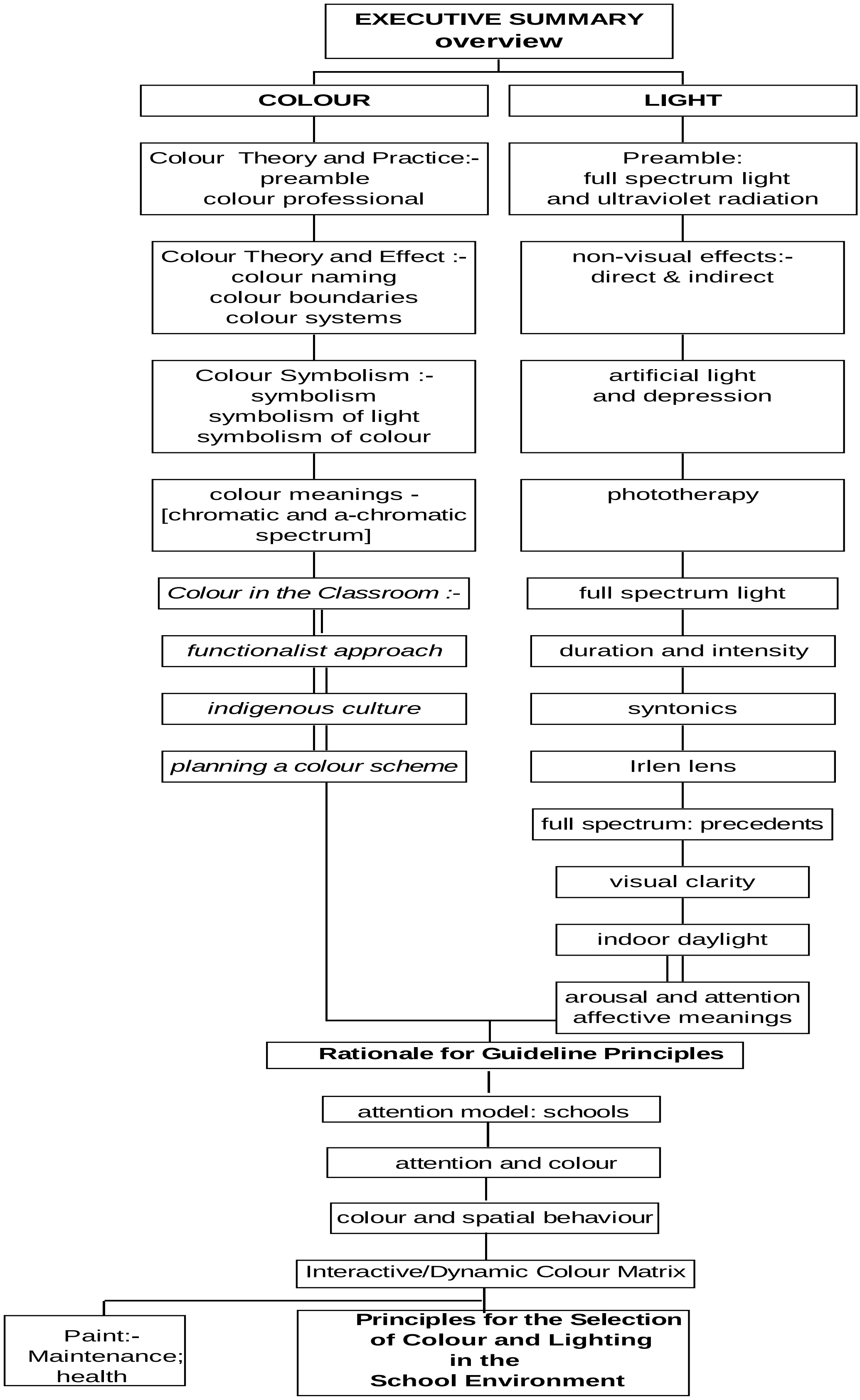
Robert Samuels and Harry Stephens 1997

COLOUR AND LIGHT IN SCHOOLS

THEORETICAL AND EMPIRICAL BACKGROUND


EXECUTIVE SUMMARY
overview
COLOUR
LIGHT
Colour Theory and Practice:-
preamble
colour professional
Preamble:
full spectrum light
and ultraviolet radiation
Colour Theory and Effect :-
colour naming
colour boundaries
colour systems
non-visual effects:-
direct & indirect
Colour Symbolism :-
symbolism
symbolism of light
symbolism of colour
artificial light
and depression
colour meanings -
[chromatic and a-chromatic
spectrum]
phototherapy
Colour in the Classroom :-
full spectrum light
functionalist approach
duration and intensity
indigenous culture
syntonics
planning a colour scheme
Irlen lens
full spectrum: precedents
visual clarity
indoor daylight
arousal and attention
affective meanings
Rationale for Guideline Principles
attention model: schools
attention and colour
colour and spatial behaviour
Interactive/Dynamic Colour Matrix
Paint:-
Maintenance;
health
Principles for the Selection
of Colour and Lighting
in the
School Environment

EXECUTIVE SUMMARY

The NSW Public Works Department, Education Branch, is responsible for the design of State Schools in New South Wales. Their client is the NSW Education Department, whose mission is to educate public school students for the benefit of each individual, the community and the nation. An integral aspect of this is to ensure that the design of the school buildings is the most appropriate to ensure the fulfilment of this mission. In turn, an integral aspect of the design of schools is the use of colour.

It is widely recognised that colour impacts on people, but there is little objective and empirical research confirming such influences on educational performance. Without a “principles guideline”, colourists and educational managers have no means to cross-check and evaluate colour decisions, and choices become personal, fashionable, political and so on, which is not an acceptable way in which to ensure that the quality of the learning environment conforms to the best practice in terms of the available knowledge.

Sound knowledge based on substantial experience is the hallmark of professionalism and this must be demanded of the colour designer whose education and experience cannot be equated with or subordinated to the personal taste of the amateur. The large body of well researched and documented knowledge available to the colour professional has been trivialised by a decorating industry which tends to suggest to the amateur that “anyone can do it”, an attitude that must be rejected at the outset.

Present systems of communicating information about school colour schemes are inadequate, because of the complex and interrelated nature of environment, symbolism, culture, spatial arrangement, colour, light and attention, performance, visual acuity, mood, behaviour, health and so on - and interior designers have to rely on their experience which is necessary but not sufficient.

Given that colour is inseparable from light, and that light has been shown to have a profound affect on well-being and performance - despite its apparently ethereal nature - no colour principles guideline would be acceptable without a corresponding

integration of best practice knowledge currently available concerning the psycho-biological effects of light. The research reported on herein constitutes a review of contemporary knowledge relating to both colour and light.

- Based on this information, a non prescriptive, interactive and dynamic Colour and Light Principles document is presented, separately, as a basis for discussion between colourists and education managers to assist them to achieve satisfactory if not optimum colour schemes in the schools for which they are responsible.

- The work reported on here is divided into two main sections, dealing with theoretical and empirical aspects of colour and light respectively, and a series of appendices, which include issues of paint maintenance and toxicity.

Ideally, both reports should be read by managers and colourists, since they are complementary; but in practice it is likely that colourists will read only the Principles document, which, particularly if used in conjunction with the electronic database, should be sufficient in itself.

SECTION 1: COLOUR

This section is presented in three parts dealing with **Colour Theory and Effect**, with **Colour Symbolism** and with the application of **Colour In The Classroom** respectively, a severely abridged introduction to a vast field of knowledge with the majority of which the professional colourist would be familiar.

PART 1: COLOUR THEORY AND EFFECT

The vocabulary used to express colour concepts appears to have evolved in a similar manner in all languages. This is not inconsistent with the notion that there is a basic human response to colour which is independent of cultural influences. Berlin and Kay (1969) have demonstrated that there are eleven basic colour categories which they maintain demonstrate “pan-human perceptual universals”. They showed it appears that in the evolution of all colour languages, words for black and white are the first to emerge, that these are then followed by red, then green, yellow, (or yellow then green), then by blue, then brown and then all or some of the colours pink, orange, purple and grey.

The domain of colour is clearly a seamless continuum with one colour almost imperceptibly transforming into the next. That we perceive and devise words to express our understanding of differences in this continuum is a testimony to our basic need to give names to everything in our experience of the world. The naming of colours indicates the perception of boundaries in the colour continuum. Fixing these boundaries can be a very difficult matter and the degree to which it is done is a product of cultural and subcultural imperatives. Once the most obvious colour division has been made, we experience considerable difficulty trying to express the subtleties of colour in words. Whilst our eyes are able to distinguish many thousands of colours, our means of speaking about them are by comparison extremely limited.

Many colour systems have been devised to facilitate this process. Both Plato and Aristotle spoke of ways in which the colour continuum could be systematically divided whilst in our time a number of systems are used in various situations for various reasons. A commonly used system for many years has been the Munsell system. Like most other systems it depends upon envisaging the colour continuum to be a sphere-like solid evolving out into colour from a graded grey core with poles of black and white respectively. By giving the colours spatial coordinates based on hue, chroma and value, theoretically ***any*** colour can be defined. However, no system would ever be able to adequately and accurately describe a colour without a visual referent. This means that a colour chart of selected sample colours tends to be a part of most systems. The designer may or may not use colours from such charts depending upon a wide variety of reasons ranging from the functional, scientific or pragmatic to the most esoteric.

Most colour systems simply set out to accurately *define* a colour in some way. They do not provide the means of understanding the complex dynamics of colour nor of arriving at colour harmony. A system which attempts this is that devised by Johannes Itten. Itten’s particular genius has shown us that the ***context*** of the colour is the essential aspect. No one colour will ever appear to be the same in two different contexts. He devised a way of looking at colour based on what he described as the “seven contrasts” that are possible when seeking harmonious relationships between colours. A working knowledge of these allows the colourist a control over the dynamics of colour afforded by few other methods.

PART 2: COLOUR SYMBOLISM

Proceeding from the fact that the human person intuitively seeks meaning in the surrounding environment, whether it be the natural environment or the built environment, and that colour is a most significant aspect of this, the following attempts to arrive at an understanding of what meanings might be attached to colours when used in the design of schools.

It is noted that the very notion of *meaning* is a philosophically difficult issue. Current work, particularly in the fields of linguistics and psychosemantics, illustrates this difficulty. However, with all due respect to the concerns of those in these fields, the work at hand proceeds from a point of view more closely aligned with what is most accurately described as the Traditional view, a view not without philosophical difficulties for many but which in the present context is clearly appropriate. Issues of meaning are essentially cultural issues and any understanding of them must of course seek an understanding of the traditional origins of the ideas within the culture. Meaning in such a context will also involve a concern for a wide variety of influences including customs, folklore, memory and even superstitions.

> "Colours are forces, radiant energies that affect us positively or negatively whether we are aware of it or not. .... The effects of colours should be experienced and understood, not only visually, but also psychologically and symbolically”. (Itten, 1973).

The present cultural significance of colour cannot be fully appreciated without an understanding of its history, even the most cursory investigation of which reveals that the symbolism of colour is of central concern. The study of symbolism in its historical context shows that current usage of the term is stripped of much of its original meaning and in order to achieve a useful insight into the subject, original meanings must be comprehended. The study therefore begins with a short discourse on the Traditional understanding of the symbol.

The word “symbol” in current usage is virtually synonymous with “sign” which robs it of its essential metaphysical dimension, a dimension of paramount importance in any discussion on colour. The Traditional view is that a symbol is a sign in one plane of existence of a greater reality in a higher plane, which in turn is similarly a reflection or symbol in that plane of an even greater reality in a higher plane and so on. All cultures have a Traditional view of the world which sees that the many layers of existence which constitute Creation, not just this physical world but all that IS, the entire realm of **being**, are intimately linked by means of a vertical "communication system" and that to understand this communication system one needs an understanding of the language of symbolism. This language has often then become part of the folklore and whilst its origins may be lost, its significance remains potent.

In a sense light and colour are synonymous but their relationship is more like the relationship between space and time - one without the other would be impossible. A discourse on the meaning of colour should therefore begin with light.

The opposition between light and dark is the first source of meaning for us. We will attribute to a colour its primary significance based upon its lightness or darkness. This primal response is echoed in the literature of antiquity in Western civilisation and is to be found in all cultures in some guise. For the Ancient Greeks, to "be in the light" was synonymous with "being alive". This symbolism remains with us to some extent in Western culture as is attested to by its remnants in our language - enlightenment, illuminating, luminous, dazzling, bright, effulgent, beaming, radiant are all words used to speak of positive attributes.

The primary symbolism of light is refracted into its many components in the rich symbolism of colour. Every colour has a meaning which can reflect either its positive or negative qualities depending upon context. These meanings are explored with reference to their objective realities. Colours speak in a direct language understood at some level by everyone. Subjective attitudes towards colours however, will vary from person to person depending upon their "personality psychology". The different subjective responses to the same colours are analogous to the differences of colour significance observed in different cultures. Where the basic *meanings* remain the same, the significance these meanings have for the cultures will vary.

The major positive and negative meanings of the eleven basic colour categories common to all colour languages (see Berlin and Kay, 1969) are presented. These generally refer to the **pure saturated chroma** of the colour. The meanings of colours will vary as the colours change their value and move away from their pure chroma. Tinted colours will have a corresponding slight change of meaning taking account of the weakening effect of the white. Tinted hues are generally weaker in meaning than the original hue while meanings of shaded hues are weaker but in a relatively more negative or malevolent sense.

We rarely experience colours in isolation. Our experience of a particular colour is virtually always in context with other colours. Whilst all of the meanings listed herein hold good for colours in isolation, the meanings will change according to the colour context in which they are experienced.

PART 3: COLOUR IN THE CLASSROOM

The often quoted functionalist colour theories of such writers as Faber Birren and Manhke & Manhke are of very little use to the serious colourist who is attempting to create the colour environment most conducive to good educational outcomes in the classroom. They pay very little systematic attention to the two most fundamental determinants of colour significance - culture and colour context. This current work has put forward a series of issues that ought to be taken into consideration when designing colour schemes for the classroom but it does not attempt to prescribe precise colour schemes - to do so would be a meaningless gesture and would be counter-productive as every school context will be different requiring a different colour response from the designer.

SECTION 2: LIGHT

Optical radiation, whether sunlight, daylight or artificial light, produces both visual and non-visual or actinic (chemical) responses in human beings. Non-visual effects result from light stimulation that travels from the retina via the so-called "energetic" portion of the visual pathway to the neuro-endocrine system, particularly to the pineal, the *photo*neuroendocrine gland, which has light-sensitive melatonin receptors and also functions as the 'biological clock'. Where melatonin secretion is not suppressed by natural light the pineal continues to secrete it, and depression, or the so-called SAD syndrome (seasonal affective disorder) can result. SAD is experienced as emotional depression, a drop in physical energy, and so on. Non-visual impacts are also mediated by infra-red and ultra-violet radiation. Given that UVR is absorbed by windows, light diffusers, and furnishing interior light is UV deficient. A link between malignant melanoma and fluorescent lighting has been suggested, given its increasing incidence world-wide during the last 30 years *and* its more common appearance in ***indoor*** workers. The ubiquitous use of cool white fluorescent lamps in schools is challenged in this report, and a recommendation made for a change to full spectrum or daylight-simulating artificial lighting.

Phototherapy is a new field which seeks to counter light deprivation by exposing SAD patients to *bright* (2500 lux) full spectrum light; or to coloured light of specific frequencies - which has been shown to affect general performance, behaviour and academic achievement. Bright light also plays an energising role and can counteract a commonly experienced mid-afternoon energy slump. Some research, however, suggests that even low intensity, standard indoor levels of full spectrum lighting experienced over long periods can be effective in increasing well-being (energy levels, occurrence of headaches) and satisfaction with lighting conditions indoors. Furthermore, fluorescent light flicker may affect accuracy during reading, and cause headaches and eye-strain. Electronic ballasts (currently very expensive) can virtually eliminate flicker.

Further impacts of colour on performance have been suggested by research with Irlen lenses, which filter specific light frequencies and thus change the colour of the page, which apparently can result in a decrease in reading and learning disabilities.

Several studies over the past 20 years have evaluated the effects of full spectrum artificial lighting on people in light chambers, schools, offices, etc. Examples relating to schools show:- the health of school children being impaired when exposed for long periods of time to artificial light with a reduced spectrum; as well as students becoming less lively and more lethargic, and exhibiting unnaturally low cortisol levels - suggesting a similar depression of arousal levels. Full spectrums, on the other hand, have been linked with enhanced visual acuity, reduced overall fatigue, improved work performance, lower rates of illness due to colds, a decrease in hyperactivity and learning disabilities, and an increase academic level.

Examples relating to office workers can be found in the document.

One aspect of great importance relates to the visual clarity hypothesis, viz. that people appear to rate full spectrum lighting as **equally satisfying** as standard lighting which is nonetheless emitting light at a lux level some 20% higher. Implications for energy efficiency are elaborated upon in the text.

A final, important, issue is that of indoor daylight. Modern school design ensures the maximum penetration of daylight, for both efficiency and performance, but it is not commonly recognised that indoor daylight is *attenuated* *ie* <u>not</u> full spectrum light. Glass does not transmit the full spectrum of daylight. UVR is largely blocked, and even 3mm clear glass permits only 86% visible spectral transmission. The importance of this realisation is that indoor daylight will not have the psycho-biological benefits of outdoor daylight, and supplementation with full spectrum artificial light is thus further emphasised

The section on Light concludes with matrices highlighting the relationship of physiological arousal - blood pressure levels etc, and attentiveness to both light and colour, and with research programs conducted with both full spectrum lighting and psychodynamic colours in classrooms (both yellow and blue). These indicated enhancement of positive mood, less absenteeism, stimulation of the left hemisphere of the brain (which controls judgment, reasoning, logic and writing skills), an increase in IQ, lowered blood pressure, and decreases in both aggressive and non-attentive behaviour.

