imprinted on racial memory as embodying the essence of vegetal (ref 14) and biological life. This comes out best, perhaps, in the Islamic delight in precise geometrical filigrees of viridian-green tendril interlacements, as in the honeycombs of so many Arabic mosques. These green organic patterns can be compared with the precise modulations of the human voice tuned to the communication of specific information. At this level, colours 'converse' rather than 'shout' or 'whisper'.

Thus, if you suffuse blueness and darkness over a stimulant red it is as if a 'cold cast of thought' has been thrown over the fire of human action. The modulant reds, or reds of restraint - oxblood, burgundy, and plum red, have played a fascinating role in the history of cultures as symbols of moral responsibility, from the colour of the first Durex contraceptive packs to the dark-blood symbol of sexual obligation in the images of Shakti in Tantric art. The addition of blue, the relaxed colour, seems to inhibit rather than relax a red, and the moderate reds can be very morose and sombre, even used by some children to express sultry moods of inhibition and foreboding. In interior design, this maroon colour used on loo walls of one factory much reduced the time people spent in lavatories. In a good sense it can relate well to 'ethical' expression, in a bad to the guilt-ridden and anxiety-laden (ref 15).

As to the moderate amongst the blues - deep peacock blue, the biologic and aquaeous qualities of greenness are combined with the receding qualities of blue, here more appropriately associated with water than sky. Greenness (which has been called by many schizophrenic painters the colour symbol of the 'biologic and vegetative' self - as against the reasoning and judging self) is made more cool and aloof by the addition of blue. The resulting turquoise colours have been called the Narcissistic and aquarian colours, not after the picturesque story of the youth who loved his own reflection in the sea-green pool, but because they enhance flesh by giving it a healthy glow when put alongside. Colour-preference statistics confirm the role it plays in relation to the self-reflective emotions, as of self-esteem (ref 16). Derivatives of the greener cobalt pigment, Delia Robbia blues and some of the Sevres blue-greens have well lent themselves to expressions of aesthetic elegance. These hues have been used as a symbol of pride as often as the peacock itself; and they are colours which have become a civic cliche in many new town centres.

When yellow is darkened it turns a greenish citrine or gall yellow, the modulant amongst the yellows, and classical symbol of the choleric temperament. This is a colour of exquisite beauty - or sick-making ugliness if you don't like it, carrying all the more bitter and sour associations of yellow. In this modulation of yellow the quality of 'gushing radiance' is inhibited as if an expression of the retention of impulse. Maybe this colour can be seen best in Dada art, as for example, in Marcel Duchamp's studies for the 'Bride stripped bare by her Batchelors Even ...' Statistical preference surveys suggest that citrine has a unique appeal for the hypersensitive critic. Disliked by many for its sour and bilious effect, a distinquished few see in it a spicy attractiveness. As a fashion colour, it is as much in favour today as ever before. Perhaps this says something about our age.

The Tranquilant level

On the other hand, many blues seem to recede and to be further away than the surface they are on. The opposite of red, blue rays focus in front of the retina, so that the eye has to make the same adjustment - it narrows the lens - as it does when it looks at things further away. This makes almost all blues invaluable in expressing distance, and concepts and symbolisms relating to things one step removed from this world (ref 17), ideal, philosophical, mystical, or just fanciful. The tranquilant blues are the non-specific low-intensity grey blues as of the night sky darkening to night, creating as it were, a ready dream-screen for our half-conscious fantasies. The relaxed and dusky blues, Chinese blues and the shyam blue concept of the Rajputs, demonstrate the tranquilant effects of blue at the lowest reaches of the gradient - passive heteronomy, or as Kandinsky put it, 'supernatural rest' (ref 18).

The sedative greens, olive, sage, and sludge are often used to create a rich, humid and sensuously relaxed effect, as in the background of the Mona Lisa, or more menacing in the rather gruesome personification of the spirit of Nature in the Dadaist Max Ernst's 'Nymph Echo' otherwise known as the Chlorophyl Spider. The most lively member of the sedative group of greens is that of the pigment Scheele's Green which can be seen in a great deal of Finnish design today, especially the Riya products.

Even red can be relaxed - by the addition of brownness, creating a whole range of earth reds, warm and elemental; Bokkhara red, Venetian red, and the brown reds, burnt umber and burnt sienna. These have what the designer, Itten, described as 'earthy and earthly' qualities (ref 19), - as of the umbers in paintings by Dubuffet, or the trendy browns of American Colonial architecture. Soft-and-rough textures as of hair or fur, will reinforce the familiarity and warmth of contact these colours so easily evoke, and they complement the 'Soft' trend of the early 1970s.

The tranquilant yellow is made by reducing yellowness to an ochre, beige or the colour of natural substances such as sandstone or dry sponge. Almost all intensity drained away from yellow results in a very subdued effect, as it were an expression of 'impulse discharged' or the soothing quiet after the storm - a placid expression of calm as in Nolde's painting called 'Silence'. These yellows can be seen at their best perhaps in the work of the Cubists, who were reacting amongst other things, to the overbearing emotionalism of the Expressionists' use of the red, green and purple primaries.