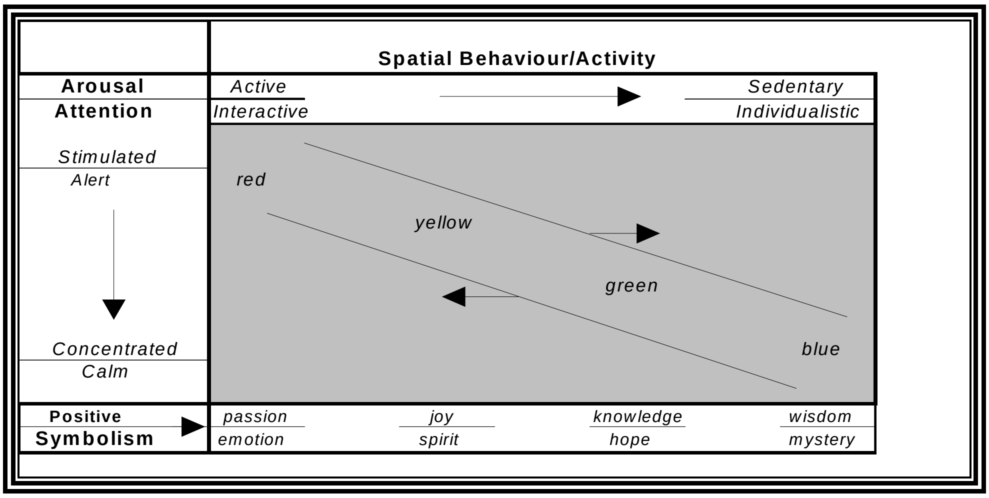
Two theoretical models are finally presented, the first of which indicating how ‘exciting’ means both pleasant and arousing, ‘relaxing’ both pleasant and unarousing, ‘distressing’ both arousing and unpleasant, and ‘boring’ both unpleasant and unarousing. From this model, and an understanding of colour symbolism and physiological arousal, a ***hypothetical model*** - more appropriate for schools - is derived. Here the elements of arousal and distraction are introduced. Attentiveness ranges along the *aroused-calm* axis depending on the activity appropriate to a specific time and place. Given that school children have to be variously alert or calm, depending on the activity they are engaged in, and in which spatial setting, and at which time of day the activity takes place, a variety of colours would seem appropriate - within the constant ambient conditions provided by full spectrum light and natural daylight.

The element which is common to both aroused attentiveness and calm attentiveness is the *pleasantness* of the stimuli. From this realisation it can be deduced that colour *preferences* could play a major role in colour appropriateness, in other words, the psychological and experiential elements are at least as important as the physiological and physical.

The rationale for the use of the underlying Interactive/Dynamic Colour matrix as *an aid in assessing colour schemes* is contained in these realisations, since the matrix is a derivative of activity/spatial behaviour factors, arousal/attention factors, and symbolic/colour factors.

A simplified version of the essential principles of the colour design matrix is presented below.

It is self-evident that the diagonal 'colour band' can shift, depending on a wide range of external variables (age of students, for instance), and is itself symbolic. Although mention is made of red, blue and so on, this is a convention, a convenient nomenclature representing, in fact, a vast array of hues and other characteristics under each colour label. In a sense, it might be better not to label the spectrum but to only indicate that the colour band ranges from the warmer, saturated, brighter and 'extroverted' *longer wavelengths* to the cooler, unsaturated, subdued, and 'introverted' *shorter wavelengths*.



SECTION 1[1]

COLOUR : THEORY AND PRACTICE

PREAMBLE

When it comes to planning an architectural colour scheme, no crash course on colour nor any short written colour guide would ever be able to substitute for sound knowledge based on substantial experience. The do-it-yourself mentality that is fostered by the “decorating” industry in the interests of selling more product, is unfortunately too often encountered in the professional realm where the amateur, convinced he/she has a good “colour sense” and is able to choose colours intuitively and do it well, ventures to offer opinions often in conflict with those of the professional. And what is worse, such opinions are too often considered by those in decision-making positions to be at least as valid as professional knowledge.

The Colour Professional

The well-educated and experienced colourist, just like the professional musician, has spent a great deal of time painstakingly and methodically studying and practicing. An education in colour theory and practice is a long process involving a great deal of practice with the elements of colour, learning from the masters and from personal experience. It is simply ludicrous to imagine that such education and experience may be equated with or subordinated to the personal taste of the amateur and every effort should be made to ensure that those given the responsibility of selecting the colours for our schools are well qualified colour professionals familiar with the best information available on the subject. The object of this work is to provide an introduction to this information.

The following is a compilation of data selected from some of the most reliable sources dealing with the fundamentals of colour. It does not pretend to be anything more than a severely abridged introduction to a vast field of knowledge with the majority of which the professional colourist would be familiar. As a Colour Guide document, it can be little more than a checklist of some of the more important issues and cannot be read as an authoritative text containing all that needs to be known about colour.

Structure of Section 1

This section is divided into three parts. Part one, Colour Theory and Effect, deals with the evolution of colour language and our propensity to recognise and categorise colours. It makes mention of a couple of the many colour systems that have been devised to assist in this process and goes on to provide an introduction to the principles of colour effect. Part two, Colour Symbolism, deals with the meaning of colour and takes as its major theme the metaphysics of colour. Beginning with a short discourse on the nature of symbolism, it presents a catalogue of the positive and negative meanings of eleven of the major colours. Part three, Colour in the Classroom attempts to draw the major elements of the preceding parts together to focus them on this particular application. A critique of influential work done in this area is augmented by comments on some of the issues that should be given consideration by the colour professional working in schools.

---

[1] Section 1 prepared by Harry Stephens, Lecturer, School of Architecture, UNSW, 1996

SECTION 1: PART ONE

COLOUR THEORY AND EFFECT

INTRODUCTION

Science has not and predictably never will provide us with a "unified theory of colour". Even the very meaning of the word presents us with difficulties. "The meaning of the term *color* is one of the worst muddles in the history of science" (Gibson 1966)[2]. There has however been a huge amount of research done into the nature and effects of colour, much of which points to the existence of some constants which make it possible to predict to an extent the responses one might expect to the use of various colours in our built environment. It must be said at the outset however that it is far from being an exact science.

What follows is an introduction to the origins of our colour language and a highly selective look at some systems that have been devised to deal with the complexities of the phenomenon.

COLOUR NAMING

We exhibit a basic need to give names[3] to everything in our experience of the world. This naming process is an evolutionary one and a record of this process is to be found in the vocabulary of all cultures. That different cultures have different names for colours is self-evident. It would be impossible in a work of this nature and scope to make a detailed study of these differences[4]. The intriguing reality is however that

---

[2]**Gibson, J.J.,** 1966, *The Senses Considered as Perceptual Systems*, (Boston, Houghton Mifflin Company) p. 183.

[3]From the Sanskrit *nama* which has the same root as "number" and Traditionally to name something is both a qualitative **and** quantitative act.

[4]By way of a hint to the complexity of this issue Krauss (1968) gives the following example: "The Shona speaker forms a color category from what we call *orange, red* and *purple*, giving them all the same unpronounceable name. But he also makes a distinction within the band we term *green*. Here we have a clear case of speakers of different languages slicing up the perceptual world differently. And, of course, it is also the case that the kinds of slices one makes are related to the names of the slices available in his language".

human perception of colour categories is remarkably consistent across cultural boundaries.

Basic Colour Terms

After the now famous work of Berlin and Kay (1969) titled *Basic Color Terms,* concerned with colour naming in 98 different languages and dialects, research has blossomed in a wide variety of disciplines. This highly influential work has demonstrated that there are eleven basic colour categories which are unquestionably "pan-human perceptual universals"[5] - categories that are common throughout the world.

Berlin and Kay assembled 329 colour chips from the Munsell colour system[6]. They selected forty hues equally spaced in the system and collected chips representing eight degrees of brightness for each one, all at maximum saturation. These were arranged in order from brightest at the top to darkest at the bottom and from left to right the forty hues beginning with the reds going through yellow-reds, yellows, green-yellows, greens, green-blues, blues, blue-purples, purples to red-purples. They then added nine chips of neutral hue at the left hand end with white at the top going through seven equally stepped greys of decreasing brightness to black at the bottom to complete the set.

Subjects were chosen from twenty different language groups speaking ninety eight different languages/dialects. The "basic" colour terms[7] in each vocabulary were isolated. Each subject was asked to indicate on the chart the chips which they recognised as being represented by the various basic colour words in their language. What emerged from the study was that basic colour terms fell into eleven different categories.

---

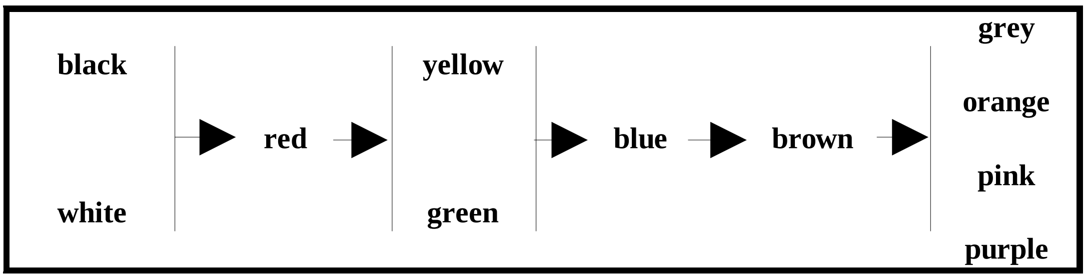
[5]**Berlin, B. and Kay, P.** 1969, *Basic Color Terms* (Berkeley and Los Angeles: University of California Press) p.109.
[6]This colour system is described under the heading" Colour Systems" below.
[7]A "basic" colour term was defined by Berlin and Kay among other criteria as being monolexic (where its meaning is not predictable from the meanings of its parts) and not having its signification included in that of any other colour term.

The Berlin and Kay Rules

The research also revealed the following set of rules:-

1. All languages have terms for black and white (light or dark).
2. If a language only has three basic colour terms then one will be a term for red.
3. If a language has four basic colour terms then it has a term for green *or* yellow but not both.
4. If a language has five basic colour terms it will have terms for green *and* yellow.
5. If a language has six basic colour terms one of them will be for blue.
6. If a language has seven basic colour terms one of them will be for brown.
7. If a language has eight or more basic colour terms it will have terms for purple, pink orange, grey or some combination of these.

This may be expressed as follows with the increase in complexity of the language evolving from left to right.



(From diagram presented in Rossotti[1983] p.223.)

Thus Berlin and Kay have illustrated that the colour vocabulary in a range of languages is an obvious guide to the number of colours needing to be talked about in the various cultures and that so-called “primitive” cultures have few colour names whilst more “highly evolved” ones have a greater number of colour names. Their findings are mirrored in the gradual increase in the complexity of our own colour vocabulary. Gage (1993) documents this evolutionary process from the initial primary concern with light-dark distinctions through the various limited palettes of three or four colours to our present large and complex colour vocabulary. Gage and other commentators have identified colours according to their occurrence in this gradual process. The act of naming colours within the colour continuum implies the existence of perceived boundaries between the colours thus named.

COLOUR BOUNDARIES

"Fuzzy" Edges

Sloane (1989) remarks that two observers of the same colour which lies somewhere between two adjacent hues[8] may name the colour differently - where one may see greenish blue the other may see bluish green,[9] which is an indication that the question of colour boundaries is not an easy one with which to deal. The edges or boundaries where one colour meets another are very "fuzzy". Hardin (1988) approaches the issue of establishing boundaries between colours as follows:

> "Let us address the problem of fixing color boundaries by considering a simplified case: the hue boundary between orange and red. We shall examine in imagination the phenomenal hue stretch between unique red and unique yellow. (One must always bear in mind that imagination is but an *ersatz* for experience and that promissory notes issued here must - and can - be backed by experiment). The stretch will be represented by estimated percentages of phenomenal red and yellow in each of five hues in the range, along with the hue names associated with them.

100% red	(unique) red
75% red, 25% yellow	yellowish red
50% red, 50% yellow	yellow-red (orange)
25% red, 75% yellow	reddish yellow
100% yellow	(unique) yellow

> The three intermediate hues exhibit a perceptual tension between red and yellow. Yellowish red seems more red than yellow; reddish yellow seems more yellow than red. The boundary of red in the broadest sense extends to the immediate neighbourhood of unique yellow, and the breadth of that spread we acknowledge by

[8]Adjacent hues on the "colour wheel" or in the white light spectrum (the rainbow).

> our use of the modifier 'reddish'. But, in a somewhat narrower sense, the boundary between red and yellow falls at the point at which the perceptual “pull” of yellow is equal to that of red. This point is, of course, orange. But once we introduce orange as a distinct hue category, its boundary with red is at issue, and the extension of 'red' must be contracted to make room for the oranges. The natural red-orange boundary would seem to fall at the 75 per cent red, 25 per cent yellow region which was well within the scope we took 'red' to have when we were concerned to compare red with yellow.
>
> “The principle that appears to be operating is that the unique hues are at the core of (humanly) natural color categories, the extent of which will be governed by the phenomenal tensions between them and the number of intermediate categories that come to be defined by a person's culture and subculture as well as by the pragmatic requirements of the task at hand. And, as is usual in such cases, experts draw the boundaries more precisely and reliably than laymen. In the instance of colors, the common system of classification is simplified and made more precise and regular for expert use up to the point of precision of discrimination at which it begins to lose its value (because, for instance, individual differences have come to play too large a role)”[10].

The Colour Continuum

This illustrates the fact that there is what Sloane calls a “colour continuum” wherein there is no physical or scientific method of stating precisely where one colour stops being that colour and becomes another. And that what is more, as the spectral continuum fails to take into account all dimensions of colour (“light or dark, bright or muted, matt or shiny”), under each colour name we include a huge (in fact an

---

[9]**Sloane, Patricia** 1989,op cit. p. 13.

indefinite) number of hues. To give generally understood, accurate and unambiguous names to even a fraction of these hues would be an impossibility.

Colour Language not Exact

Nevertheless, we need a language of colour and in our culture we have developed a very elaborate one which draws on many sources. Sloane (1989) gives an excellent summary of the origins of our colour language[11] which it would be superfluous and far too extensive to try to adequately report on here. It will suffice to comment that our language is extremely complex with a vast vocabulary. It is however far from being a logically developed or scientifically structured language and is of virtually no use in trying to determine exact meanings. The most common source of colour names is the "natural" environment. Once beyond the primary and secondary colours we find the majority of colour names to have been borrowed from the world about us - avocado, bronze, carrot, dusk, emerald, fuschia, gold, henna, ivory, jade - and so on through the alphabet. Very few colour names have other sources.

And the reality is that no system of words would be able to convey the very fine subtleties that the eye can detect in colours. Sloane (1989)[12] gives the example of "blue", a colour name which will be properly assigned to an indefinitely large number of different hues. If we qualify the kind of blue we mean to the degree that we call it "dark cerulean blue" then we eliminate a huge number of the other blues but we are still faced with the fact that there are a very large number of dark cerulean blues that the eye can detect and theoretically an indefinite number that can exist.

COLOUR SYSTEMS

Need for Precision

We have need to talk about colour and often very precisely. The inadequacy of words to accurately communicate about colour coupled with the desire to impose some kind

---

[10]**Hardin, C.L.,** 1988, *Color for Philosophers: Unweaving the Rainbow* (Indianapolis/Cambridge: Hackett Publishing Company) p.183-4.
[11]**Sloane, Patricia** 1989, op.cit. pp.3-54.

of order upon the confusingly complex colour realm, has led at times to the development of "colour systems". And there have been many from Plato and Aristotle through to Munsell, Ostwald and Itten (to name just a few) who have endeavoured to devise them.

Munsell

Albert H. Munsell[13] ([1905] 1961), building on the work of the Romantic painter Otto Runge, (1777-1810), developed a system he called *A Color Notation: An Illustrated System Defining All Colors and Their Relations by Measured Scales of Hue, Value and chroma* which he first published in 1905. Munsell, an art teacher, devised the system for two reasons, (i) to try to take the uncertainty out of good colour planning (to ensure "good taste" in its use) and (ii) for those in industry to accurately define a colour according to a "scientific formula" (as a chemist might define a chemical compound). Using numbers and letters he devised a three dimensional system for locating a colour in space within a "colour solid" (a sphere). The three dimensions of space in the sphere became the three dimensions of "any" colour - its **hue** (the name of the colour - yellow is a hue), its **chroma,** (sometimes called degree of saturation, intensity or purity of the hue) and its **value** (its brightness or reflectivity). White, black and the greys are *achromatic* colours. The sphere had a core of greys moving in equal steps from black through to white where the central grey (mid grey) lay at the centre of the sphere. A horizontal cross-section through the sphere appeared as a series of ten spokes radiating out from the centre. Each spoke represents one of ten hues which he called:-

> **R** (red), **YR** (yellow-red), **Y** (yellow), **GY** (green-yellow), **G** (green), **BG** (blue-green), **B** (blue), **PB** (purple-blue), **P** (purple) and **RP** (red-purple).

---

[12]Ibid p.18

[13]**Munsell, A.H**., *A Color Notation: An Illustrated System Defining All Colors and Their Relations by Measured Scales of Hue, Value and Chroma,* ([1905] 1961, Baltimore: Munsell Color Company).

Munsell’s Colour Atlas

Munsell produced a colour atlas which contains 1,200 colours on separate chips of paper. Each page of the atlas represents a vertical slice through one half of the colour sphere and illustrates the various intensities of chroma and various values of a particular hue. The coloured chips closest to the core of the solid (the edge of the page) are one step away from the grey scale where the chroma is not very intense heading out towards the surface of the sphere where the chroma is at its most intense (or “pure”). Each coloured chip is given a notation (for example PB 5/8: purple-blue with a *value* of 5 - level with mid-grey and therefore to be found level with the equator of the sphere; and a chroma of 8 - an indication that the colour under consideration is quite intense).

Limited Application of Munsell System

The Munsell system, a mechanical way of ordering the vast and confusing domain of colour, was extensively used from the first and continues in use today although not to the same extent. As a means of achieving “good taste” in colour planning it was doomed from the outset as no system could ever deal with the indefinite array of subtleties which come into play in every colour context. Its value is merely that it makes the job of finding a given colour in an atlas simple if one knows the coded address of the colour. The coded address however is useless by itself. The actual colour indicated, if it is to be replicated or discussed with any accuracy, must be compared to the sample in the atlas.

Ostwald

Wilhelm Ostwald, a physical chemist, produced a colour notation system published a little later than Munsell's which was also based on the colour sphere and had similar aims and aspirations. His system took as its three spatial coordinates hue content, black content and white content. The systems are incompatible in a number of ways beginning with the fundamental difference in the division of the colour wheel -where Munsell had a ten part division, Ostwald used a twenty four part division. Ostwald's system was also used extensively but again its formulae claimed to guarantee harmonious colour selection have proved to be as barren as those of Munsell's.

Neither Ostwald nor Munsell allowed for context or proportion, both of which are crucial to colour effect.

Use of Colour Atlases

Every designer who has worked with colour knows that the only effective and accurate way of working is by visual means - not by the slavish application of set formulae but by educated, practiced visual judgment under controlled lighting conditions. Referring to samples of the colours in atlases or charts can be of great assistance particularly if one wishes to use the same colour in different contexts at different times. Such collections of colour samples are many and varied and some are “better” or more acceptable than others. No system of samples can include every possible colour in the colour continuum let alone deal with the complexities of placing these colours into a context. The compiler of the system therefor acts as editor and selects from the indefinite number of possible colours those to be included. The value of the samples to the user will then depend on the judgment made by the user about the quality of the editing process. A “good” set of colour samples for one user may be a “poor” set to another depending on a vast array of conditions and circumstances.

DULUX Master Palette

There have been other colour atlases produced since Munsell and Ostwald but few as extensive as either of them. Recently however the Dulux company published a very large colour system called the Master Palette which has been widely accepted. It makes no pretence to be a system which guarantees harmonious colour selection. Its value lies in its accurate reproduction and systematic display of a very large number of colours the composition of each being carefully recorded to ensure extremely accurate reproduction as often as one wishes.

Itten

Strictly speaking Johannes Itten (1973 [1961]) did not devise a “system” in the same manner as did Munsell and Ostwald. He did not produce a vast colour chart and attempt to name, number or in other ways categorise a huge number of hues. His contribution to our understanding and use of colour however has been of enormous importance and he is included here in preference to many others who could be considered because of his holistic vision of the subject. The principles with which he deals are dealt with by most colour theorists in one way or another. Itten however remains arguably the most thorough scholar to have worked on colour in application.

Colour Context and Proportion

Itten's particular genius was attracted to the *context* and *proportional arrangement* of colours and how a colour is altered by association with other colours in various contexts. “...the effect of a color is determined by its situation relative to accompanying colors. A color is always to be seen in relation to its surroundings”.[14] This of course was not the first time in history that attention was given to this essential aspect of colour application - the medieval glaziers again (to name just one group of colourists whose work is excellent by any standards) had a profound appreciation of the manner in which colours interacted with adjacent colours. They made careful selections from a strictly controlled limited palette of just the right colours to go together to reinforce each other. Such devices as strips of white glass to separate two strong colours to prevent the inevitable changes to one colour or the other due to halation were masterfully employed.

Harmony through Contrast

Itten taught at the Bauhaus where he was appointed in 1919 as one of its first teachers. Itten's colour course was based on seven “contrasts” which were an elaboration of the colour theory of his teacher Adolf Hoelzel, Stuttgart painter and teacher. Itten was committed to a fundamental belief in the harmony to be achieved by the application of the seven-fold contrasts and his highly refined theory has been the backbone of much colour education ever since. He offered a pedagogical form of education calling his students to undertake a long and complex series of exercises aimed at allowing the students to “discover” for themselves the dynamics of colour effect in different

---

[14] **Itten, J.** 1973 [1961] *The Art of Color* (New York: Van Nostrand Reinhold) p.144.

contexts. With current moves away from pedagogy as a form of education coupled with the impatience of "consumer" students who expect instant gratification of any quest for knowledge, Itten has fallen from favour in many quarters. His reputation as a "mystic" has also done him little good in an age when everything must be "demystified" to be worth investigating. Nevertheless, his contribution to our understanding of colour has been profoundly important.

And for all of Itten's insistence upon the attainability of colour harmony through a knowledge of the laws of colour, he had an obvious respect for the "mystery" of colour. "What we call laws of color, obviously, can be no more than fragmentary, given the complexity and irrationality of color effects".[15]

Itten's Seven Contrasts

He begins from the observation that we make judgments about our world based on comparison and observes that colour effects are intensified or weakened by contrast. The seven kinds of colour contrast he identifies are:-

1. *Contrast of hue* - The simplest of the seven, it is best illustrated by the contrast between colours in their most intense luminosity. The most fundamental example would be the contrasting juxtaposition of the three primary colours, yellow, blue and red.

2. *Light-dark contrast* - This is the contrast between light colours and dark colours, the most pronounced of course being between black and white. "Day and night, light and darkness - this polarity is of fundamental significance in human life and nature generally"[16] In the realm of colour proper, the next most pronounced contrast is between yellow and purple - respectively the lightest and darkest colours in the colour wheel (for colour wheel, see below).

[15]Ibid. p.12.
[16] Ibid, p.41.

3. *Cold-warm contrast* - The two opposite poles of this contrast are the warm red-orange and the cold blue-green. Not only do these contrasting colours relate to our subjective feeling of heat and cold, the warm colours appear to have no depth and in fact may seem to advance, whilst cool colours like blue-green seem to have most pronounced depth and appear to recede. When cold and warm colours are contrasted with each other these qualities are more exaggerated.

4. *Complementary contrast* - The contrast between a pair of complementary colours such as red and green. Complementary colours are to be found directly opposite one another on the twelve-colour colour wheel (see below). Any such pair will contain all the primary colours and, as a mixture of all the primaries (using pigments as opposed to coloured light) will produce a neutral grey-black, any two complementary colours mixed together will produce a neutral grey-black. The physiological reality that the eye tends to supply the complementary of any observed colour in what is a tendency towards a balanced state around mid grey, plays a significant role in any harmonious arrangement of complementary colours.

5. *Simultaneous contrast* - This contrast depends on what is known as the simultaneous effect just mentioned. Whilst observing a colour, the eye automatically supplies the complementary colour in a tendency to “balance” the effect. “Simultaneous effect is of paramount importance to all who are concerned with color. Goethe said that simultaneous contrast determines the aesthetic utility of color”[17]. Each of two adjacent colours which are not precisely complementary will seem to want to shift the other colour in the direction of its own complement creating a dynamic effect. A knowledge of this effect and how to manage it is crucial for any colourist.
6. *Contrast of saturation* - The contrast between pure intense colours and dull diluted ones. A typical pure contrast of saturation would contrast areas of the same hue which differ in saturation from intense to dull.

7. *Contrast of extension* - This is the contrast between two different areas of colour, one large and one small but, due to the relative strengths of the two colours, they appear to be balanced. It is the contrast between "much and little, or great and small"[18].

Itten maintains and illustrates with ample evidence that a working knowledge of these contrasts is essential if the colourist is to achieve harmonious colour schemes.

Itten encourages the student of colour to undertake a large number of colour exercises beginning with the making of a twelve colour wheel based on the three primary, three secondary and six tertiary colours which in colour education he equates with the musical scales known and constantly practiced by the music student[19]. This fundamental exercise begins a very detailed exploration of colour effect.

Spatial Effect of Colours

Each colour has "within it" what Itten described as "forces acting in the direction of depth"[20]. These forces will of course be modified by context and proportion. Yellow on a black background will seem to advance very markedly, however, when placed on a white background, it will seem to be held back. On a white background, a dark colour will appear to be thrust forward. When combined with the specific effects of one or more of the seven contrasts, the range of possible spatial effects with colour is indefinitely vast. By way of example the following extract from Itten illustrates the complexity of the issue:

> "Among cold and warm tones of equal brilliance, the warm will advance and the cold retreat. If light-dark contrast is also present, the forces in the direction of depth will be added or subtracted or will cancel out. When equally brilliant blue-green and red-orange

---

[17] Ibid, p.87.
[18] Ibid, p.104.
[19] Ibid. p.34: "Unless our color names correspond to precise ideas, no useful discussion of colors is possible. I must see my twelve tones as precisely as a musician hears the twelve tones of his chromatic scale".
[20] Ibid, p. 122.

> are seen against black, the blue-green retreats and the red-orange advances. If the red-orange is lightened somewhat, it advances still further. If the blue-green is lightened, it advances to the same level as the red-orange; if lightened sufficiently, it advances further and the red-orange recedes."[21]

The spatial effects referred to above deal with colour as it is applied to a two dimensional surface. The same forces remain operative when translated into three dimensional space, however, the complexity of the issue becomes even more pronounced. Reality confronts illusion. The dimensions and proportions of the space may be accentuated, neutralised or even denied by colour that is purposefully and intelligently applied. For some examples of how these effects might come into play in the planning of a colour scheme, refer to the final part of this section.

[21] Ibid, p.122.

SECTION 1: PART TWO

COLOUR SYMBOLISM

INTRODUCTION

Difficulty with Meaning

It is the meaning of colour with which this part of the work is primarily concerned, and whilst there may be a deal of confusion about the meaning of colour, the literature abounds with just as much confusion about the meaning of *meaning.* Current philosophical notions about *meaning* are focused almost exclusively on the psychophysical/semantic (Fodor, 1987; Putnam, 1988 amongst many others). There is however a dimension to the issue which encompasses the metaphysical aspects of meaning - a dimension which cannot be ignored in a discussion of this nature.

Physical, Psychological and Metaphysical

Colour, like all other phenomena in our world, may be investigated from many different points of view within the three broad categories of the physical, the psychological and the metaphysical. For colour clearly has demonstrable physical and psychological effects on us and a metaphysical dimension wherein we may seek to understand what meanings it holds for us.

Symbol vs Sign

The metaphysical may be approached through “symbolism”, a domain that needs to be clarified before we begin for in current usage the word “symbol” is almost always treated as being synonymous with “sign”. This is far from its original meaning and such a usage creates considerable difficulties not only for those seeking an understanding of the origins of meanings, but also for those who would wish to have the broadest possible view of current meanings. It would be grossly inadequate if it were to accept from the outset a limitation of this nature for we would thereby be locked into a consideration of our subject from a fashionable but nevertheless particularly narrow point of view.

Need to be Inclusive

We are concerned with what colour means not just to the modern philosopher, psychologist, psychophysicist, anthropologist, cognitive scientist or linguist but to the populous at large, to the “folk” - to people in general who are our “clients”. And as they come from every corner of the globe, from a vast range of ethnic, social and religious groupings, we are obliged to be as inclusive in our study as possible.

Primacy of Symbolism of Materials

Furthermore, to consider colour in the abstract unconnected to the object or material which is coloured, is to see only a portion of a much larger and more complex issue. A shiny red rubber ball is obviously very different to a red velvet ball gown and each will have very different “meanings” to us even if the colour is *exactly* the same on each object. And more to the present point, a brown painted plasterboard wall will have very different meanings to a timber paneled wall of exactly the same colour. We respond to our *total context* and colour is merely one aspect of this context.

Importance of Symbolism of Materials

It would seem that there is a fundamental human need to seek some kind of an alignment with materials which have a resonance with our human nature. The pleasure that is experienced through contact with a beautiful piece of timber or stone is not merely an aesthetic experience, it is an experience which touches a deep and essential chord within us, an experience that is open to exploration through symbolism. Our reading of the symbolism of the materials which surround us (not to mention the rich and beautiful symbolism of the various parts of our buildings - walls, columns, doors, windows - and their arrangement in space) plays a most significant part in how we respond to our immediate environment.

It is therefore important that the designer does not merely see colour as something that is to be applied as nothing more than a thin coating over a neutral anonymous base material. Colour coating or painting is only a very small aspect of a much larger and more complex reality. This work cannot hope to adequately address this wider issue but for any of what follows to have any significance whatsoever, it must be seen in this wider context.

SYMBOLISM

What is a symbol?

The word "symbol" comes from the Greek *synballo* meaning literally "to throw together" in which sense it means to see creation as a whole. It has been understood throughout the ages and in all cultures that the many layers of existence which constitute Creation, not just this physical world but all that IS, the entire realm of **being**, are intimately linked by means of a vertical "communication system" the comprehension of which requires the understanding of the language of symbolism.

According to the traditional doctrine of *adequatio*, the adequacy or efficacy of a symbol may be measured as the degree to which that symbol participates in its greater reality. The symbol is in a **real** sense a part of that which it symbolises and a holistic view of existence is impossible without an acceptance of such a view of symbolism.

Plato saw the connection between the symbol and what is symbolised as profoundly significant. He maintained that all that exists in any realm of manifestation, depends for that existence upon principles which reside in a higher realm. If we are to understand any aspect of existence, then we must be able to see not merely the manifestation but also its origin *in principio.* It is by means of understanding symbols that this way of seeing the world is possible for us.[22]

Symbol: a "Vertical" Referent

A symbol is a sign in one plane of existence of a greater reality in a higher plane, which in turn is similarly a reflection in that plane of an even greater reality in a

---

[22] cf. **Plato**, *The Republic,* Bk.VI, 508 d: "When the mind's eye is fixed on objects illuminated by truth and reality, it understands and knows them, and its possession of intelligence is evident; but when it is

higher plane. In this sense, the symbol participates in its higher reality to the extent that it is not merely an image of it but it **IS** that reality re-presented in a guise appropriate to the plane of existence in which it is located.

It is always a vertical referent and never a horizontal one. A "horizontal" referencing system is a "sign system", a study of which might be undertaken within the discipline of semiology, but the profound distinction between the sign and the symbol must be understood if we are to comprehend the origins of our language of colour and thereby gain an insight into the metaphysical dimension of our subject.

The Two Aspects of the Symbol

Frithjof Schuon reminds us that

> "There are two aspects in every symbol: the one adequately reflects the divine Function and so constitutes the sufficient reason for the symbolism; the other is merely the reflection as such and so is contingent"[23] (Schuon, 1956).

The first is an absolute value, universal, unchanging. The second, being a part of the world of things, of existence, is on the other hand subject to the contingencies which govern that level of existence and therefore to the change which is inevitably a condition of existence. Both aspects of the symbol are integrally related, the latter being a means whereby we may gain insight into the former - which is another way of saying that everything that exists is a reflection of its creator, a central tenet of all Traditions[24]. (Nasr 1981)

If symbolism is concerned with connections between the physical, mental and spiritual levels of existence, what use is such knowledge in a world which has largely forgotten this and is either indifferent or antagonistic to the notion of a spiritual dimension of life? If the modern, generally accepted language of "symbolism" is, in

---

fixed on the twilight world of change and decay, it can only form opinions, its vision is confused and its opinions shifting, and it seems to lack intelligence."

[23]**Schuon, F.** 1956, *Spiritual Perspectives and Human Facts* (London: Faber and Faber) p.39.

Traditional terms, really nothing more than a language of sign systems, then is there any value in a work of this kind speaking about symbolism at all?

Just as it is well beyond the scope of a work of this nature to present a thorough survey of the most up-to-the-minute cutting-edge philosophical thought, it is similarly well beyond its scope to present a full-blown treatise on symbolism. All that can be practically done here is to give a short introduction to the traditional view of symbolism - and this only because such a view would maintain that the ability to "read" symbolic language is an integral part of what it means to be human, even if such a view is "unfashionable" and even if much of the learned literature either ignores or belittles the importance and the richness of the symbolic language which is our heritage - and finally it has its place here because of the particular richness of the symbolic language of colour.

In the introduction to his seminal work on color, *The Art of Color (Kunst der Fabre),* Johannes Itten (1973 [1961]) spoke in these words:-

> "Color is life; for a world without colors appears to us as dead. Colors are primordial ideas, children of the aboriginal colorless light and its counterpart, colorless darkness. As flame begets light, so light engenders colours. Colors are the children of light, and light is their mother. Light, that first phenomenon of the world, reveals to us the spirit and living soul of the world through colors.
>
> "Nothing affects the human mind more dramatically than the apparition of a gigantic color corona in the heavens. Thunder and lightning frighten us; but the colors of the rainbow and the polar lights soothe and elevate the soul. The rainbow is accounted a symbol of peace.

[24]For a clear exposition of the meaning of "Tradition", see **Nasr, S.H.** 1981, *Knowledge and the Sacred,* (Edinburgh: Edinburgh University Press) Ch. 2 "What is Tradition?" p. 65.

> “The word and its sound, form and its color, are vessels of a transcendental essence that we dimly surmise. As sound lends sparkling color to the spoken word, so color lends psychically resolved tone to form.
>
> “The primeval essence of color is a phantasmagorical resonance, light become music. At the moment when thought, concepts, formulation, touch upon color, its spell is broken, and we hold in our hands a corpse.
>
> “......... But the contemporary interest in color is almost wholly grounded in intellectual and emotional experience. It is a superficial, external toying with metaphysical forces.
>
> “Colors are forces, radiant energies that affect us positively or negatively whether we are aware of it or not. .... The effects of colors should be experienced and understood, not only visually, but also psychologically and symbolically.”[25]

THE SYMBOLISM OF LIGHT

All-pervasive Light Symbolism

We experience our world in many ways and of these arguably the most significant is visually - by way of light. In every human culture at some stage or other there is to be found a rich symbolism of light. That the symbolism of light played a key role in the fabric of Western culture is attested to not only by the almost constant repetition of light images in the Scriptures but also by the remnants of an obviously elaborate and all-pervasive light symbolism in our language. We still speak “lucidly” of “brilliant ideas”, “sparkling wits” and a host of other such terms related to light in our every-day language.

---

[25]**Itten, J.** 1973 [1961] *The Art of Color* (New York: Van Nostrand Reinhold) p.13.

Similar terms may be found in many other cultures and at many other times indicating a reflection of the Universal in the quality of our symbolic language. The particular emphasis given to the symbolism of light in the Judeao-Christian Tradition springs from this universal language, but it has its immediate roots in the ancient western world.

Meaning of Light in Ancient Greece

For the Ancient Greeks, the symbolism of light plays a central role to the point where to “be in the light” is synonymous with “being alive”. Bultmann (1948) observes that

> “the joy from light, the longing for light and the bliss of being in the light is .. expressed in the language: `being in the light', `see the light' mean being alive, and `life' means seeing the light”[26].

This earthly “light of life” is seen as a gift from the heavenly realm wherein the gods and their clothes and armour eternally radiate a shimmering golden light.

The opposition of light and dark in the thought of Greek antiquity represents the opposition of “well-being” and “disaster”, represented by the light and the dark respectively. So firm is the connection between well-being and light that Sophocles has Ajax using the paradoxical words “Darkness you are light to me, Erebos, shining brilliance to me”[27] (Sophocles cited by Bultmann, 1948).

For the Greek mind light was not only the means whereby one could physically orient oneself - whereby one could see the physical world around one - but more importantly and precisely, it was the luminance or brightness of the world through which one passed and which enabled existence to comprehend itself. Thus to “see” is still for us to “understand”. Indeed the degree to which one is alive to the world might be understood as the degree of illumination one perceives in the world to the extent that, and particularly for the Greeks, life and light are inseparable aspects of the same thing.

---

[26] **Bultmann**, Rudolf, *Zur Geschichte der Lichtsymbolik im Altertum,* in Philologus, 97, 1948, p.4.
[27] **Sophocles**, Ai. 395f. - cited by Bultmann, ibid, p.10.