Gradient zones of the colour-solid

Impact, or the 'stimulus' of the stimulus gradient, is not just another parameter like hue, luminance and saturation, but a function of all three. It may be graded through the designer's colour-solid, making nodes, zones and strata which shift with every new field contrast. However, in spite of these shifting configurations it is possible to construct more or less identifiable areas of maximal stimulus, high stimulus, unambiguous stimulus, and weak equivocal stimulus. The shifting loci of these zones are described in the Journal of the Colour Group no. 14 p. 156 (ref 20). The colours I have called stimulants, especially including the subtractive primaries, crown the 'head' of the colour-solid; the power colours, especially the additive primaries, tend to make a cylindrical cope wrapping the main body of the Colours; the modulants, especially including low intensity subtractive primaries, more or less girdle the waist and skirt of the solid, while the tranquilants, especially the low intensity additive primaries, occupy the core of the solid.

One may see in the zones of the chromatic stimulus gradient, what the paint Paul Klee, possibly the greatest of all colourists, meant when he spoke of the 'phenomenon of many simultaneous dimensions which help drama to its climax (ref 21).

NOTES

1 KLEE, P. *On Modern Art*. Faber, 1948
2 ALBERS, J. *Interaction of color*. Yale University, 1963 Albers quotes and illustrates Goethe.
3 ALBERS, J. Op cit. Albers describes the Weber-Fechner law.
4 ALSCHULER & HATTWICK. *Painting & personality*. Chicago, 1947
5 Munch used yellow and red in his picture 'The Scream' and explained that he 'felt a scream pass through nature' and 'painted the clouds as red as blood. - The colours were screaming.' LANGAARD, J.H. Edvard Munch Oslo, 1964.
6 The special role of yellow and green in the colour preferences of patients suffering from gastric ulcers is described in publications of the German Psychosomatic Society, Bismark. St. 61. Berlin-Charlottenburg under Dr. H. Schmidt.
7 KANDINSKY, W. *Concerning the spiritual in art*. N.Y. 1947 (First edition.,1912)
8 ERBSLOH, J. Uber die Erkennungsmoglichkeit der Dyspareunie in Farbentest. Die Medizinische Welt, n 51. 1955
9 ITTEN, J. *The art of color. The subjective experience and the objective rationale of color*. Reinhold. N.Y. 1961
10 ALSCHULER & HATTWICK. Op cit.
11 KANDINSKY, W. Op cit.
12 ITTEN, J. Op cit.
13 Picasso, for example, said that the artist 'goes through states of fullness and evacuation .... I walk in the forests of Fontainbleau. I get green indigestion. I must get rid of this sensation into a picture.' Zervos, C. Cahiers d'Art, 1935.
14 BAYNES, H.G. *Mythology of the Soul*. Methuen. 1949
15 FURRER, W. *Die Farbe in der Personlichkeitsdiagnostik* Test-Verlag, Basle. 1953
16 FURRER, W. Op cit.
17 THYLESIUS, A. *De coloribus*. 1528
18 KANDINSKY, W. Op cit.
19 ITTEN, J. Op cit.
20 See also *Colour as stimulus* Athene, Journal of the Society for Education through Art, Vol. 15 n 2.
21 KLEE, P. Op cit. p 17.

Colour in Architecture

D L Medd

Colour is part of every aspect of our lives. This makes it difficult to disentangle those aspects which are central to the architect's concern.

RELEVANT CHARACTERISTICS OF COLOUR

Colour as illuminant and as absorbent

Colour as illuminant - the surface is a source of light - it is luminous.

Colour as absorbent - light strikes on the surface.

Sky is a coloured illuminant. Earth is a coloured absorbent. The first is intangible. The second is material and definitive. The first is a vague surface, hard to focus on and disruptive of architectural form. The second is articulate, hard and defines architectural form.

As architectural expression is a question of clarity and absence of confusion, the implications are obvious - a surface is better not to appear as a hole - architecture is not camouflage. {*A group of slides showed confusion of surface in terms of light and dark and how patterns and texture can clarify surfaces was shown*}

Attributes of surface colour significant in design

Hue, Lightness, Greyness/Clearness and Weight. These attributes are made explicit on the BS Basic Range for the Coordination of Colours for building purposes and thus becomes a design tool.

Design is always a matter of making decisions in terms of these attributes.{*A group of slides illustrated the attributes and showed appropriate ranges of contrasts.*}

Absolute and relative values

Architects are concerned with the appearance of colour on the job - not the appearance of the sample on the shade card, and therefore have to be able to reckon with the modifying influences. {*A group of slides showed modifying influences in practice.*}

THE PURPOSE OF COLOUR SCHEMES

Character

In recognising character as a first purpose, we are associating colour with people, their activities and the purpose of the building - and we are therefore not accepting dogma, fashion and formulae. Each situation breeds its own conditions and opportunities. {*Examples of colour responding and contributing to appropriate character were shown.*}

To express form clearly

Colour in combination with light can clarify or obscure form, and ambiguity is irritating - therefore colour can assist in architectural expression. {*Slides showed examples of disruption and articulation.*}

To promote good lighting and vision

Lightness of colour results in increased illumination through reflection.

Direct and reflected light have a pronounced effect on character, the first being controlled by the magnitude of the light sources - windows or artificial, and the second controlled by the nature of the colour on the surfaces on which direct light strikes.

Small windows and dark surfaces can combine to make gloomy or depressing interiors, or dramatic ones if spotlight circumstances are appropriate.

As reflected light assumes a bigger proportion of the total illumination, so it becomes easier to see in all parts of the interior - the interior becomes more unified - but the character may be either uplifting or anaemic. {*Examples were shown of how varying proportions of direct and indirect light, determined by colour, affect the character of an interior*}

Glare has to be alleviated. This occurs when brightness contrasts are too great for the eye to embrace. Examples of how colour causes or alleviates glare were shown.

The brightness round objects of attention has to be controlled, as the eye adapts to the brightest areas and surfaces less bright become difficult to see. {*Examples of how colour prevents or helps our ability to see what we want to were shown*}

THE CHARACTERISTICS OF MATERIALS

Natural materials have five important architectural visual characteristics:-

1 variation of surface

2 the closer you look the more you see

3 they are attractive to contemplate

4 minor blemishes do not appear as such; accidents are not disasters

5 age-change does not usually detract

There are also five considerations when putting paint on natural materials:-

1 preservation

2 the expression of function

3 the tendency to suppress texture

4 the ageing associated with aesthetic deterioration

5 that colour should enhance the natural material's qualities not confuse or dominate.

Examples of how colour can confuse or compete or enhance the qualities of natural materials were shown.

Industrially produced materials dramatically extend our range of expression and have yet to be mastered both in manufacture and use. Natural materials are associated with generations of familiarity and experience. Their limitations bred disciplines that are absent now.

INTEGRATION

We would probably agree that in the best architecture all the elements of design play their respective part in harmony to achieve a unified result that has a character appropriate to the situation. No aspect can be considered in isolation. Design is an indivisible process. A planning decision is a colour decision - a colour decision is a lighting decision and so on. Yet how often is colour considered the last job in the design process? Examples were shown of colour integrated with the plan and purpose of building, and of polarities of expression.

I have tried to describe the attributes of colour which the architect must understand!, to state the purpose of colour in architecture, and to show that these purposes are concerned with character, form and light irrespective of the dramatic changes in our contemporary vocabulary of design. I have also tried to show that good design integrates purpose, plan, form, light and colour.

Perhaps I can best summarise by a quotation from Charles Morgan's *Challenge to Venus*.

"Everywhere else light gives one a feeling that it is in some degree opaque and that it has colour. One speaks of 'curtains' of light, of 'beams' and 'shafts'. However wrong scientifically, one thinks of it as something almost touchable; that's why I said 'opaque'. Something coming through the air, distinct from the air, 'falling on' things, 'touching' them. But on the Rocca, looking over the plain or up to the sky one sees light differently. It isn't separate from the air, and the air and the light both are - well, Lord help me, I am in deep water - what do I say now? both are <u>clearness</u>, absolute clearness, lucidity. The air in a Bellini Landscape."

The Seven Colours

Ralph Brocklebank

Presented to the Group on Wednesday 9th May 1973 by the retiring Chairman.

The persistent popular belief that there **are** seven colours, in spite of repeated demonstrations that there are only four, or conversely that there should be thirteen, or even seven million, requires some investigation. It seems that the way we use words, such as colour names, may have a greater influence on our theories than is sometimes admitted. Concepts can alter percepts, as well as the other way round. Differences in usage between cultures need some sort of explanation, and if, for instance, the Greeks needed four different words to describe colours that are all 'blue' to us, perhaps it is our own usage that needs 'explaining'. Two kinds of explanation might be sought: the intrinsic (or organic) and the extrinsic (or historical); both are attempted.

Different answers to the question 'How many colours are there?' will of course depend on the concept attached to the word 'colour'. As defined in colorimetry, every different setting of the colorimeter (perhaps one should say, every discernibly different setting) yields a different 'colour', and though nobody has counted them all, estimates range from five to ten million, with seven million as a reasonable compromise. But I am glad to note that the CIE has now recognized that the concept of colour as a colorimetrically specified Stimulus is not universally useful, and does not even correspond very closely with what is usually meant by 'colour'. Groups of very similar settings give what would generally be considered as variations of the 'same colour', which implied that discernibly different stimuli are clumped or clustered into a smaller total number of conceptually distinct 'colours'.