> The "characteristic of light as the brightness which affords us the possibility of seeing also finds expression in the fact that the eye can be called light or light be called the eye, or that there is talk of the light of the eyes, just as the eye can also be called the ......reflection /counterpart of the sun's face"[28] (Bultmann, 1948).

Plato gave expression to a light symbolism that was to be taken up time and again in the evolution of western culture[29]. At the basis of his thought lies the Greek view of reality as consisting of things which are "formed matter". Those things are real which can be grasped, described, measured. In the process of seeing objects in reality, neither the seer nor the object seen is altered. Seeing and touching are synonymous. Seeing is as it were "feeling the shape of things". It is also comprehending the form or idea of the thing. The verb *id* (to see) lies at the heart of the words *eidos* and *idea* (respectively the "meaning" and the "form" of things).[30]

And thus when we say "I see" for "I understand" we employ a language of light which comes to us from antiquity and which has a timelessness about it that speaks directly to the intellect. Such terms are "clearly" far more than mere figures of speech.

Is there a language of colour which speaks to us in the same way? Is it possible that colours could have meanings which speak to us as directly as this? Is there a universal colour language?

---

[28] Op cit, p.14.

[29]**Plato**, *The Republic* Book VI, p.307-8 of Penguin edition, trans. Lee, D. 1974"...what gives the objects of knowledge their truth and the knower's mind the power of knowing is the form (idea) of the good. It is the cause of knowledge and truth, and you will be right to think of it as being itself known, and yet as being something other than, and even more splendid (kalos) than, knowledge and truth, splendid as they are. And just as it was right to think of light and sight as being like the sun, but wrong to think of them as being the sun itself, so here again it is right to think of knowledge and truth as being like the good, but wrong to think of either of them as being the good, whose position must be ranked still higher."

[30]It should be noted that our current tendency to substitute the word "form" for "shape" in what it seems to me to be an effort to embellish our language with a air of sophistication, makes it difficult to comprehend the original and highly specific meaning of the word. For Plato and all those who see the world in a truly symbolic way, "form" refers to the pre-existent pattern or template in the subtle or mental realm which determines the shape of the thing in the corporeal or physical world.

SYMBOLISM OF COLOUR

Colour: Etymology

It can be seen that the etymology of the word "colour" links it to the idea of covering or concealing. It seems that the word came into our language as a word to describe the quality of the coverings or surfaces of things[31] (Sloane, 1989) and that it appeared at a later date than words for light and the effects of light. At first glance it is somewhat curious that a word so closely linked to the phenomenon of light - with all of its connotations of revealing, making clear, illuminating - should have roots which are superficially at least the antithesis of this. However, if the vast, diverse, contradictory and often internally inconsistent literature on colour is any indicator, then its original meanings have a ring of truth.

Plato: "A Rational Theory of Colours"

Plato gave us "a rational theory of colours" which is however a fairly a meagre account. It is quite confusing to the modern mentality informed as it is by a wide variety of influences including Newtonian physics. And ultimately it is of not much use in an attempt to understand how the Greeks appreciated or used colour. Considering the task of studying colour effect by reducing a colour to its constituent parts and then recombining them to achieve the original colour, Plato concludes would be impossible, for this is the realm of God and that "no man can or will be able to do either".[32]

Aristotle: a Seven Colour Scale

Aristotle gave us a more extensive theory of colour spread over a number of writings. In his *On Sense and Sensible Objects* 442a he seems to opt for a seven colour scale in correlation with the musical octave. Black, crimson, violet, leek-green, deep blue, grey (which could be bracketed with black) and yellow (which could be included with

---

[31]**Sloane**, Patricia 1989, *The Visual Nature of Color* (New York: Design Press) ch. 13 Light as Symbol and Visual Metaphor I, p. 106.
[32]**Plato**, *Timaeus and Critias*, 68, trans. by Desmond Lee, (1979, London: Penguin) p.95.

...) white. His exploration of the nature of colours was in keeping with the all-pervasive Greek concern with the light/dark division -

> "We do not see any of the colours as pure as they really are, but all are mixed with others; or if not mixed with any other colour they are mixed with rays of light or with shadows, and so they appear different and not as they are. Consequently things appear different according to whether they are seen in shadow or in sunlight, in a hard or soft light, and according to the angle at which they are seen and in accordance with other differences as well. Those which are seen in the light of the fire or the moon, and by the rays of the lamp differ by reason of the light in each case; and also by the mixture of the colours with each other; for in passing through each other they are coloured; for when light falls on a another colour, being again mixed by it, takes on still another mixture of colour"[33].

Traditional View of Colour Mixing

From antiquity to the middle ages artists eschewed the sort of polychromy that required pigments to be blended to obtain more complex hues. It was deemed to be contrary to the creative act to mix pigments in this way as this was destroying the authority of the original pigments. It was seen as an act of violence which went against the fundamental nature of the colour. The traditional view of art is that the role of art is to imitate nature in her mode of operation rather than in her appearance. This carries with it the imperative that the methods used in the artistic process be "true to nature" or else the work of art will be "false". Gage (1993) quotes Plutarch as saying 'Mixing produces conflict, conflict produces change, and putrefaction is a kind of change. This is why painters call a blending of colours a deflowering [*phthora:* Aristotle's term for a 'passing away'] and Homer [*Iliad* IV, 141] calls dyeing "tainting"; and common usage regards "the unmixed and pure as virgin and undefiled"'.[34] This same imperative was very much the basis of the craft of the medieval glazier whose palette was similarly restricted and had its corollary in the

[33]**Aristotle,** *On Colours* (trans. Hett) 793b cited by Gage, 1993, p.13.
[34]**Plutarch,** *Quaestiones Conviviales* 725c cited by Gage, 1993, p.30.

monophonic music or plainsong, the official music of the Church. Each piece of glass in the windows was a single colour in a unique point in space, each note in the music a single note in a unique moment in time, unmixed, pure and undefiled.

In all of this then we have an affirmation of the fact that each colour has indeed its own "nature" which has a specific value and by implication therefore a specific meaning.

Primary Colour Meanings Constant

The meanings we see in colour at a very basic level, (we might call these the "primary meanings") appear to be part of the general human condition. This is not to say that all cultures see the same significance in the same colours - far from it. How various cultures put similar information to use in different ways is the hallmark of cultural diversity.

Correspondences between colours and human responses are of course contingent upon a vast plethora of influences which will to some extent alter their "secondary meanings" from one context to another but will not alter the nature of the colours themselves. They will always speak the same language. The various cultural filters through which this language is translated will inevitably leave their nuances on the meanings we read in colours but the colours themselves, like "light" and "dark", will always speak directly to the core of our human nature in unambiguous terms.

Colour Meanings: Positive and Negative

The primary contingency which will determine our reading of colour meaning in any context will be that between their beneficent and maleficent aspects, for as with all aspects of existence, colours have both a positive and a negative dimension.

> "The beneficent aspect of colours - and of elements - is always essential, direct and unconditional; their maleficent aspect is

> accidental, indirect and conditional, for it exists only by opposition and negation”[35] (Schuon, 1956).

But exist it does. Every symbol has both a positive and a negative aspect and either may be used depending upon the message and the context. It is somewhat disappointing to read Gage (1993) saying that symbols in the Middle Ages were arbitrary inventions of individuals, “were fluid; inventions of the imagination” and go on to defend this assertion with reference to opposing uses of the same symbol “- the lion, because of its ferocity was sometimes compared to the devil but since it was fearless it could be compared to Christ”[36]. Of course! Both meanings are to be clearly seen in this one magnificent symbol whose efficacious use goes much further back in human history than the medieval Christian era. Such a misunderstanding of the nature of symbolism, whilst common in modern literature, is surprising in a scholar of the stature of Gage. He says that in the light of this arbitrariness “it is not at all surprising that modern students of medieval colour-symbolism have been hard put to it to reach any general conclusions about the meanings of individual colours”[37]. Difficult it is but the difficulty is only compounded by such fundamental misunderstanding of the nature of symbolism - a misunderstanding which is so deeply ingrained in most current thought that the traditional view is rarely proclaimed and even more rarely acknowledged to have anything of substance to contribute.

J.E. Cirlot ([1962]1984) says

> “Colour-symbolism usually derives from one of the following sources: (1) the inherent characteristic of each colour, perceived intuitively as objective fact; (2) the relationship between a colour and the planetary symbol traditionally linked with it; or (3) the relationship which elementary, primitive logic perceives”.[38]

---

[35]**Schuon, F.** 1956, *Spiritual Perspectives and Human Facts* (London: Faber and Faber) p.43.
[36]**Gage,J.,** 1993, *Colour and Culture* (London: Thames and Hudson) p.83.
[37]Ibid p.83.
[38]**Cirlot, J.E.,** 1962 [1984], *A Dictionary of Symbols* 2nd edition, trans. from Spanish by Jack Sage (London: Routledge & Kegan Paul).

Cirlot observes that modern psychology and psychoanalysis tends to lean more heavily upon the third source but it is the first of which Schuon speaks for it is this which is most directly connected to the authentically traditional understanding of the nature of symbolism. The second of Cirlot's sources is, as he says, more a reflection of the "theory of correspondences" whose truly vast scope is concerned with the reading of Creation as a holistic interconnected system.

Lüscher's Colour Test: an Indicator of Constant Objective Meanings of Colours

That colours have their own nature and that they speak in a direct language understood at some level by everyone, has been demonstrated by Lüscher (1969) whose intriguing popular *Colour Test* has been the centre of many an after-dinner discussion. Not that it is just an amusing diversion. Lüscher made use of it as one of his professional tools of analysis of personality as a psychologist. He proclaimed it a very reliable tool because it provided him with what he regarded as a constant - *the* basic human response to colour. At first glance it seems to be based upon a number of crude generalisations about "primitive" human colour response (going back to the cave and talking about "primitive man" in the wearisome manner of those whose world view seems totally conditioned by the notion that we are evolving towards some higher state and leaving our ignorant origins behind us!) however, the meanings ascribed to the colours used in the test are clearly generally accepted meanings. Lüscher says the "objective meaning" of each colour is constant, remaining "the same for everyone - dark blue for instance, means 'peace and quiet' regardless of whether one likes the colour or dislikes it"[39]. The efficacy of the test is based on the fact that subjective attitudes towards each colour will vary from person to person depending upon their "personality psychology" at the time of the testing.

Supremacy of Rorschach Test

A professional cloud has always hung over this work however. Lüscher was justifiably criticised by his colleagues for making his test available for amateur, do-it-yourself personality testing - not because they thought the test to be flawed but because they understood that "decisions made on the basis of this kind of personal

[39]**Lüscher, M.,** 1956, *The Lüscher Colour Test*, trans. by Ian Scott (London: Pan Books) p.24.

diagnosis can lead to unfortunate consequences" (Sharpe 1974)[40]. The more "professionally acceptable" Rorschach Inkblot Method, which is often employed in clinical psychology, is based on similar hypotheses. And according to Sharpe (1974), although research has not always completely supported it, no method has proven to be better.

Cultural Differences

The different subjective responses to the same colours which form the basis of these tests are analogous to the differences of colour significance observed in different cultures. Where for example red is seen to signify happiness (and when combined with gold *special* happiness)[41] in the Chinese culture, yellow is more likely to be the colour which most closely signifies happiness in western culture.

Considering colours in their physical manifestation, Schuon comments on some colours drawing attention to

> "their own nature and direct language. Red has intensity and violence; blue has depth and benevolence. The eyes can move and lose themselves in blue, but not in red, which raises before us as it were a wall of fire. Yellow has both intensity and depth, but in a 'light' manner; it has, in relation to the two 'heavy' colours, a certain transcendent quality and marks, as it were, an emergence towards whiteness. When it is mixed with blue, it gives to the contemplative quality of the latter a quality of 'hope', of saving joy and of liberation from the enveloping quietude of contemplation. Red excites, awakens and 'exteriorises'; blue collects and 'interiorises' and yellow rejoices and 'delivers'. Red is aggressive and acts towards the outside; the radiance of blue is deep and welcoming and passes inwards; that of yellow is 'liberating' and

---

[40]**Sharpe, Deborah T.,** 1976, *The Psychology of Color and Design,* (Chicago: Nelson-Hall Company), p.59.

[41]The Byzantines also had a special respect for this colour combination for they saw an affinity between them which was also seen by the Romans of Antiquity. Red and gold are the colours closest to light in their culture. The medieaval glass makers used gold in the making of ruby glass. Very thin layers of ruby glass were "flashed" onto the surface of white (clear) glass to make a red glass.

> spreads in all directions. The mixture of a turning in to oneself (blue) with joy (yellow) is hope (green). Hope is opposed to passions (red) because it lives, not in the present like passion, but in the future; it is opposed to passion in its two aspects of introspection and of joy”.[42]

It should perhaps be restated here that the symbolic reading of colours must be an inclusive process which “throws together” all aspects of the phenomenon. The narrow, exclusive view is unfortunately the norm. For example the almost laughable but quite common assertion that purple is a royal colour because the process whereby it was originally produced was a very time consuming and expensive one only accessible to kings, is one example of such a narrow view where a modern preoccupation is projected onto the interpretation of the past. Our current almost pathological concern with notions of the use of power as determining human relations - in this case the use of power by the ruler over the populous - has led to such shallow conclusions permitting only a fraction of the rich story to be read. There is no doubt a correspondence between the rarity of the means of production and the meaning of the colour - a royal colour ought to be a rare colour for its symbolism to be complete, but this is not the only consideration. Purple is the natural colour of royalty for it is a combination of red and blue. These two colours allude to two characteristics which are desirable in any king - the red dimension to the quality of love for his subjects and the blue to the quality of wisdom with which all rulers should rule. That the colour has malevolent (or at least negative) connotations as well is obvious - all colours do. But in any consideration of the cultural meanings or symbolism of colours as indeed for all symbolism, the beneficent connotations are almost always of primary significance.

COLOUR MEANINGS

The following notes on the meanings of various colours have been taken largely from Schuon (1956) and Cirlot ([1964] 1984) for the major references to symbolism whilst

[42]**Schuon, F.** 1956 op. cit. p.41.

Sloane (1980), Varley (1980) and Gage (1993) were mainly used for the more contingent or subjective meanings. The colours are arranged in the order in which they seem to be recognised in the language of any given culture as described by Berlin and Kay (1969).

BLACK

Positive meanings:

The first colour in the ascending scale of colours, it is generally seen as having negative meanings however, as with all colours, its meaning will depend upon its context and it can have positive meanings. In the school context it would be unlikely that one would use black as the dominant colour in any interior other than perhaps a theatre (and there are much more imaginative dark colours which would serve the same function). Black represents the primal darkness or chaos (as opposed to cosmos or ordered creation) and therefore to pure potentiality - mysterious and powerful. It stands for all preliminary stages representing the descent into the underworld as an atonement for all that has gone before (Guénon, 1950). It is therefore the colour of penitence in Christian symbolism. That Noah released a black crow before he released the white dove from the ark is an affirmation of black as the colour of the preliminary stage. Germination takes place in the secrecy of the darkness - there is therefore a connection with the blackness of the cave and the feminine aspect which is echoed in many traditions in many ways. Black also stands for time (as opposed to the timelessness of white).

In its more contingent aspect, black has a certain dignity and stiff formality which is reflected in the black leather of the executive furniture, the black cassock of the clergyman and the gentleman's formal evening wear.

Negative meanings:

Of all the colours, black is the only one whose negative or malevolent nature is primarily the dominant one. Black is the colour of the night, inherently ominous, sinister, evoking spontaneous fear. It is the colour of death and mourning. The early

Greek notion that light and life are synonymous has as its opposites, death and darkness - black is the colour of darkness *par excellence*. It is the colour of sin and evil. We talk of being in a state of black despair, in a black mood, on a blacklist, to be blackballed, to have one's reputation blackened, to be blackhearted.

WHITE

Positive meanings:

White, as the brightest of all colours, derives its significance from the sun, brightest light in our world whereby it symbolises mystic illumination. Symbolically it is also related to gold, the “brightest” of all elements (the ultimate goal of the alchemist). The next brightest colour is yellow which, in its purified state, is like white. White in this way borrows from yellow its joyous meanings. The Christian burial is marked by the use of white vestments to symbolise the joy of the birth of the deceased into the next life. This is set against the background of black clothing with its connotations of sorrow and mourning. White is the obvious colour of purity and particularly of sexual purity where its meaning extends to the pale colours used in the clothes of the sexually innocent (in contrast to the sexual provocativeness of women's black underwear)[43]. The white lily is the symbol par excellence of the Virgin Mary - the pure white receptacle - a symbolism that abounds in Christian art. White signifies timelessness when opposed to black in its meaning as time.

Negative meanings:

White has the quality of lividness and as such is similar in its negative aspect to green or greenish yellow which in their negative meanings are the pallid colours of death. (White is the colour most often associated with death in Japanese culture). It is the colour of the moon and if the light of the sun is seen as positive, then its reflected light in the moon is its negative aspect. To send a white feather is to accuse someone

[43]**Sloane, Patricia,** 1989, op. cit. p.120.

of cowardice, a practice based on the notion that a white feather in a fighting cock's tail was a sign of degenerate stock according to Varley (1980).[44]

RED

Positive meanings:

Red is the first colour to appear in the language after black and white (light, dark). It is the colour of blood and fire and has an obvious and immediate connection with passionate emotions, particularly with love. It is an aggressive colour with a "masculine" nature and has always been linked to combat - Mars, the Red Planet and the god of war; the Roman general had his face painted red in triumphant processions. In Christian symbolism, whilst black stands for penitence and white for purity, red stands for charity and love. Red stands for the creative principle - the mother goddess of India is red. Red was seen as "the colour of light" in Antiquity (Gage, 1993)[45]. Gage observes that "the ancient tradition of interpreting the values of colours according as they more or less embodied light was a very persistent one"[46]. In Aristotle's colour-scale red was placed next to light. It was seen as the colour of the sun in Antiquity and early medieval times. As to "be in the light" was to "be alive", red was seen as the colour of life, a direct correspondence with red as the colour of the creative principle. The Chinese culture makes abundant use of red where its connection to life, good fortune and happiness is emphasised. When red is combined with gold, special happiness is signified. In architecture, the eaves of the building and the outer wall of the courtyard would be painted red, symbolic of the South, the sun and joy[47]. In their solar rites they utilise a tablet of red jade which symbolises the Element of fire.

With purple red has always had regal connotations. Royal livery is commonly red and to "roll out the red carpet" is to show the greatest respect, respect fit for royalty.

---

[44]**Varley, Helen,** editor, 1980, *Colour* (London: Mitchell Beazley Artists House) p.178.
[45]**Gage,** 1993, op. cit. p.25.
[46] Ibid p.27.

Negative meanings:

Its passionate aspect may be seen as negative in its association with sexual lust and with crimes of passion. Whilst it is the colour of the sun it is also the colour of fire and therefore the colour of hell and Satan.

YELLOW

Positive meanings:

Yellow is the happiest of colours. It is the colour of joy, particularly spiritual joy. It is the colour of gold and as such has some of the meanings of red but not as passionately - rather more “light heartedly”. Yellow symbolises enlightenment, the state sought by the Bhuddist monk in robes dyed with saffron (which produces a slightly orange hue). It is the lightest of colours and therefore shares some of its meanings with white. It is the final colour on the alchemist's series denoting the path of spiritual ascension - black, white, red and finally gold. In Chinese culture, yellow, with its solar connotations, is related to royalty - the Emperor in the Ch'in Dynasty wore yellow “implying the brightest sunlight and greatest power”[48].

Negative meanings:

Yellow in its negative aspect has the malevolent symbolism of gold - not only is it a very precious metal symbolically associated with the sun and all of the positive symbolism that attends to this, it is the focus of a lust for worldly riches and power which can consume one in a conflagration of greed. The medieval stained glass windows depict a yellow-clad Judas betraying Christ. The very word has a negative ring to it in English where it is generally reserved for negative metaphors - to have a yellow streak is to be cowardly. Positive metaphors use the word *gold* rather than *yellow* - we have golden sunny days not yellow ones; yellow hair is called golden. It is also the colour of sickness, particularly jaundice.

---

[47]**Yau, Victoria**, 1994, “Use of Colour in China”, *British Journal of Aesthetics,* Vol. 34, No. 2, April, p. 157.
[48]Ibid pp.155.

BLUE

Positive meanings:

Blue suggests the vastness of the sky and the depth of the ocean. Deep and mysterious, feminine, blue is the colour of wisdom, quietude and contemplation and as such is associated with spirituality, particularly female spirituality. The medieval artists used blue for the Virgin's cloak for all of the above connotations and French baby girls are often clothed in her colour. The great French medieval cathedral of Notre Dame (Our Lady) at Chartres has so much blue glass in the windows that the light within the building appears, quite aptly, to be blue.

Negative meanings:

Unlike all other colours with the exception of white, blue cannot have any truly malevolent meanings. Its more or less negative meanings have to do with its darkness in comparison to its complementary yellow - blue stands to yellow as black stands to white, but only faintly. The cool deep darkness of blue is not the complete darkness of black. Rather than the fear and dread evoked by black, the depths of blue suggest a melancholic state of inertia. The broken hearted spurned lover may die as a result of prolonged blue melancholy.

GREEN

Positive meanings:

Green, as the synthesis of blue and yellow, takes on their meanings modified appropriately. The inward turning (contemplation) of blue when undertaken with a sense of joy (yellow) results in the hope symbolised by green. Green is the colour of hope, promise, happy awaiting and good news. Of the secondary mixed colours (green, orange and purple) it is the “first” in that it is the most positive. Because of its two dimensions (yellow and blue) and because of its bright, happy nature, it has a strangely surprising and mysterious quality. It is the colour of verdant growth and is strongly suggestive of new life. In Christian art it is therefore often associated with Easter, with the new life and hope promised by the resurrection of Christ. Paired with its complementary colour red which symbolises love, green stands for knowledge.

Negative meanings:

Green is the colour of death, of rotting flesh, of envy and jealousy, perfidious and venomous. It is the colour of mould and decay.

BROWN

Positive meanings:

Brown is a complex colour which is able to be produced by a mixture of all of the primary hues. As such it can tend towards yellow (ochre), red (umber), green or blue and still be able to be identified as brown. It is the colour of clay and earth and therefore has a primary positive meaning associated with the potential of soil to support life. As the colour of clay it is linked to the origins of life, for clay is the primal matter from which life emerged both in the scientific evolutionary sense and in the Biblical account of the creation of mankind.

Negative meanings:

Its secondary and predominantly negative meanings are borrowed from its dominant constituent hue tempered by the presence of other hue(s). A brown which leans towards red will reflect some of the meanings of red but its “muddiness” or impurity will be echoed in its meaning as a hue which has been broken down or modified by its complementary or opposite hue, green (which is already a complex hue being the product of two primary hues). Brown is the colour of faecal matter and of rotting humus and as such carries the meaning of death and decay - exact opposites of the positive meanings of its constituent colours red and green.

ORANGE

Positive meanings:

The combination of red and yellow produce a colour whose meanings spring from both to some degree. In orange yellow loses its bright happy disposition and becomes a more sensual excited colour as it borrows some of the passion of red. It represents the joyous excitement of desire. It is evocative of the ripe fruit of late summer, a more mature colour than the youthful yellow but not quite yet the aged tawny colours of autumn.

Negative meanings:

Orange has few negative meanings but those that it does have relate mainly to its aspect as an overheated heavy yellow. It is the colour of seduction. The greed for worldly riches represented by yellow becomes more insidious as it takes on the lustful overtones of red.

PURPLE

Positive meanings:

Purple combines the love symbolised by red with the wisdom symbolised by blue and marries them in the royal purple where they represent the two most desirable characteristics of the good monarch - the wise, caring ruler. To the contemplative inactive and cold blue is added the harmoniously opposing blindly “unthinking” active and hot red to arrive at a colour which retains much of the mysterious depth of blue but with a passionate smouldering dimension.

Negative meanings:

Purple takes many of its negative connotations from black as it is the next darkest colour. Because the colours from which it is mixed are both “heavy” colours, the resultant colour is ponderous and overloaded evoking fatigue and languor. It is the colour of regret and mourning.

PINK

Positive meanings:

Pink naturally takes its major meanings from its parent colour red however as it is muted by white and is clearly not as powerful, its meanings are similarly less “intense”. As the colour of flesh, it is seen to be a sensuous colour linked to the emotions. The masculine passion of red is tempered by the white component to make it the colour of romantic love and to take on a feminine nature. It is the colour associated with the rose (Latin languages use the word “rose” for pink) and as such borrows some of the reserved, slightly formal dignity of this noble flower.

Negative meanings:

The few negative connotations of pink have to do with the consequences of an abandonment to the senses and to an unthinking surrender to the emotions.

MID GREY

Positive meanings:

Mid grey is exactly half-way between black and white, strictly speaking colourless and as such is completely neutral having no meaning of its own. In so far as to be neutral or uncommitted is a positive attribute, it is well represented by mid grey. It evokes a state of equilibrium.

Negative meanings:

The uncommitted nature of the colour may suggest a degree of concealment and therefore a degree of deceit. It also has the negative meanings of white and of black compounded in the one colour although modified to some extent one by the other. The pallor of death that is represented by white is clearly a significant aspect of grey.

TINTS, SHADES AND COMBINATIONS

Meanings Change with Change in Value of Colour

“Tints” and “shades” are hues whose values have been changed. Tinted hues have been altered in value[49] by the addition of white while shaded hues have been altered in value by the addition of black or their complementary colour. In the above list we have dealt with single colours in isolation and with very few references to anything other than the “pure” hues. The meanings of the various colours will of course vary as the colours change their value and move away from their pure chroma. A tinted colour will have a corresponding slight change of meaning taking account of the

[49]The “value” of a colour refers to its brightness or reflectivity.

weakening effect of the white. This has been elaborated only in the case of pink above, however the same kind of reading may be made of all of the other colours. Tinted hues are generally weaker in meaning than the original hue while meanings of shaded hues are weaker but in a relatively more negative or malevolent sense.

Colour Context will Change Meaning

We rarely experience colours in isolation. Our experience of a particular colour is virtually always in context with other colours. Whilst all of the meanings listed above hold good for colours in isolation, the meanings will change according to the colour context in which they are experienced. Where red and blue are juxtaposed for example as they so often are in medieval stained glass, the startling contrast gives greater emphasis to both colours. The fiery opaque nature of red is magnified in contrast to the cool depths of adjacent blue whose qualities are similarly magnified by the juxtaposition. This is a powerful example of “cold-warm contrast”, one of the seven contrasts of Itten (1973 [1961]) discussed herein.

SECTION 1: PART THREE

COLOUR IN THE CLASSROOM

FUNCTIONALIST APPROACH

Faber Birren ([1969] 1982) maintains that "modern principles of color applied to schools will improve in a striking way the scholastic performance of school students ... A well designed environment not only facilitates learning new subject matter, but reduces behavioural problems".[50] Birren sees the "problem" of colour in the classroom to require nothing more than the application of what he calls "functional color", colour which is "practical". He feels personal opinion and even whims about colour choice should be set aside in the interests of practicality. He then goes on to make a number of suggestions as to which colours ought to be used in which areas of the school.

The notion that colour may be used purely in its functional mode as suggested by Birren ([1969] 1982)[51] is a concept that is clearly discredited. The human person is not able to be considered in the mechanistic manner which seems to be taken for granted by the rarely identified "scientific sources" Birren relied upon for recommendations about how to use colour in our built environment. As with similar work by Mahnke and Mahnke (1987)[52], there is a frustrating lack of reference to specific corroborative source material.

Futility of Formulae in Colour Choice

The desire to find a formula for assisting in the selection of colours to maximise the chances of eliciting certain responses or determining behavioural patterns in the classroom runs the very real risk of leading to simplistic colour schemes which will be doomed from the outset. Knowing that light green or blue can be "soothing"

---

[50]**Birren, F.,** [1969] 1982, *Light, Color and Environment,* (New York: Van Nostrand Reinhold) p.83.
[51]Ibid p.83.
[52]**Mahnke, F.H. & Mahnke, R.H.,** 1987, *Color and Light in Man-made Environments,* (New York: Van Nostrand Reinhold).

colours and wishing to create a soothing mood in a classroom, the colourist may take the obvious step and devise a colour scheme based completely on one of these colours in one or more shades or values of it. Now whilst this may indeed be "soothing" for most people for some time, the reality is that people tire quite quickly of such things. We are creatures of change and seek change and variety in our environment. Our response to colour is a multi dimensional complex phenomenon influenced by a huge variety of factors and no "scientific" formulae will ever be able to be devised which will guarantee behavioural outcomes.

Birren ([1969] 1982) seems to be acknowledging this when he observes that the human person cannot be considered as merely a body which responds to its environment in a predictable mechanistic manner but that "body, mind, emotion, spirit, represents a coordinated unity, a microcosm, and color pervades all aspects of it"[53].

Like all too many writers in the field of human behaviour, Birren pays lip service to the notion that *mind, emotion and spirit* are somehow separate, distinct entities, then treats them as aspects of what, from a traditional metaphysical point of view, is clearly just *mind*. A holistic view of the human person would dismiss such a view as confused at best.

Validity of the "Folk" View of Colour

The authentic traditional view is that the human person must be considered as a tripartite creature having *body, mind* and *spirit* where these three parts are discernible but inextricably dependent upon each other within the whole. This remains, what is often disparagingly referred to in the sophisticated and largely esoteric language of too much modern writing, as the view of the "folk", implying that whilst it might be part of the culture in a general sense, like "folklore", it is somehow more *superstition* than hard-nosed fact. It is however the "folk" who will be using the classrooms and their sensibilities and sensitivities and even their *superstitions* are precisely what the designer must consider. It is not for the designer to judge whether the individuals being designed for are mentally or spiritually crippled but there is an imperative to allow for the possibility that all people are in fact whole as traditional views of the world have always consistently maintained, whether this conforms to the world view of the designer or not.

Limitations of the Recommended Palette

Birren has made recommendations concerning colour use in most aspects of our built environment. His recommendations regarding colour in schools extend to the listing of an “appropriate palette” of colours. These recommendations have been echoed in the work of others most notably in that of Mahnke and Mahnke. They begin with broad generalisations such as “Children of kindergarten and elementary-school ages are mostly extroverted by nature. A warm, bright colour scheme complements this tendency, thereby reducing tension, nervousness, and anxiety.”[54] They go on to recommend that colours such as “light salmon, soft warm yellow, pale yellow-orange, coral, and peach” be used in a kindergarten room with “moss-green floor and olive-green tables”. These are precisely the colours recommended by Faber Birren ([1969] 1982).[55] Now clearly such a colour scheme may indeed be appropriate in *some* kindergarten *somewhere* at *sometime*. The problem with making recommendations of this kind is that the uninformed or colour-ignorant, given little other hard recommendations to work from, might feel justified in arguing that *all* kindergartens should *always* use these colours.

Without interrogating the wisdom of using colours which complement the tendency for children of this age to be generally extroverted, (although we must not rule out such questioning as to do so is obviously valid), no two kindergarten rooms will present the same opportunities for colour use in this way. A room which faces the sun all day long is already a “cheery” space and could indeed remain cheery even if it were coloured with predominantly cool colours with highlights and accents of bright hues. Indeed, in an environment which is hot and sunny for most of the year as is

---

[53]Op.cit. p.27.
[54]**Mahnke, F.H. & Mahnke, R.H.,** 1987, op.cit. p.83.
[55]**Birren, F.,**[1969] 1982 op cit. p.84.

experienced in parts of north west New South Wales, it is not inconceivable that a classroom in warm colours like this could in fact become oppressive.

Cultural Significance of Colours: Insufficient Data

And then there remains the question of the symbolism of the colours. Without doubt yellow is a joyous colour, however, it also has powerful symbolic cultural dimensions which must also be considered as part of its context. To give just one example, the Chinese traditionally reserved yellow for the exclusive use of the emperor. We simply do not know how much of this importance is residual in the Chinese community let alone the full significance of the colour to the other cultures who form the basis of the school community.

Mahnke and Mahnke, following Birren, make similarly limited and potentially limiting recommendations for colour use in classrooms for older students. Working from the premise that “Softer surroundings created by subtle and/or cooler hues have a centripetal action, which enhances the ability to concentrate”, they go on to list beige, pale or light green, and blue-green as colours which are appropriate for improving concentration “by providing a passive effect” in the classroom. Using almost exactly the same words as Birren, they discuss the notion of a different end wall treatment in the classroom wherein the students face one way. In Birren's words:

> “End wall color treatments are particularly appropriate to schools. In classrooms where students are oriented to face in one direction, the wall so faced can safely be toned to great advantage and comfort. The best practice is to use a tint like Oyster White, Sandstone or Beige for side and back walls, and to have the front wall in medium colors, such as Terra Cotta, Old Gold, Avocado, Emerald Green, Turquoise, Sapphire Blue. The advantage here is that the colorful end wall will (1) relax the students' eyes upon looking up from their tasks; (2) add greater visibility to the teacher and to the lessons or educational materials displayed and (3) break

> up monotony by giving the classroom a different appearance from different directions."[56]

Variety and Diversity

The "feature wall" has been a perennial means of achieving the kind of variety and diversity we seem to require in our environments. It is one of those devices which fall into and out of favour from time to time. At the time that Birren wrote this and then when he was echoed by Mahnke and Mahnke, it was obviously "in". It may indeed be an appropriate device to achieve the desired degree of variety and diversity of colour in the classroom, however, it is not the only means available to the designer and once again these recommendations run the great risk of becoming prescriptive. For example a degree of flexibility permitting controlled change to occur (sliding and/or rotating wall panels, display or pin-up boards, blinds, curtains, screens) might be even more appropriate.

INDIGENOUS CULTURE

Primary Importance of Indigenous Culture

There is an imperative upon all designers to endeavour to fully understand the context within which their works will be set. Everything that has been said above strongly supports the proposition that the traditional viewpoint is of paramount importance in the reading of colour meanings in the built environment. Notwithstanding the fact that our schools cater for people from a bewildering array of ethnic backgrounds and cultures, the indigenous cultures are of primary significance in the Australian context and clearly ought to be closely investigated in any attempt to use colours in a culturally meaningful way in the school.

Interpolating from Berlin and Kay

At the time of writing this work, little published material has come to light which might allow definitive pronouncements to be made concerning the meanings of

[56]Ibid.

colours to the various indigenous peoples. In the light of the work of Berlin and Kay (1969) and from a purely superficial look at the indigenous art, it can be opined that the indigenous colour languages in Australia would almost certainly contain words for light and dark, for black, white and red and that the symbolism attached to these would be similar to that which is generally elaborated herein. The positive meanings of black would logically be assumed to be of primary importance - black as representing original states, beginnings, pure potential - while the white ashes used in rituals would seem to be associated with notions of death and mourning and the red ochres with life forces. Beyond this we would not dare to venture.

Information from the Indigenous Communities

When working in an Australian context, but in particular where indigenous peoples are involved in any way whatsoever, in the absence of good documentation of specific colour meanings, it would seem that the onus must fall back upon the designer in the first instance to ensure that every avenue of inquiry is followed up. The first and most obvious is to ask the communities and the individuals what they understand about the traditional meanings of colours and how they ought to be used in this context.

PLANNING A COLOUR SCHEME

Colour Idea or Theme to Reflect Life Events

There are as many ways of planning a colour scheme as there are colourists. Every colour scheme however will inevitably be based upon an idea or theme, just as every building is an expression of more or less appropriate architectural ideas[57]. Logically the idea should have something in common with the architectural ideas but of greater importance is that the ideas or themes used to guide the selection of the colours ought to be very strongly related to the life that is to go on in the spaces.

[57] **Kollar, L.P.**, *On The Architectural Idea*, 2nd. edition, Sydney, 1987.

To give due consideration to the principles outlined above, this must be seen as more than just the "human activities" that are planned to take place here. To every life event we bring our whole selves in all of our extraordinary complexity and any satisfactory architectural response to this demands more than a functionalist approach to cater for the physical activities that are to take place here. And this naturally extends to the colours used in the spaces.

Some Factors Influencing Colour Effect

The factors that will have a bearing on the spatial effects of colours in interiors are indefinitely numerous. The following list includes just a few such factors. For each factor an example of an effect is mentioned. It must be clearly noted that this is merely one of innumerable examples that could be mentioned and is included to give a hint as to the extremely vast and complex realm with which we are dealing:-

- *Size and Proportions of Space*

A light, cool coloured ceiling tends to seem higher, however on a very lofty ceiling, the effect is neutralised to an extent by the height.

- *Major Lines, Directions in Space*

The horizontal is generally suggestive of stasis and is evocative of calm. An emphasis on horizontality in a space would be opposed by the use of warm, active colours.