One attempt to divide the total range of colours into conceptually distinct, rather than perceptually discernible, groups, is the ISCC-NBS Method of Designating Color. This has 267 distinct designations, which may be grouped in turn under less specific headings, and eventually reduced to 13 indispensible colour terms, the basic colour names.

Other attempts using other methods arrive at similar rtumbers: having learned to assess colours in terms of Munsell scales, one can conceive of, and consequently recognise fairly accurately, at most a few hundred distinct 'colours' - while the Munsell system is based on 10 hue terms plus 3 Neutrals. Again, counting through a dictionary I found about 200 colour terms where I could recognize what sort of Colour was indicated, and of these 17 were words whose primary sense, in English, was to describe a colour.

Not much sign of seven so far. Even if we follow the usage of discounting achromatic colours, we can eliminate only a few.

If we take another concept of colour, not descriptive, but what might be termed constitutive, then we can agree that some colours can be regarded as being mixtures or blends of others, and we find that the minimum number of essential constituents is reduced drastically - we are left with only 3 'primary colours' or at most 4 'unitary hues'. Not seven.

Is then the notion of the seven colours a complete myth? In the sense that a myth satisfies a human need while its truth is not literally obvious, I think we do have a case here of a modern myth - modern, because it appears to satisfy the requirement of being 'scientifically proved'. The popular belief in 'seven colours' is not based on any consistent concept of what is meant by 'colour', but on Newton's well-known experiment with the prismatic spectrum. Indeed, the matter is no longer left to be settled by common judgment, and mnemonics have been devised to make sure that you remember the right seven colours and in the right order; it is taught as an established fact.

The picture of the apparently pure white light revealing its components in seven colours makes a powerful impression on the imagination, and it has been used time and again in all sorts of metaphorical and even poetic contexts. Orpen, when his portrait of the Archbishop of Canterbury was criticized as not being a good likeness, replied 'I see seven Archbishops, which shall I paint?' One man revealed in seven moods: the source of the imagery seems clear enough. But is it based on scientific fact?

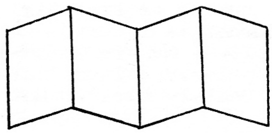
Before turning to have a look at the spectrum and Newton's treatment of it, let me say a few words about the nature of words. At one extreme, clearly and even narrowly defined, they serve the purpose of science; at the other, in an aura of associations and the emotive effects of the sounds themselves, they serve poetry. In between, in everyday life, they serve to express our concepts and relate them to our percepts, and because we are always being faced with new situations, it is necessary that our words be sufficiently flexible to allow for new meanings. Thus every word really must have a range or cluster of meanings if language is not to grind to a halt under an impossibly large vocabulary. We have already seen how colour names have to cover a cluster or range of perceptibly discernible colours; we should expect that such ranges might need to shift over the years, to meet new situations, and that languages that developed or diverged under different conditions might clump the percepts together into quite different conceptual groups.

An example of this is ancient Greek, which has about the same number of basic colour terms as English, but organized in a way that bedevils translators. For instance, there is no single word for yellow, but one for orange yellows (xanthos) and another for greenish yellows (chloros) which also has to serve for yellowish greens. Again, kvaneos is blue, but not all blues are kvaneos; some are halouraon. which might also refer to a purple, but probably only a bluish purple, because phoinikeos also meant purple as well as red. Bluish greens as well as greenish blues were qlaukos. and other kinds of blue were laxourion. charopos and aeroeidesi with no common term to cover the lot.

This example might suggest that the actual clumping of percepts is a result purely of historical accident, following no universal law of development. On the other hand, a recent linguistic study of basic colour terms in a large number of languages, by Berlin and Kay, seems to show that almost all languages fit into a clearly ordered scheme, in which additional colour terms are acquired in a definite sequence. For instance, all languages have words for black and white, and if they have a third term it is a word for red (thus confirming my belief that red is 'more primary' than other 'primary colours'). The next word to be acquired may be for yellow or for green, but not until both are in use will there be the need for a word for blue. After that comes brown, and we pause to note that at this stage we have seven distinct colour names. However, few languages pause in their development, and soon words for purple, pink, orange and grey will be added, though in no particular order. Each new term added will restrict the range of older terms, thus refining the concepts used: 'red' is a more precise term for us than it is for people with no words for orange, purple or brown, though we still find cases of the term being applied with a wider range implied, as you will observe if you match actual samples of red gold, Tyrian red, or red sandstone with patches in the colour charts.

This linguistic scheme shows that although there may be an innate requirement for colour concepts to develop in a given order, there is nothing special about the number seven.

Another thing to watch for is the way that concepts can alter percepts. We are not always aware that the process of perception involves more than merely recording sense-impressions; that we take an active part in formulating what we see. An obvious case is in the interpretation of ambiguous figures (as here, horizontal roof or vertical screen?), but a similar thing happens with colour mixtures, and once one interpretation has been learned, it may be very difficult to appreciate the possibility of a different perception.



This can be seen in the widening and narrowing spectrum (where in a projected spectrum, the slit-width can be varied over a range at least as wide as the dispersion width), especially when it is in motion. In one case, when contracting, the approaching yellow and blue edges overlap to 'make' green - or do they unfold to reveal the green that was already present in both? In another case, when expanding, do the red and green overlap to 'make' yellow, or do they unroll to reveal it as a new colour? (It is reallv necessary to see these processes both happening and 'un-happening' to appreciate the dilemma. Helmholtz, who studied these effects closely to understand what was going on, said that he had got quite used to seeing yellow as a mixture of red and green, and Aristotle - or whoever it was who wrote the *Meteorologica* described the yellow in the rainbow as not a new colour, but just the overlap of red and green, <u>phoinikeos</u> and <u>prasinon</u>.)

Habits of thought can be very hard to shake off, but one must admit that the experiment *itself* does not make the decision for you, so that no amount of unprejudiced observation will decide the matter. It is a question of choosing appropriate concepts, as much as finding the right words.

The Prismatic Spectrum

So now, in pursuit of our seven, let us look at the spectrum in its various proportions.

Newton is not really much concerned about the number of different colours revealed by the prism; he is more interested in the great disparity between the length of the spectrum and its breadth, and his diagrams mostly show five small displaced images of the hole in his window-shut, occasionally six or eight. His descriptions, too, typically employ only five colour names, and in his letter to the Philosophical Transactions, generally known as *The Origin of Colours*, there is very little indication that seven might be the preferred number. Indeed the only hint is in the fifth paragraph of the Doctrine, which reads as follows:

> There are therefore two sorts of colours. The one original and simple, the other compounded of these. The original or primary colours are Red, Yellow, Green, Blew, and a Violet-purple, together with Orange, Indico, and an indefinite variety of intermediate gradations.

So, although the famous seven are here named for the first time, five of them are preferred over the others, and the real point is that the number is indefinite. Only in the *Opticks*, published thirty-two years later, comes the description of the experiment in which an 'Assistant, whose Eyes for distinguishing Colours were more critical than mine' (that is Newton's) drew lines across the spectrum to note the confines of the colours, thus producing the diagram 'divided after the manner of a Musical Chord' into seven intervals . . . a comparison that has been much misrepresented (though that is a subject for another occasion) . . . and later in the book, the seven-segmented colour circle.

If the width of the aperture relative to the dispersion is correctly adjusted, then it is seen that the proportions of the seven steps quite reasonably represent the changes in hue; but if the width is reduced to present a more nearly monochromatic spectrum, then these proportions no longer seem correct: the blue and yellow are relatively narrower while the green is wider. The light blue practically disappears completely, leaving only what Newton called indico. What remains invariant is the 'indefinite variety of intermediate gradations'.

It is the continuity of this scale that has been important for colour science, providing the new dimension in the physics of light. The seven steps have really played no part in the development of the science of optics, though it is just this feature that has caught the imagination of the general public.

Before trying to account for this appeal of the seven colours in an historical context, I should like to look at the later course of colour science, to see whether the number seven turns up again, and whether there is any evidence from colour mixing or physiological optics that might help to provide an organic explanation of the need for seven.

Colour Mixing

The colour-mixture diagram used by painters, whether shown as a triangle, hexagon, or circle, has red, yellow and blue as three primary colours and orange, green and violet (or purple) as the secondaries, making six. One might add black in the middle to make seven, but apparently this never occurred to the painters; as colourists. they thought of the centre of their diagram as white, or non-coloured, and it was not until the painter Philip Otto Runge invented the Colour Sphere that an acceptable place was found for black - central to the six hues, yet opposite white.

It is noteworthy that these six hues are all named in Newton's seven, and that the one omitted, indico, is the one name that has never caught on in general use. Indeed, most modern descriptions of the spectrum extend the range of the word 'blue' right across to the violet. Did Newton introduce 'indico' to preserve the symmetry of the pattern? In some passages he uses the term 'blue' to cover all the colours at the most-refracted end of the spectrum, even including the violet, but in the famous seven there is no doubt that the name 'blue' is restricted to the turquoise or cyan colours, as we should call them today. The tendency to shift the place of the name 'blue' towards the violet, and look for a new name for the colour nearer to green, may be a case of that semantic change I have already referred to.

Another example is seen in the case of red. When Goethe arranged the prismatic colours and their complementaries into a hexagonal pattern expressing the symmetries of the spectrum, he used the term 'red' for an extra-spectral colour, complementary to green, produced by the additive mixture of the two ends of the spectrum a colour that today we should call magenta. For him the spectrum red was a 'yellow-red', not a pure sensation, and he certainly believed he was following the ancient tradition in thinking that this magenta colour was the legenday 'pure red', leaning neither towards the yellow nor towards the blue, that was so difficult to attain with colorants. (No wonder he was so excited with his prismatic experiments - remember that painters did not then advertise the secrets of their profession.) There is no doubt that the concept of red as an additive primary is a different concept from that of red as a subtractive primary, and nowadays most people would think of spectrum red as 'pure' and a magenta as distinctly 'bluish'. Perhaps there has been a semantic shift here too, encouraged both by the popularity of Newton's seven colours (with no place for magenta), and also by the fact that red is often thought of as the colour of blood, and that there was a shift of thinking here too, about the same time.