- *Rhythms, Patterns etc. Inherent in Structure and/or Materials*

The coursing of brick- or blockwork, the joints in a panel system, the spacing of columns - all such patterns will have a specific effect. Colour may be used to enhance, compliment or negate these effects. For example, using one colour over a complex surface with a strong pattern will tend to neutralise the rhythms.

- *Size and Location of Coloured Surfaces*

A warm coloured wall in a predominantly cool coloured space might provide a very welcome relief and focus of attention. If however the size of the wall is quite small in relation to the others, the intensity of the colour would need to be increased if it is to have a similar effect to a large wall.

- *Orientation - Quality and Quantity of Daylight in the Space*

A space with windows facing west will receive very different natural light to the space facing south-east. The type and intensity of the sunlight will have a very strong effect on the space which must be responded to in the colour selection. A space which faces west might feel unbearably warm if it were coloured in strong warm colours.

- *Nature of Incident Light on Coloured Surface*

The apparent colour of a surface will depend upon the type of light that it reflects. If this light is the cool light reflected from the southern sky, then it will give some emphasise to cool colours whilst tending to mildly dampen the effect of soft warm colours.

- *Texture Of Surfaces*

The same colour will look completely different on a textured surface and a smooth surface. If the dominant colour effect needs to be constant, then the colour needs to be adjusted for the different surfaces.

- *Dominant External Colours*

The colours used in the interior will not only respond to one another producing different effects by their proximity to each other, but dominant external colours will also influence the internal colours due to the effects of simultaneous contrast. A large amount of green borrowed from a leafy garden will have an influence on the internal colours by suggesting its complimentary colour, red.

For each one of these examples there are countless possible ways in which they could have an influence on the effects of colours. Such complexities cannot be reduced to a simple set of rules. The successful colour scheme will be the result of the informed and sensitive application of the experience and intuition of the good colourist. This point cannot be stressed too much.

Need to Articulate the Ideas

Any work done by one claiming professional status must naturally be professional and be able to be shown to be so. The professional therefore needs to be able to clearly articulate the ideas and guiding principles being used in the work. In the world of colour design, colourists are too often permitted to hide behind their work claiming that it “speaks for itself”. Such a stance is dubious at best and intellectually and professionally bankrupt at worst, for if the ideas with which the work are dealing are of value, then they will be able to be expressed and discussed.

Any colour scheme proposed for use in schools must be supported by a soundly reasoned and well articulated **statement of intent** clearly explaining the ideas upon which it is based and why each part contributes to the whole. At the very minimum, all issues covered by this work should be addressed in such a statement.

THEORETICAL AND EMPIRICAL BACKGROUND

SECTION 2

LIGHT AND PSYCHO-BIOLOGY [58]

PREAMBLE AND RATIONALE

Introduction

The impact of light on human functioning - other than for vision - has been recognised as important only relatively recently, but the implications of these *non-visual effects* and their relationship to full spectrum light, are now relatively well developed and confirmed.

Inevitably there will be queries about the psychobiological efficacy of full spectrum artificial lighting (re: mood, attentiveness/arousal, performance and visual acuity, activity and hyperactivity, seasonal affective depression and circadian rhythm balance...) as well as about capital costs and running costs (energy efficiency), the positive and negative impacts of ultraviolet radiation, the acceptability and climatic-appropriateness of the blue colour of full spectrum artificial light, and the capacity of interior natural daylight to act as a substitute for daylight-simulating fluorescent lighting. These are legitimate concerns; and are over and above those complex issues relating to symbolism attached to colour, cultural interpretations of colour, sensations of hot or cold associated with colour, physiological effects of colour (raising or lowering blood pressure, activating or deactivating neural activity, etc).

This introductory rationale to the psychobiology and photobiology of light is intended, thus, *to highlight and synthesise some essential and salient aspects* relating to health, well-being and performance (many of which are developed at greater length

[58] Section 2 prepared by Dr. Robert Samuels, Senior Lecturer, School of Architecture, UNSW, 1996

in the text - thus, at the risk of being repetitious) in order *to elaborate on the scientific basis for the recommendation of the installation of full spectrum lighting in schools in NSW.*

ENDORSEMENT OF FULL SPECTRUM LIGHT & ULTRAVIOLET BLACKLIGHT (UVA)

- All studies relating to full spectrum lighting and/or UVA or 'blacklight' enriched light discussed in the report *endorse full spectrum*/daylight simulating fluorescent lamps, while ***not one*** *recommends standard cool white lamps.* [59]

- The standard white lamps are rejected in comparison to the full spectrums - cool whites being associated with headaches, lower visual acuity, lethargy, hyperactivity...

An holistic, non-reductionist, approach would assume that all humans everywhere require natural full spectrum light (sunlight and daylight) for normal functioning. To whatever degree they might be deficient in this natural requirement, they should, in ideal circumstances, be compensated. The baseline is the same everywhere - however close or far from that goal one falls is the issue.

If less artificial full spectrum lighting is required to make good the shortfall, all the better; but there is a strong likelihood of a shortfall, even in countries blessed with abundant sunshine like Australia, given contemporary lifestyles (see Sydney and light deficiency, below).

Similarly, humans have evolved with ultraviolet light. They are dependent on it, for Vit.D synthesis, for calcium absorption in bones, for immunologic responses, for circadian rhythm balance, for melatonin suppression. Now, due to the depletion of the protective ozone-layer, contemporary humans have to adapt accordingly when outdoors; but, indoor situations have their own characteristics, which must be evaluated separately.

GENERAL DESCRIPTION OF FULL SPECTRUM LIGHT, AND ITS IMPACTS

The visible spectrum of natural sunlight at sea level is about the same as the spectrum of an ***ideal incandescent*** source radiating at a temperature of 5,600 degrees Kelvin (degrees Celsius above absolute zero). The solar spectrum is essentially continuous, whereas artificial light, albeit full spectrum, also has peaks at certain wavelengths.

- When a particular wavelength is missing in an artificial light source the biological receptor specific to that wavelength apparently responds as if it were in total darkness, even though other wavelengths are present (Ott 1982, p23), with consequent biological and psychological reactions.

- Similarly, even where full spectrum light is available but is of inadequate brightness (*ie* illuminance) - or of inadequate duration at lower levels of illuminance - the co-called body-clock (the photoperiodic response) can become imbalanced.

These phenomena can lead to the *in*appropriate secretion of neuro-endocrine chemicals, in particular melatonin from the pineal gland (having a depressive effect, and disrupting circadian rhythms) while influencing the secretion of the hormones cortisol from the adrenal cortex and ACTH from the pituitary (both stress-hormones), which have further behavioural, attentional and mood manifestations.

These complex relationships are discussed at more length later, but are better documented in specific documents - such as the New York Academy of Sciences special conference on the effects of light on humans in 1985.

---

[59] About 70 studies are cited, plus 45 papers in the New York Academy of Sciences special conference on medical and biological effects of light in 1984, the basic source of information for the research on

Standard incandescent lamps have a Correlated Colour Temperature (CCT) of 2850K, so are shifted strongly towards the red, long-wavelength side of the spectrum. The full spectrum lamps recommended in this report, however, are rated at about **5500K**, as close to the solar spectrum as possible (CIE 55). 6,500K lamps are available (eg. Siemens "Biolux") but are not recommended here, although they are technically equivalent to the CIE [60] sun and sky rating of D_{65}. They are considered, here, to be too cool *ie* too blue for normal use inside schools; given that our normal colour experience is made up of sky blue mediated by yellow sun rays.

ULTRAVIOLET LIGHT

Ultraviolet radiation (UVR) is made up of UVA, UVB and UVC.

- UVA is the so-called 'near UV' or 'blacklight' (315/320 - 380/400nm) and follows immediately after visible violet. UVA passes through most types of glass (Electricity Technology Centre [ETC] documentation). "To date, there is no data incriminating damage to normal skin from the relatively low intensity of UVA light emitted from fluorescent lamps....Individuals who develop adverse cutaneous responses to UVA...are rare" (Harber et al, 1985). They are considered to be a special group with either photoallergic dermatitis or solar urticaria. Nonetheless, the possible interaction of UVA with UVB is still uncertain, and the field is still developing (Cole et al, 1985). There is evidence that UVA waves and visible light at the short end of the spectrum largely influence the timing of the diurnal rhythms in humans (Bickford, 1980).

- UVB is called 'middle UV' (280 - 320/315nm), the shorter wavelength, (also called the 'erythemal band'), commonly associated with problems of skin irradiation and skin reddening, and the effects of which, on humans, need to be

light reported here.

[60] CIE = Commission Internationale d'Eclairage (International Lighting Commission)

generally moderated; there are some therapeutic effects (Vit D synthesis, some skin ailments, eg).

- UVC is of even shorter wavelength (100 - 280nm, averaging 250nm). Damage to eye tissue occurs with maximum effect at 253nm (ETC documentation). UVC is also called the ‘bactericidal range’, the rays having a strong germicidal effect.

Natural exposure to light stimulates the secretion of melanin, which results in a darkening of the skin. This pigmentation effect protects against further UV radiation, natural or artificial *ie* regular exposure to sunlight for short intervals is considered beneficial (Beral et al, 1982).

The ozone layer and the atmosphere absorb UVB wavelengths shorter than 290nm so that solar radiation that reaches the earth consists chiefly of UVR in the 290-380 range, visible light in the 380-770 range, and near infrared in the 770-1000 range (20% is >1000nm).

- Humans have evolved with UVR naturally. It is suggested that only excessive UVR is damaging, *especially the shorter wavelengths (B and C)*, and particularly when the sun is high in the sky and rays are not oblique (where the atmosphere absorbs a lot of the rays), and in ozone-depleted seasons (from October to December in Australia).

Schools should erect shade structures for when children are outdoors during these periods, particularly between the hours of 11am to 3pm in summer periods, so they can still benefit from the full spectrum natural daylight but avoid direct sunlight. Light will also be reflected from certain surfaces, which could have other landscape implications not the subject of this report.

- It is submitted here that it is <u>not</u> *indoor*s that we should be limiting *longwave* UVR. It is there that it is deficient.

- **Glass and plastic** (the glass of which the fluorescent lamps is made, and the plastic of the diffusers which usually shield the lamps) effectively stop the shortwave UVR and only the longer wavelength UVA and visible light are transmitted (Ott, 1982).

All fluorescent lamps emit UV photons. It is how they function. The electric arc through the mercury vapour emits UVR which bombards the phosphor [61] coatings on the inner side of the glass tube, and visible light and some UVR is emitted. Ronchi & Bodmann (1984) [62] state that fluorescents *emit* very small amounts of UVR, and that due to the absorption of the glass envelope there is **practically no emission in the UVB range (below 315nm).** Glass, thus, is even more effective at absorbing UVB than the atmosphere and ozone layer. In the longer UVA wavelength there are also two spectral peaks generated (from the mercury excitation) at 334nm and 365nm. Thorington (1967; 1985) confirms that the glass bulb and diffuser absorb all UVB; as do Cole et al (1985) who suggest using egg-crate diffusers to get a greater transmission of UVR waves in general. Some fluorescent lamps also emit a trace amount of UVC, but this is usually totally absorbed by the glass envelope of the lamps (Cole et al, 1985).

- **Vitalites** ⍉ (full spectrum lamps used in almost all experimental studies cited in this report/US Patent #3670193) simulate the solar spectrum in the visible spectrum, the *near* ultraviolet region *ie* emit blacklight or UVA (320-380nm) - about 220❍w/lumen, and about 8❍w/lumen in the UVB range.

- **Ott-lites** ⍉ also have radiation shields at the cathodes, to protect against x-ray emission.

- The comparable full spectrum lamps used in the Samuels & Ballinger (1992) field experiment in Sydney were Siemens Maxilux de luxe Daylight/no.12, (CCT

---

[61] Luminescent compounds that emit visible radiation of characteristic colours when bombarded by UV photons. Standard cool white fluorescents are strong in the green range, tri-phosphors in the red range, and full spectrums in the whole range, especially picking up on the blue range deficient in the other lamps.

[62] Ronchi is Chairperson of the CIE Division 6 Group: Photobiology and PhotoChemistry

5400K; CRI 98) which closely approximate the Vitalite specifications, and were imported from Germany by Siemens, Artamon. Vitalites proved to be too expensive.

Artificial daylight/full spectrum lights meet all parts of the BS950 Part 1 standard; and the Vitalite lamp is listed with the US Federal Drug Administration as a medical device.

The 1981 Commonwealth Department of Science and Technology report on Artificial Light at Work (Occupational Safety and Health Working Environment Series: 6) stated that 'blacklight is harmless to the eyes'.

RUSSIAN RESEARCH ON UV

The research reported below is extracted from Hughes and Neer (1981), who do not distinguish between the UVR bands in their reporting.

Besides the melatonin, circadian, VitD and calcium absorption requirements (see Hughes and Neer's research on the elderly), *immunologic response* is also enhanced by exposure to UV rays.

Dantsig et al (1967) and Volkova (1967) indicated an immunologic responsiveness to UV light, which promoted good health (reducing the incidence of colds, viral infections...) and recuperation from illness (related to leukoytic phagoxytosis, and serum bactericidal lyozme activity). Pertsovskiy & Kunitsym (1977) related similar findings to accelerating metabolism by the release of glucocorticoids and catecholamines leading to an increased capacity of the oxygen transport system in the activation of mitochondria. Ellinger (1957) recorded an improvement in work output from doses of UV, eg a 60% increase on the bicycle ergometer, and a measured decrease in fatigability (measured by cardiovascular responses).

INTERIOR DAYLIGHT ID_{65}

- While the very thin glass in fluorescent lamps allows some *shortwave* UV to pass through, the thicker glass used in *windows* **does not** (Ott, 1982, p30).

However, the absorption rate of window glass of UVB and UVC is variable, depending on the amount of contaminants present, especially iron, in the raw materials/sand. It is thus that some UVB sometimes gets by.

- Interior daylight is natural light which has penetrated though glazing, and has thus been filtered to some extent. To that degree it is considered deficient (see chart below).

Clarke (1979) shows how glass alters the spectral power distribution (SPD) of daylight by selective absorption over the whole range of wavelengths, except around the mid-wavelengths (green/yellow) but especially at the short (UV) and long (IR) wavelength ends of the visual spectrum. Transmission below 320nm *ie* of UVB, is virtually zero.

Effect of 6mm clear glass on SPD

Wavelength (nm)	*Daylight/D_{65}*	*Interior Daylight/ID_{65}*
310	7.8	0
320	20.2	0.4
330	32.4	9.8
340	40.6	21.3
350	43.8	32.6
360	47.9	41.9
370	49.6	45.6
Reduces until equal at 440 nm, starts to drop again at 560nm		
650	81.3	76.2
700	71.9	64.3
750	61.7	52.6
800	58.6	47.2

Source: Clarke 1979

Kok et al (1985) in a paper presented to the CIE show from their field experimental work how ultraviolet content (the most important wavelength region in an *actinic* sense *ie* prompting chemical reactions in humans) is higher when windows are open (again reflecting on the spectral transmittance of glazing), and also how furnishings and building materials absorb blue light and UV, thus lowering the Correlated Colour Temperature (CCT) of interior light towards the warmer, red end of the spectrum. Again, proof that interior light is deficient in blue and UV wavelengths.

The table below also indicates a similar effect:-

	% Daylight Transmittance
3mm regular glass	.86
6mm green float	.75
3mm grey glass	.31 - .71
13mm bronze	.25

Source: ASHRAE Fundamentals, 1985, Chap 27)

- It is not sufficient to claim that schools have adequate natural daylight indoors, given that this light is likely to have been filtered through glazing and depleted by the absorptive capacity of internal furnishings and materials.

ID_{65} might well be adequate for purposes of visual acuity, be perceived and experienced as more pleasant than artificial light (Collins, 1975), and be effective in reducing energy bills, but interior daylight is still inadequate on a psychobiological level. Supplementation with full spectrum artificial lighting cannot thus be excluded by such arguments.

SUBJECTIVE AND OBJECTIVE MEASURES OF MOOD, ATTENTIVENESS AND PERFORMANCE

- Human experience of issues such as fatigue, alertness, attentiveness, headaches...*is* subjective.

These qualitative experiences cannot be measured with a slide-rule, or against a standardised objective benchmark, like the expansion of aluminium at x^{O}C might be. Such subjective measures, nonetheless, can be evaluated by standard techniques used in the social and environmental-design sciences to measure and record human experience. This does not make them less valid than measures of cortisol excretion in urine, for instance.

- All these subjective and objective measures are complementary, and together make the case for the installation of full spectrum lighting.

Inevitably, a good proportion of studies investigating human performance and light effects will be based on subjective responses to questionnaires, or teacher observations, or observer checklists, or video-recordings of behaviours, or estimations of behaviour change after exposure to certain colours (see Syntonics, in report), or IQ tests. Nonetheless, this report cites field experimental studies that also measured physiological and photobiological responses, using quantitative measures such as heart rate, endocrine/hormone excretion, brainwave activity/arousal, visual acuity measures, etc.

SYDNEY X NORTHERN HEMISPHERE X INCIDENCE OF LIGHT DEFICIENCY

The photoperiod (day length x sunshine hours) is better in Sydney than New York City, eg.

- However, the point at issue is the *real* exposure of humans to natural or full spectrum daylight simulating light as would be normal in situations appropriate for evolutionary development. Contemporary lifestyle diminishes this exposure, to whatever degree.

- School children, even though they are the most active of humans, and spend proportionately large amounts of time outdoors compared to their parents, are nonetheless exposed to a diminished light spectrum while indoors during school time. At very best windows might be open and thus admit undepleted outdoor daylight; at worst windows, curtains/blinds and furnishing will filter out a proportion of the spectrum, irrespective of the daylight that might be available outdoors.

Savides et al (1986) undertook a study on the duration and timing of illumination exposures *exceeding 2000 lux* (the critical level for melatonin suppression and circadian balance), in Southern California (San Diego 33^0N)[63] during the summer/autumn period, for 3 months, 24 hours a day.

Subjects had different activity cycles and were exposed to varying degrees of indoor light given their daily functions. All subjects who commuted to work or school experienced illumination greater than 2000 lux briefly (5-35minutes) between 8.00am and 10.30am. Overall, **the subjects experienced illumination *exceeding 2000 lux* for a mean of 6% of the 24 hours ie about *1.5 hours*,** some of whom only experienced 26 minutes a day.

- Wever et al (1983; 1985) showed that *at least 3 to 8 hours* of light at intensity of 3000-4000 lux is required to synchronise circadian rhythms, while phototherapeutic treatments for seasonal affective disorder (SAD) are generally of several hours exposure at about 2500 lux, sometimes twice a day (Lewy et al, 1980; Rosenthal et al, 1990, *inter alia*).