It used to be thought that the bluish blood in the veins was purer, more delicate and refined, while the arterial blood was contaminated, coarse and opaque; whereas now we are taught that the arterial blood has been purified by fresh air while the venous blood is laden with waste products. It may be that the link between pure red and pure blood is of no account, and the change in both a curious coincidence, but I mention it as a reminder of the possible influence of all sorts of outside associations on our theories of perception.

The facts of colour mixing have never been used to support the status of the seven colours - rather the reverse - yet if there is an organic explanation, it cannot be far away.

Physiological Optics

The work of Young, Maxwell and Helmholtz led to a new interpretation of the facts of colour mixing in the trichromatic theory of vision, with the additive primaries taking a prominent place. Even those who still taught that 'red, yellow and blue' were the primaries used vermilion and ultramarine for their red and blue; such teaching lost contact with the realities of colour mixing and became merely dogmatic. Yet Maxwell himself did not seem to realize that it was not just a matter of substituting green for yellow in the primary triad: a total reversal of thinking about colours was needed. People argued hotly that the primaries were red, yellow and blue - or red, green and blue - without seeming to realize that one red was as different from the other, and one blue from the other, as green was different from yellow. At least in photographic science the subtractive primary red and blue were renamed magenta and cyan to avoid confusion. But the real argument had shifted from colouring processes to visual processes, to the correlation between light stimuli and colour sensations

Some people thought that the argument about primaries had been settled in an ingenious way when Hering proposed that both green and yellow should be considered as primary colours, and it took some time before it became generally accepted that Hering was using yet another, and totally distinct concept of what colour was.

Based on an introspective assessment of the quality of colour sensations, the opponent-colours scheme is an elegant and economical way of describing perceived colours, and one that is readily learned. Note that it corresponds to a fairly early stage in the Berlin and Kay development scheme. But more important for our search for an organic explanation of the seven colours, the opponent-colours system correlates very well with certain features of the nerve activity that can be recorded between the eye and the brain.

Unfortunately it is still very difficult to sort out the interactions between percepts and concepts, to separate sensations from their associated linguistics in the total response. Far too often the opponent-colours scheme is taught dogmatically, so it is really no surprise that so many students respond to their stimulus situations in terms they have learned. In fact, the type of questions and answers that are supposed to show that green is a unique hue while purple is a mixed blend could equally well be used to show just the reverse. The fact that there are some people who do see green as a blend of blue and yellow, and others who see purple as a unique hue, can of course be explained by their history of learning, but all linguistic responses must have a history of learning, and this part of the process finds no place in theory as it is usually presented.

Hering's scheme, with four unique hues in two opposing pairs, together with black and white as unitary sensations, comes very near to accounting for seven key colours, but not for Newton's seven. According to the linguistic development pattern, the next colour should be brown, but there is no place for a unique brown in Hering's system. The late Forrest Dimmock proposed to make grey a unique colour, bringing Hering's six unitary colours up to seven, but the number of people who see grey as unique seems to be small compared with those who see it as a blend of black and white (when it is not a dim white or a pale black), so this suggestion has found little favour.

Ostwald, while adopting Hering's scheme, was reluctant to abandon any of Newton's seven colours, so he added an extra yellow-green, while shifting the principal blue to the indigo slot, as already mentioned. This makes a total of eight hues, preserving the four-fold symmetry of Hering's opponent pairs, and introducing the 'balanced blends' as their equals; with black and white as well, such a scheme cannot account for the need for seven colours, though it includes Newton's as members. I must just add that Ostwald's Red 8, supposedly an unambiguous red, neither yellowish nor bluish, seems to be universally loathed by artists. It is, of course, neither an additive nor a subtractive primary, and thus has an ambiguity of another kind.

The opponent-colours scheme is supposed to represent a stage in the visual process in which the trichromatic information from the receptor system is re-coded for transmission through the optic nerve. If it is an efficient re-coding, it will preserve the same number of degrees of freedom per unit signal. The simplest representation of a trichromatic system is with three channels, each binarily switched (that is, either on or off). Such a system will have a resting place (all channels off) and seven signal states. Of course, the visual system is not so simple, but these seven signal states will still represent the maximally different signals within the system. Re-coding involving sums and differences, ratios, and so on, may not be entirely efficient (perhaps this is why there are only six unambiguous signals in the opponent-colour phase), but if such signals can be re-coded once, I do not see why they could not be re-coded any number of times, perhaps to fit in with various memory stores. This could allow for variations in the patterns of learning, such that some people seem to organize their colour perceptions in terms of hue, saturation and brightness, others in hue, strength and greyness, others more directly in accordance with the opponent-colours scheme, and some evidently in terms of trichromatic colour mixing, additive or subtractive. There should even be the possibility of accounting for the existence of the unique brown that is an indispensable part of some people's colour experience. Through all this, in any transformation of the signals, one might expect to find seven key points, though they might turn up in any pattern.

Here I might interpose that several authors have suggested that the occurrence of seven labels for colour qualities can be rationally explained in terms of brain function. They usually cite a paper by George A. Miller entitled *The Magical Number Seven, Plus-or-minus Two, or Some Limits on our Capacity for Processing Information*. In fact, Miller does not have much to say about colour, though he does explain why there are probably about 15 to 20 identifiable colours, which agrees quite well with some of the attempts at enumeration that I mentioned earlier. If the colours are confined to a single variable, as in the prismatic spectrum, then the number of readily identifiable colours drops to about nine. But this is simply an experimental finding that he reports (from Eriksen), rather than a rational explanation. He points out that when we add more variables to the display, we increase the total capacity, but we decrease the accuracy for any particular variable. He describes how the information-handling capacity of a system can be increased by re-coding bits of information into chunks, which is rather what the ISCC-NBS system is doing. Such an approach may eventually help us to understand why we cannot have as many colour concepts as we have percepts, and why Berlin and Kay found an upper limit to the number of basic colour terms in any language, but it does not explain what is so special about a system of seven colours.

In talking about all these physiological processes, from the retinal receptors to the brain, there is one point that I wish were more widely understood. We have been reminded that, to speak properly, the rays are not themselves coloured (nor yet the wavelengths), that objects are not coloured in themselves but have only the disposition to reflect some rays more copiously than the rest, and (as we were told at the Stockholm AIC meeting) the receptors should not be labelled red, green and blue but **long**, **middle** and **short**. I would only ask that the same caution should be applied to the activity detected in the optic pathways. We talk about red wavelengths, red roses, and red receptors in each case only on the basis of a correlation, and the opponent processes in the nerves are no exception. Without the correlation with visual experience there would be no way of telling whether any nerve impulse would evoke a sensation of red, or blue, or even brown.

Summing up the physiological evidence, it would seem that there is some organic reason why there should be six basic terms more basic than the rest, so that any additional terms, although linguistically as basic as the others, are yet regarded as blends or mixtures when considered introspectively. And perhaps there is even room for one such additional term to take precedence over the remainder. But these six or seven colours are not the same set that we attribute to Newton.

Colour Experience

In colour science, whether physics, chemistry or physiology, we follow Newton in distinguishing between the objective, measurable entities and the subjective qualities that we experience directly, and in trying to correlate the two Newton's simple one-to-one correlation between the perceived colours and the measured angles of refraction has long since been replaced by complicated formulae attempting to account for metamerism, adaptation and other phenomena. But through all the changing correlations the direct experience of colour qualities remains an enigma; the simple percepts of redness, whiteness, yellowness and the rest do seem to be given us - we do not make them up - but where they come from we really do not know.

I shall come back to this point, but would first like to deal with an approach to colour that tries to remain entirely within the realm of direct experience. As you might expect, this is a concern of artists rather than scientists.

My first example must be Munsell, who sought to produce a colour notation based only on the appearance of the colour, and not on the means that had been used to produce it. He was not at all concerned with the results of colour mixing, but followed Runge in arranging the neutral colours in an axis from black to white, with the hues circling round in a three-dimensional array. He reckoned that purple could not adequately be described as reddish blue or bluish red. On the other hand he considered orange a dispensible term - in any case he disliked colour names that were derived from flowers or fruit, and included only terms that he regarded as genuine colour names. The result was a colour system with seven key colours: black and white, red, yellow, green, blue and purple.

My second example is Rudolf Steiner, who in a course for painters given in 1921 made the distinction between what he called 'alanzfarben' and 'bildfarben. The former, with a glowing or shining quality, were given as red, yellow and blue - not the subtractive primaries, as you might suppose, but the colours from the two ends of the spectrum. When Goethe separated the spectrum into two edge-spectra, he noted that the one seemed to be sharply divided into red and yellow, with but a hint of orange between, while the other seemed to be mainly blue, fading out into violet. These edge-spectrum colours have a dynamic character which contrasts with the 'bildfarben'. These latter have a static, image-like quality, and include black and white, green and its complementary colour, magenta; they are the points of balance in the spectrum development as Goethe treats it - the primal polarity out of which the colours arise and the final polarity in which they reach their perfection. Three glanz and four bild make a total of seven, and if magenta can stand for purple (indeed, purpur is Goethe's word for it), it is the same seven as in Munsell's system.

Again we find a set of colours close to Hering and to Berlin and Kay, rather than to Newton's famous seven. And it turns out that this particular set has a very ancient historv.