[63] Sydney is 33^0S

It is likely that people living in urban Australia would, similarly, have lifestyles that keep them indoors at work or at school for most of the day, and that they would not experience sufficient full spectrum light above the minimum photobiological level in a normal day. School children will come out of school at about 3pm, and often enjoy outdoor light either at home or at an Aftercare centre, but this exposure is, in a sense, too late. They have already spent the whole day at school, where attentiveness and calmness would have been of most benefit.

BRIGHT LIGHT AND STANDARD LEVELS OF LIGHT AND PHOTOBIOLOGY

The issue of doses of 2000 to 2500 lux of artificial indoor light being the level required to ‘entrain’ the photoperiodic response is possibly more relevant for photo*therapy*, where an imbalance is put right. Melatonin is not immediately suppressed by low intensity light, as an acute remedy, but some studies suggest that long-term exposure of ‘normal’ people to lower intensity artificial light appears to be different.

- In order to maintain an appropriate quality of indoor light for 'normal' people it would seem a much lower, *quite standard level of illumination is adequate*, something in the range of 400 lux which the AS1680 standard requires for reading and writing activity in offices, so presumably in schools too, as long as exposure is constant and over long periods of time. Duration at standard lux levels (as well as to high intensity light) has been shown to be effective (Kuller 1987; Samuels and Ballinger, 1992).

This has important implications for lighting in schools. Bright, 2000 lux lighting, which would have other negative impacts such as glare, reflectivity, and energy inefficiency does not seem to be necessary. Rather, the regular exposure to standard illumination levels seems to be all that is required.

Kuller and Wetterberg (1993) found that *high* levels of simulated daylight (1700 lux) over a one-day period evoked a negative response - social evaluation of a space decreased and visual discomfort increased. It is suggested, here, that high levels of light should only be used in therapeutic situations, and in relatively short bursts, for instance, in the treatment of SAD sufferers - not in standard working or learning environments.

However, their results indicated that there was an ***alpha increase*** (EEG reading: delta indicates drowsiness) *ie* ***increased alertness, under the 450 lux daylight lamps,*** which would confirm other studies (and possibly also suggest 450 lux as a target for school illumination levels where full spectrum lamps are installed.)

In personal communication with Rikard Kuller, at the Environmental Psychology Unit, School of Architecture, Lund Institute of Technology, Sweden, in October 1995, he suggested that flicker might be the reason for the discomfort at high illumination levels, and thus recommended the use of high frequency ballasts or modulators to counter this. Golla and Winter (1959) and Wilkins *et al* (1988) showed relationships between flicker, high frequency ballasts and headache episodes [see Other Studies :Offices etc].

- The IES Lighting Handbook (1981) does *not* recommend a single illuminance level for classrooms. It depends on visual tasks, age, importance of speed or accuracy etc. A range between 200-500 lux is recommended. The British Dept. of Education and Science Guidelines (1979) recommends not less than 300-350 lux where daylight is also present. The Ontario Ministry of Education recommends 500 lux for a general purpose classroom.

- About ***400 to 450 lux*** *of full spectrum lighting is recommended in this study*.

- Post-occupancy evaluations, after installation of full spectrum lights, could be carried out to confirm before/after changes in behaviour and well-being, and lux levels adjusted accordingly.

INTENSITY OF LIGHT AND PHOTOBIOLOGICAL IMPACT

Further, the issue of intensity of light is vital. Outdoor natural light in the shade of a tree on a summer's day is in the range of 100,000 lux. Indoors, however, standard illumination levels are about 300-500 lux.

- Ronchi and Bodmann (1983):..."at usual daylight levels of up to 100,000 lux the exposure of man to UV radiation is higher by three orders of magnitude than under fluorescent lighting". In other words, indoor illumination at eye level in artificially lit rooms is commonly less than 10% of the light normally available outdoors in the shade of a tree on a sunny day (Wurtman, 1975).

It would be fallacious to equate the two, and assert that full spectrum lamps would emit light that would be harmful because it would be too intense.

Furthermore, luminous flux = quantity of light emitted (lumens) *at a source*, say a fluorescent lamp on a ceiling; while illuminance = lux (lumens/m^2) is the amount of light received *on a surface.* This surface intensity is influenced by the inverse squares law *ie* where 1 lumen of flux falls on a surface area of $1m^2$ = 1 lux; where 1 lumen falls on a surface area of $2m^2$ the intensity of light is only 1/4lux; on $3m^2$ it is 1/9th lux. Illuminance intensity changes inversely with the square of the distance.

UV radiation penetrating the atmosphere also varies markedly with the season, down to about 1/15th in winter of summer levels; otherwise the spectral composition is essentially similar all year.

SELECTED STUDIES (INDICATIVE OF DIFFERENTIAL METHODOLOGIES) CONFIRMING THE BENEFICIAL EFFECTS OF FULL SPECTRUM ARTIFICIAL LIGHTING

Hollwich studied the effects of light on people over a period of about 35 years, and discovered the so-called ‘energetic pathway’ (at a similar time to Wurtman in the USA) where light travels to the hypothalamus and pineal, as well as to the visual cortex. In a 1980 paper (with Dieckhues), reporting on an experiment with bright light sources (3500lux) - one approximating the spectrum of daylight and one not (cool white fluorescent), they found stress-like levels of ACTH and cortisol in the group exposed to the spectrally deficient source after just two weeks exposure.

- “This explains the agitated mental and physical behaviour of children staying the whole day under artificial illumination with strong spectral deviation from daylight” (p188) - referring to the study by Maas et al, 1974 on fidgety behaviour and fatigue of pupils performing mental activities under cool white fluorescent lighting.

Ott (1982) refers to several studies (other than his own: see report) on hyperactivity using full spectrum and cool white fluorescent lamps (and incandescent lamps) in American schools - often using radiation shielded cathodes, and extra UVA light provided by a blacklight tube.

- He cites a 1975 study by the County Office of Education in Santa Cruz, California where a decrease of 32.3% in hyperactivity was recorded when cool white fluorescents were substituted with standard incandescent lamps.

An observer counted incidents (on a pre-agreed checklist of hyperkinetic activity - such as jumping up and walking around, standing on chairs, clapping, yelling etc). 201 incidents were recorded after the lights were changed compared to 297 before.

- Similarly, he cites a study by Mayron, with 4 windowless classrooms, two equipped with standard cool white fluorescents and two with full spectrum/radiation shielded lamps, about 50 children in each setting, and time-lapse hidden video cameras used to record behaviour at monthly intervals. Significant differences in hyperactivity after 60 to 90 days exposure were recorded.

- Another study cited looked at situations with standard fluorescents and natural lighting without fluorescents, using a manual for coding the discrete behaviours of second-graders. Students spent a statistically significantly greater time in attentive behaviour when the fluorescents were turned off.

- In a study with severely sight-impaired students (by Werlin, Director of the Overbrook School for the Blind, in Philadelphia), these individuals saw objects for the first time when exposed to long-wavelength UVA rays (from a blacklight source). Werlin also reported a calming effect on the children from the blacklight. Other studies using Werlin’s blacklight UV equipment reported similar beneficial results (cited in Ott, 1982).

- Munson and Ferguson (1988) found hyperactive behaviours decreased under daylight simulating tubes as compared to cool white tubes.

- Kuller (1987) found in an office study conducted over a period of about 7 months that there was less visual fatigue, more alertness *and* less melatonin secretion in the full spectrum conditions.

- Samuels and Ballinger(1992) the only study of this kind conducted in Australia, found significantly less (self-reported) fatigue and headaches amongst workers in a Sydney office building exposed to the full spectrum lamps for 8 months.

- Lindsten and Kuller (1987) examined the health impact on one hundred 8-9 year old school children from lack of natural daylight, over a period of one year, using methodologies ranging from behavioural observations and teacher assessment to urine analysis (for cortisol).

In the classroom situation with no external windows there was most disturbance in levels of the hormone (eg, levels kept falling when those in other situations were rising normally).

Kuller and Lindsten (1992) assessed the effects of light, both daylight (interior, *ie*) and artificial (full spectrum and standard), over one year, with 90 school children. *Low to moderate cortisol* levels (stress hormones, *ie*) were associated with and seemed to ***promote individual ability to concentrate***. On average, the classroom with both skylight and full spectrum tubes (which also had the highest lux levels) had the best overall level of concentration (only falling when temperature levels rose to uncomfortable levels, up to 32^{o}C.).

“Work in classrooms without daylight may....influence ability to concentrate or co-operate...” (p.316).

- It is also interesting to note, here, that Wurtman and Weisel (1969) found larger testes, ovaries, spleens, hearts, pineals and adrenals in rats exposed to full spectrum lighting in comparison to those exposed to standard cool white lighting.

COLOUR AND PHOTOBIOLOGICAL IMPACT : AROUSAL TABLE

An Arousal and Attention Table relating to physiological and psychobiological effects of *colour* is presented in the document, but does not cover the full range of colours, being drawn from the research available. Some salient aspects of that matrix are noted below.

Gerard (1958) noted that the autonomous nervous system and visual cortex were less aroused when stimulated with blue, rather than with white or red. This was also associated with significant differences in feelings, such as less anxiety and hostility in the blue conditions. Increased physiological activation and subjective disturbance (anxiety, tension) were recorded during red stimulation. Aaronson (1971) showed similar effects of colours on activities and arousal as Gerard (cited in Hughes, 1980). Wohlfarth (1958) conducted early experiments which demonstrated that colour has a measurable and predictable effect on the autonomic nervous system.

Arousal theory suggests that intense stimulation attenuates the alpha rhythm *ie* alertness in the brain, shown, in the case of Gerard's work, with red versus blue *light*, and with red versus blue *colour,* in Mikellides' 1989 dissertation at the Lund Institute of Technology.

- This would suggest that over and above the qualitative effects of the full spectral range in the daylight-simulating lights, that the *blue colour of the light itself* could also assist in lowering tension and assisting relaxation in school settings.

Plack and Schick (1974) reported similar effects of specific colours on activation and arousal, also confirming the effect of selected colours on behaviour and physiology. Even blind subjects were affected. They reported effects of colour on non-visual processes including changes in mood and emotional state, psychomotor performance, muscular activity, rate of breathing, pulse rate and blood pressure.

See also section on Syntonics for further confirmation of effects of colour on humans.

THE INTERACTIONAL MATRIX

- The interactional matrix presented as a basis for colour scheme evaluations, and which attempts to relate *Attention/Arousal to Activity/Spatial requirements to a Colour Spectrum Band* (all within the context of full spectrum light), is the only model of its kind in the literature.

It is an innovation generated from the research reported and synthesised here. It is not an absolute model, but is relative to numerous variables, all of which cannot be elaborated upon here. This would require a separate study in its own right.

It is suggested as a complementary tool for colour designers and education managers, not an all-inclusive replacement model.

- Nonetheless, given that no other models exist, the other alternatives are to rely on experience and intuition. Valuable as this may be, it is unscientific and non-empirical, and should be complemented by use of such a matrix.

Presumably if the PWD Education Branch had been satisfied with these existing methods they would not have commissioned a further study into the influence of colour and light [64] on the performance of school children.

- ***Psychodynamic colours: blue-yellow range, and full spectrum lighting***

  Wohlfarth & Sams (1981) conducted a field experiment using *full spectrum lighting and shades of blue* in a classroom; handicapped children. They reported a drop in systolic blood pressure [down 20 pts] - for both blind and sighted children. Sydoriak (1984) replicated this study and found significant reductions in both systolic and diastolic blood pressure in blue classrooms. Wohlfarth and Sams also reported a large drop in aggressive behaviour [down 56%], in non-attentive behaviour [down 23%]; and that teachers were more relaxed, and reported more work completed.

- Wohlfarth (1986) extended his earlier work by including yellow in student's vision and blue in teacher's vision, *together with full spectrum lighting.* This was an

[64] Full spectrum lights are fluorescent tubes that fit into standard luminaire fittings. No adaptation is required. Egg-crate diffusers would allow ultraviolet light to reach students. High Frequency Ballasts reduce flicker, and increase energy efficiency, but are currently expensive to purchase.

extensive empirical study undertaken in Canada, with four elementary schools, grades 1 to 6, over a 10 month period.

The control school had standard lighting and so-called ‘traditional’ wall colours in the *off-white⌫brown⌫subdued orange range* (and dark brown carpets); one of the three experimental classroom types had ‘psychodynamic ‘colours only *ie* walls painted in *cool blue and yellow with warm, brighter blue and yellow accents*, medium blue chalkboards (and light brown carpet); another had both psychodynamic colours *and* full spectrum lighting, and the third was fitted with full spectrum lighting only (control colours). Further experimental classroom situations involved altering ultraviolet and electromagnetic radiation levels.

Dulux colour numbers cited below are derived from a visual comparison with a copy of the original colours. They are approximations only. Glidden Paint numbers are exact.

Colours in experimental rooms: (Glidden Paint Numbers)[approximate equivalents in Dulux Master Pallette Fandeck]:-cool yellow walls in student’s vision (73-85)[southern cross/60YY77/332], cool blue walls in teacher’s vision (77-30)[glistening sea/50BG62/133], warmer yellow wall accents (73-50)[sunny side-up/37YY61/877], warmer blue wall accents (77-34)[brookhaven/70BG35/308], blue chalkboards (77-18)[blue jay/70BG28/169], light brown carpets (78-69)[sandy cove/00YY30/200].

The Wohlfarth study was ‘quasi-experimental’ in the sense that there were no exact equivalences between the control and experimental groups, as in all field studies, where all variables cannot be controlled for. Inevitably, a range of confounding extraneous parameters influence outcomes. The researcher himself states that the blending of cool and warm colours in the same room was a major fault in the experimental design (because of field of vision effects).

Further Constraints: Environmental controls such as time spent outdoors, window opening, extent of indoor natural daylight, overshadowing etc were not controlled for. Such variables are critical, however. Moreover, changes in performance/ achievement (not significant), rather than mood (significant), would be expected to *develop over periods considerably longer than the 10 months of the experimental field work.*

Results of the Wohlfarth study:-

- Mental ability/cognitive development and academic achievement (reading, vocabulary, mathematics):- findings were too variable to draw conclusions. A wide range of tests were used, appropriate for different grades (Otis-Lennon Ability Test, Metropolitan Achievement Tests, CTBS Reading and Maths Tests etc), but equivalences between them are not certain. Some significant changes were evident, but overall the results were inconclusive.

- Attitudes to school subjects (measured on the Schools Subjects Attitudes Scales):- results were inconclusive, other than the largest decrement being recorded in the control group (grade 6).

- Misbehaviour (aggressive, destructive, disruptive behaviour - measured by observation):- no significant differences.

- Absence due to illness, tested only in the full spectrum conditions and full spectrum/ultraviolet augmentation condition (using egg-crate diffusers):- no significant differences.

- Visual acuity:- no significant differences (Snellen Vision tests)

- Blood Pressure:- Staff showed no significant changes (but they are mobile and thus not exposed only to the blue colour condition), while students results showed sporadic changes. Only a sample of students were tested.

- Mood States (measured by the Preadolescent Mood States or PAMS test) were measured on four dimensions: surgency (cheerfulness, etc), sadness, aggression and mastery/self esteem. *Scores for mastery/self esteem were significantly and consistently lower in the control and colour only classrooms. The researchers considered this to be a robust finding for the beneficial effects of the full spectrum light/colour and full spectrum light only classroom conditions.*
  "In general, students in the light/colour and light only schools were found to have greater feelings of surgency and mastery/self-esteem compared to those students in the control school". " The control school students scored significantly higher on aggression than did those in the light only and colour only schools" (p.89).

- Noise levels were measured in the library of the two architecturally identical schools (the control and light/colour schools). Significantly less noise was measured in the light/colour school (5-6 dBA quieter).

- In an extension to this research, two classrooms in the four schools were fitted out with full spectrum ultraviolet 'supplemented' lights *ie* where egg-crate style diffusers permitted UV radiation in the 280-400nm range (.01 UVB and 8-20 UVA, at desk top height); the other two had conventional lighting. *Significantly lower levels of dental caries* were recorded over a 22 month period *in classrooms fitted out with full spectrum/UV lights*. (See also Hargreaves and Thompson, 1987).

- In the light only school, two classes both receiving full spectrum lighting but one UV supplemented, as above, were tested for Absence due to Illness. Significantly less absences were recorded in the UV supplemented group (311 in the unsupplemented group, compared to 138 in the supplemented group, over the school year). Zamkova and Krivitskaya (1966), of the Pedagogical Institute, Leningrad, also noted substantial improvements in school children exposed to ultraviolet erythrine lamps in schools in the USSR. Wohlfarth also cites 6 further studies where ultraviolet light had positive effects on school children, the elderly, factory workers, and animals.

- Another study, where significant differences were found, formed part of the Canadian schools field experiments. Ingraham (1983) examined the effects of electromagnetic radiation - emitted by the fluorescent lamps - in heterogenous grade 3 groups, on 'off-task' or hyperactive behaviour, using classrooms with cool white/unshielded lamps, full spectrum/unshielded lamps and full spectrum/*shielded* lamps. The significant difference occurred in the latter situation, where observers noted decreases in inattentive, disruptive, inappropriate etc behaviours (on average 3.15 off-task behaviours per minute less). Mayron, Ott et al (1977) showed similar improvements in hyperactivity in school children with full spectrum radiation shielded lamps.

- Alexander Schauss (see The Nature of Things: Living Colour, with David Suzuki, Canadian TV Series) had the front and side walls of a classroom painted bright yellow, while the front of the students desks and the back wall (in the teachers vision) were painted light blue. Students were found to have an increased heart rate, respiration rate, and stimulation of the left hemisphere of the brain - the side which controls judgment, reasoning, logic and writing skills; and an increase in IQ of 12 points. Teachers reported feeling more relaxed .

- Henner Ertel, cited in Birren (1961) mentions children being more cheerful, alert and positive, and obtaining higher standards in schools painted yellow/orange - but nothing further is stated.

Modern classroom/teaching modes are not static *ie* students do not sit always facing the front. The Canadian studies were based on the walls that students saw *most often.* However, the blue calming effect and the yellow stimulating effect could be appropriate wherever they sit, given that both alertness and calmness are valuable assets in school situations.

In other words, such dual-colour coding would provide an opportunity to be exposed to wavelengths of light which are beneficial for attention and concentration, and which are neither depressing, nor over-stimulating.