Colour Tradition

Turning back to Newton, I cannot help feeling that he knew that there was already a tradition of *seven colours*, and also that there was the notion that the harmony of colours was related to simple numerical ratios like those that underlie musical harmony. A recent author has expressed indignation that Newton should be accused of mysticism for introducing the number seven (while he saw nothing odd in himself accusing Goethe of just that for using the six-pointed hexagram as a colour-mixing diagram). But the point is that while he was deeply read in ancient wisdom, and fascinated by alchemy and astrology, Newton wanted to demonstrate the truths for himself. I can imagine that he got a deep satisfaction from having confirmed with mathematical precision one of the ancient beliefs; seven colours in seven harmonic steps - they may not have been the same seven, but at least there were seven of them, demonstrable, measurable, and forming part of the underlying fabric of the universe.

What about the old traditions? In mediaeval heraldry we see the use of a set of seven colours: Gold and silver (represented by yellow and white in cloth designs, or wherever metals were inappropriate) with red and blue, black and green and purple - added to them in order of usage. These served a useful function in design, enough to give great variety but not so many as to cause confusions, because heraldry's main purpose was as a visual language for the illiterate.

Symbolic connexions came later to heraldry, and were applied in profusion as soon as heraldry ceased to be a practical means of identification and became an attribute of social status; but one cannot deny that these connexions arose from the mediaeval delight in correspondences. It is hard for us to imagine what great store the mediaeval mind set by these links between appearances, demonstrating the underlying principles of the Creation. In alchemy and astrology the seven colours were mated with the seven planets and the seven metals, and no doubt with the seven liberal arts, the seven deadly sins and anything else that came in sevens.

Some present-day astrologers have actually linked Newton's seven colours with the planets, which seems to show little historical sense. Others have given schemes of their own, departing to a greater or lesser extent from the old tradition. I once thought it would be rather nice to collect all these schemes together, and add them up. Saturn emerges as a dark colour scheme, blacks and blues with a little violet; Jupiter is a powerful scheme of complementary colours, blues with orange and some yellow; Mars is all red, from orange to magenta; the Sun a dazzling scheme with white, yellow, gold and orange; Venus mostly green, but with some touches of yellow and light blue and even a little pink; Mercury another complementary scheme with violet and purple against yellow and yellowish green, rather muddy and brownish in places; the Moon a pale and water scheme, silvery white with pastel mauves and greens and palest yellows and blues. I believe the traditional characters of the planets are very well expressed by these schemes, but though one may have the seven planets in colour, one no longer has the seven colours.

In the ancient traditioni there was no room for aesthetic characterization; there were just seven colours, one for each planet. Even Aristotle could be quoted as an authority for there being just seven colours. In the *Parva Naturalia*, the author writes that this is the number of colours that cannot properly be described as being composed of any other - a goal very similar to Munsell's; he then rather engagingly lists eight colours, and adds that perhaps yellow might be considered as a degraded white, or better, that grey (phaion. which might also mean dull brown) should be regarded as a pale black, thus in either case making a total of seven. Allowing for the uncertainties of translation, the seven colours in the latter case are the same as Munsell's, or as the heraldic tradition.

Aristotle also mentions that there are just seven flavours, but he makes no correspondences, and no links with the planets. So surely this cannot be the source of the tradition. I get the impression that the Greek author is making the number of colours up (or down) to seven in order to satisfy what was already a tradition for him.

How far back can one go? Is there any hope of reaching a historical explanation for these seven colours? There is not much literature from so long ago and one must rely heavily on inference. And yet I think there are some clues.

Today we know more than seven planets, and more than seven metals, and they no longer correlate; but there was a time when only seven of each were known. Perhaps at the time when the inhabitants of ancient Chaldea were developing astronomy, their language had reached a stage with only seven basic colour terms. We know that the movernent of the planets was very important in their lives, and they recognized in them the signs of their seven gods. We know that they build tall seven-stepped towers to observe the movements of the stars, and no doubt at the same time worship their gods, and one description of such a tower makes the steps differently coloured. We know from their epics that they believed the gods to be working in all created things, and to believe was to experience.

I said earlier that we do not really know where the qualities of the different colours come from; but **they** knew. The seven colours were the gifts of the seven gods, and the manifestation of their working - in stones and sky, in birds and flowers, in all coloured things.

In a later, more intellectual age, such direct experience was regarded as fantasy, and belief in it naive, but the devout Newton could still believe that he had uncovered one detail of the design of God's Creation, and in it he put the seven colours.

This Address was illustrated in various ways: with the prismatic spectrum, of course, in both its Newtonian and Goethean aspects; with poetic imagery giving a picture of Blue; and with a trichromatic projection using deep blue, middle blue and pale blue light, which yielded perceptions of yellow, orange, green, white, pink, violet and, naturally, blue - on which we might have imagined my ancient Greek friend commenting: *You can see that all these seven colours are different, so why are you normally content to call them all blue?*

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