Indeed, a teacher could utilise a blue exposure to enhance the learning situation in certain circumstances, while at other times using the yellow wavelengths to enhance a certain type of performance.

The blue/yellow colours are wavelengths of light. As *perceived colours* they are, actually, incidental to the photobiological response prompted by absorption of the wavelength. Symbolically they might represent certain aspects of life, and be culturally different, and red might be sensed as warm and blue as cool, but the real issue is the invisible response to wavelengths of light.

- Thus, it is the *range of light* that is crucial here, the range being somewhere between **450nm and 600 nm (blue through green and yellow to orange).**

This wavelength range should be the core of the argument, and the basis of the colours suggested in the Interactive Matrix, with which colourists and education managers could work.

The perception that everything should be blue or yellow in the classroom is too simplistic. Furthermore, this range should be integrated with the achromatic scale, ranges of grey, which also fall into a similar position between black and white extremes.

It is worthwhile reiterating here, however, that our normal outdoor colour experience is made up of sky blue and sun yellow light, moderated by the green of vegetation. Very little red and orange is present.

Wurtman (1969: 36-37)

"There is a portion of the energy spectrum

capable of influencing neuro-endocrine functions in humans"

"Light input (or its absence)

controls pineal synthesis and the secretion of the hormone melatonin.
This hormone influences the functional activity of a number of glands,
probably by direct action on brain centres that control the anterior pituitary"

...Goethe (in his Theory of Colours) permeates each colour with a nuance of feeling
stressing not only what the eye sees but also what the soul feels
- the stillness and inward absorption of blue,
the serene, soft excitement and outward revelation of yellow...

We must approach the nature of the child through the conceptual, thinking element
and through the pictorial element, letting the child live in a world of colour.

Out of this, unity arises.

Paraphrase of Rudolf Steiner paraphrasing Goethe

GENERAL BACKGROUND: LIGHT AND PSYCHOBIOLOGY

Optical radiation, whether sunlight, daylight or artificial light, produces both visual and non-visual or actinic [65] responses in human beings (Wurtman, 1975; Thorington 1980). Visual impacts are a source of information about the environment, while non-visual impacts work via the photoreceptors in the brain, and through the skin. The focus of this research is on the positive and negative non-visual responses to artificial light in working environments.

EXPOSURE TO NATURAL LIGHT FOR HEALTHY FUNCTIONING

Taking Sydney as an example, with the sun rising at about 7 am and setting at 5pm (on average) during June and July, roughly half of the 10 hours of light are available as sunshine.[66] The other half of the time is cloudy or raining, and there are times when sunshine might not be seen for a week at a time. In any event, children at school will only be exposed to a fraction of the daylight available.

Because the human 'body clock' runs on a circadian time system, sufficient natural light is required, on a *daily* basis, for normal functioning. A certain amount of bright (2000lux) full spectrum light is required.

Secondly, a multitude of intervening factors come between sunlight and daylight and the receptors in the human eye, eg. angle of light (thus time of day), height above sea- level, air pollution and photochemical smog. The *daily pattern of contact with natural light for the vast majority of school children living in Australian cities* would be something like the following scenario:

- On awakening, remain indoors until leaving for school etc *ie* light is filtered through glass (thereby cutting out most ultra violet radiation [UVR], and distorting the spectral nature of light, to whatever extent) whether or not eastern sunlight penetrates into the dwelling ;

- Enter a motor vehicle, bus, ferry or train - where daylight is filtered through glass, and possibly even tinted glass;

---

[65] Actinic - property of light rays that produce photochemical activity and changes in humans
[66] Mean Daily Sunshine Hours, June/July, Sydney = **5.7hrs** (Melbourne = 3.5hrs)

- On arrival at destination, enter a building where light is again filtered through glass (with whatever probability that the glass will be tinted);

- Lunch breaks might well be spent indoors on cold or overcast winter or rainy days, or under open shelters, but exposure to natural daylight will in any event be diminished.

- Particularly for children who attend Aftercare, after school, and on inclement days, their natural exposure to natural daylight is diminished; in psychobiological terms.

Added to these factors, is the filtering that takes place for children who wear spectacles, and for those who wear sun-glasses outdoors - fearing the development of eye cataracts due to exposure to *un*natural levels of UVR resulting from ozone depletion. This is true for periods when ozone-depleted conditions might exist over populated areas (late spring, and first-half of summer), and during the middle of the day in particular. At other times and seasons, and especially in the morning when the sun has a low angle of incidence, rays are filtered by the atmosphere.

Research relating to these issues will be discussed below. The results from the research reported here suggest that, even in Sydney, significant benefits are possible for office workers and school children, involving a wide range of satisfactions and well-being issues, when Full Spectrum interior lighting is employed in lieu of standard cool white fluorescent lamps.

DIRECT, NON-VISUAL EFFECTS OF LIGHT

Direct, non-visual effects are mediated by infra-red and ultra-violet radiation (UVR).

Source: Szokolay, 1988, Climatic Data and Its Use in Design.

Metabolic states of organisms are influenced by infra-red radiation by means of the hypothalamic function of heat regulation; the best known effect of exposure to infra-red rays in sunlight is skin reddening, or sun burn.

Another well recognised direct, non-visual effect - attributed to the ultra-violet portion of the spectral character of sunlight (MacLaughlin et al, 1982), is the synthesis of Vitamin D_3 in the skin, which effects the absorption of calcium and phosphorous, and bone mineralisation (Hughes, 1983).

“The action of ultraviolet radiation intensifies enzymatic processes of metabolism, increases the activity of the endocrine system, promotes the immunobiological responsiveness of the body and improves the tone of the central nerve and muscular system” (The International Commission on Illumination (CIE)/cited in Birren 1972a).

Birren (1972a) quotes two researchers [without giving references for them] whose work indicated that light can penetrate into the mammalian brain via the skull (Brunt) and that light increases haemoglobin in the blood, dilates blood vessels and increases blood circulation, thereby ridding the body of toxins and lightening the load on the kidneys (Logan).

INDIRECT, NON-VISUAL EFFECTS

Indirect non-visual effects of light refer to light stimulation that travels from the retina via the so-called "energetic" portion of the visual pathway (Hollwich, 1948; 1979) to the neuro-endocrine system, and to the suprachiasmatic nuclei (SCN), two minuscule regions of the **hypothalamus,** located close to the optic tract, which have melatonin receptors and function as the 'biological clock' (Waterhouse, 1991).

Wurtman (1975) described this non-visual process as a transmission of light's stimulation via a neural pathway, through the colour sensitive transpeduncular nucleus in the midbrain to the superior cervical ganglion, which then effects the **pineal** gland. The pineal is linked to the cerebrospinal fluid contained in the third ventricle and it thus activates the hypothalamic cells with its chemical secretions.

The hypothalamus controls neuro-endocrine responses, generally, and reacts to emotional or physical inputs by secreting corticotrophin-releasing factor (CFR) which activates the pituitary, which in it's turn releases ACTH (adrenocorticotrophic hormone). The ACTH activates the adrenal cortex, which releases cortisol and other stress hormones (Samuels, 1978). Both cortisol and ACTH secretion have also been found to be influenced by the amount and quality of light entering the eye (Hollwich, 1979).

MELATONIN, THE BIOLOGICAL CLOCK, AND DEPRESSION

The pineal is a '*photo*neuroendocrine gland' - the legendary 'third eye'. The neuro-endocrine system responds specifically to light stimulation by way of the nocturnal secretion from the pineal of the light-sensitive hormone melatonin, and the suppression of melatonin secretion as a response to natural light. Melatonin acts as a chemical timekeeper, setting both daily and annual biological rhythms, by suppressing electrical activity within the SCN. Where melatonin secretion is not suppressed by natural light the pineal continues to secrete it, and depression can result.

Melatonin was first discovered by Lerner et al at Yale University School of Medicine in 1958. Later, Wurtman and Axelrod (1964) linked melatonin to light, and at about the same time Quay (1966) linked melatonin with daily rhythms in rats. A few years later, Pelham et al (1973) discovered a similar rhythm in humans, Wurtman (1975) proposed the melatonin-theory - whereby *the pineal* *converts neural input resulting from light to hormonal output,* melatonin, and Lynch and Wurtman (1975) linked melatonin to the biological clock.

In 1980, Lewy et al discovered the ability of *bright* light to reverse melatonin-induced depression in humans.

The most conspicuous relationship between daylight and humans is the diurnal rhythm, the cycle of light and dark, wakefulness and sleep, managed via the biological clock. This internal clock also controls body temperature, hormone secretion of the pituitary, thyroid and adrenal glands (Kuller, 1981) and cognitive functions (Moore-Ede et al, 1983). There is a pronounced daily rhythm in the rates at which humans secrete melatonin (highest between 11p.m. and 7a.m.); and there is also a seasonal rhythm, with lower levels secreted during the lighter part of the year (Arendt, 1979) and a longer duration of secretion in the winter (Beck-Friis et al, 1984).

Current research is focusing on whether mammals also possess secondary clocks which act as pacemakers over long time periods - the so-called "circannual clocks" (Concar, 1992).

SEASONAL AFFECTIVE DISORDER (SAD)

Cook, the Artic explorer, noted in his journal, in May 1898 :

> " The winter and the darkness have slowly settled over us.
> The curtain of blackness which has fallen over the outer world
> has also descended upon the inner world of our souls"

The rate of melatonin secretion has been linked not only to circadian functioning and metabolic functions, but to the occurrence of *depression* in people who have been deprived of natural light during winter. These episodes have been called

Seasonal Affective Disorder or SAD syndromes (Lewy et al 1982; Rosenthal et al, 1984). SAD is experienced as emotional depression, a drop in physical energy, an increased need for sleep, an increased appetite - especially for carbohydrates, and social withdrawal. Since melatonin normally induces sleep, SAD sufferers with abnormally elevated levels of the hormone in their blood tend to go to sleep early, and stay in bed for 9 to 10 hours. Their sleep, however, is intermittent, and not refreshing, and during the day they are drowsy and have trouble concentrating (Wurtman & Wurtman, 1989).

There is a higher incidence of recurrent 'winter depression' or 'winter blues' recorded in higher latitudes; with increasing distance from the equator the substantial contraction of the photoperiod during autumn and winter is a compelling environmental cue for the onset of SAD (Rosenthal et al, 1984); while milder symptoms occur nearer the equator (Rosenthal et al, 1985).[67] This pattern has also emerged as a ten-fold increase in self-report SAD-like symptoms from the southern to the northern extent of the United States (Potkin, 1986). Complaints were more frequent during inclement weather conditions. Terman and McCluney (1987) extrapolated from their survey, conducted in New York City, that over 1 million people of the 11 million inhabitants would consider wintertime SAD-like symptoms to "pose a personal problem". More women than men complained of problems due to these seasonal variations.

SEROTONIN, CARBOHYDRATE-CRAVING AND LIGHT DEPRIVATION

Carbohydrate-craving or Carbohydrate-Craving Obesity (CCO) is an ailment which has symptoms similar to those of Seasonal Affective Disorder [68] - depression, lethargy and an inability to concentrate, combined with episodic bouts of over-eating and/or snacking on carbohydrate-rich food. While SAD involves the hormone melatonin, CCO involves the neurotransmitter serotonin,

---

[67] A minimal input of illumination (2000lux) seems to be required (see Lewy et al, 1980; Savides et al, 1986, *inter alia*)

[68] also tends to be worse in winter (Wurtman & Wurtman, 1989).

which regulates the appetite for carbohydrate-rich foods. Both systems are influenced by photoperiodism, the earth's daily light-dark cycle. CCO's cycle is daily, SAD's is seasonal - but CCO also occurs during the winter months as a symptom of SAD (Wurtman & Wurtman, 1989), and has been linked to depression (Murphy et al, 1978).

During the early 1980's, Rosenthal, Lewy and Wehr carried out large-scale investigations at the National Institute of Mental Health into winter depression; this work also provided the first link between winter depression and carbohydrate-craving.

ARTIFICIAL LIGHT AND DEPRESSION

The deprivation of natural light during the winter months has implications for the provision of artificial or environmental lighting. *Where the spectral quality of fluorescent lighting is deficient, the possibility exists that people exposed to these conditions, especially during the darker parts of the year when natural daylight is diminished, will experience SAD-like syndromes or episodes.* The ubiquitous utilisation of standard white and cool-white fluorescent lamps in offices, public buildings, commercial institutions, educational establishments, hospitals etc, world-wide, means that large proportions of urban populations are habitually exposed to lighting which differs significantly from the spectral characteristics of natural light.

John Ott (1982), the key force behind the development of the first Full Spectrum lamp, the Vita-Lite took the view that *it is normal and necessary for humans to absorb UVR, and that indoor lighting should provide UVR in the same proportions as natural daylight or sunlight* (pre-ozone-depleted). Furthermore, he advocated the elimination of low level electromagnetic x-rays emitted from the ends of the cathodes of fluorescent tubes, believing such radiation to be a health hazard. His present company (Ott Light Systems Inc) now produces a Full Spectrum lamp incorporating a separate UV tube, radiation shielding of cathodes, and shielding for radio waves (Facts of Light, 1989). "Black light" lamps - such as those used in the Ott system - emit long wave UV radiation which is "harmless to the eyes" (Commonwealth DST, 1981).

PHOTOTHERAPY

Phototherapy is a new field which seeks to counter light deprivation by exposing SAD patients to bright, Full Spectrum light; or to coloured light of specific frequencies (see Syntonics).

BRIGHT, FULL SPECTRUM LIGHT

A phototherapeutic technique based on exposure to *bright (2500 lux) Full Spectrum lighting, on a daily basis,* has been found to be capable of *significantly counteracting SAD symptoms* (Lewy et al, 1982, 1986; Jacobsen and Rosenthal, 1986; Stewart et al, 1990; Rosenthal et al, 1984, 1990; inter alia). Terman et al (1987, 1989) suggest exposing patients to 10,000 lux for shorter time-periods - equivalent to the natural illumination on a cloudy day in North Europe.

- What appears to be critical is the intensity or brightness of the Daylight-simulating light, and the timing. [69]

- The rhythmic entrainment of melatonin secretion requires <u>morning</u> light exposure that exceeds sunrise levels (about 2000 lux).

It is believed that sufficient light at the right time advances the circadian rhythm and shortens the dark phase of melatonin secretion.
In addition to its circadian effect, *bright light also plays an energising role regardless of the time of day*. It can counteract a commonly experienced mid-afternoon energy slump (Terman & McCluney, 1987). The discovery that the

---

[69] consider: school children being exposed to morning light before class

human biological clock is set to sleep **twice** in the daily cycle, once between 2 am and 4 am and once between 2 pm and 4 pm, helps explain this afternoon slump in energy (and possibly why many cultures have incorporated a siesta period into their lifestyles). It also helps explain why sleep-related vehicle accidents reach their daytime peak in the early afternoon (Horne, 1992). [70]

DURATION NOT INTENSITY ?

Wurtman & Wurtman (1989) mention how some researchers have suggested that it is the duration of phototherapy, rather than its timing that is crucial. Research reported later (Samuels and Ballinger, 1992) suggests that low intensity, *standard indoor levels of Full Spectrum lighting experienced over long periods* - eight months in this case - can be effective in increasing the well-being and satisfaction of 'normal' office workers. Erikson and Kuller (1983) found similar effects in their 6 month study of office workers in Sweden. Hughes (1983), similarly, exposed wrestlers in his field experiment to only 625 - 796 lux of Full Spectrum light, yet reported significantly better Critical Flicker Fusion scores, and significantly enhanced (self-reported) positive effects on strength, stimulation etc

This issue of intensity is important, since any routine use of Full Spectrum lighting in interior environments would need to conform to the usual standards of acceptance. Lights at 2500 lux would create other problems, such as glare, and veiling reflectance, over and above the obvious energy inefficiencies involved. For this reason, the diagrams presented by Rosenthal et al (1985: 265), which indicate significant mood enhancement effects during 7 days of bright light treatment (2500 lux) but not during "dim" light treatment (300 lux), were closely examined. In both cases the lights used were Full Spectrum. A significant retrogressive change in mood was also evident on withdrawal of the bright light treatment. Although the graph shows a sudden jump in positive effect and a

[70] consider: school children - exposure after lunch

continuing increase with use of the bright lights from day 1 to day 5, there is a reduction in the rate of increase after this point, and a leveling out *before* withdrawal. This level was maintained for two days after the treatment was withdrawn and then fell off sharply. The dim lights, on the other hand, *did show a sustained increase* - albeit not statistically significant - after day 4 and until day 7 when treatment was withdrawn. Importantly, the level attained at day 7 declined very slowly over the 7 days after withdrawal, and the final level at the termination of the experiment was slightly higher than before treatment commenced. Interestingly, the final position of the dim light group was higher than the level to which the bright light group had dropped.

This result suggests that over the long term the dim lights might be shown to have an effect, and maintain that effect - as also shown in research reported here (Samuels & Ballinger, 1992). **In other words, Full Spectrum lights used at standard illumination levels might well have a beneficial influence on occupants in ordinary indoor environments.**

Kruithof (cited in Birren, 1972a) noted that objects and surfaces will have ‘normal colour appearance’ under *warm light at low levels* of intensities and under *cool light at higher levels* of intensities. In nature, dim light, such as at sunset or sunrise is warm and golden or pinkish, but as daylight reaches higher levels with the ‘rising’ sun, it shifts its tint from pink to orange to yellow and finally to white or even blue. Throughout these shifts in hue the colours of objects continue to look ‘normal’.

SYNTONICS

Syntonics is that branch of ocular science dealing with the therapeutic application of selected wavelengths of visible light, or colour - in order to overcome "visual field constrictions" (Eames, 1936) which affect general performance, behaviour and academic achievement (Liberman, 1985). Colour therapy evolved from the early work of Henning (1936) and especially Spitler (1941); later *Gerard (1958)* *and Plack and Schick (1974) described the influences of specific colours on CNS arousal, activation and emotional states.* Currently, John Downing (1988) has developed a syntonic therapeutic technique based on the application of selected visible light frequencies. Downing practitioners employ a stroboscopic instrument called a Lumatron [71], which directs a strong, flashing, beam of coloured light into the eyes of the patient who has been diagnosed as being deficient in photocurrent transmissions *ie* the quantity reaching the visual cortex. Patients undergo an analysis of the efficiency of their photocurrent transmissions for different colours, and wavebands of colour are selected as therapy. The balance centre or clock in the hypothalamus is believed to respond to the sensation of different colours by adjusting its discharge rate.[72] Where patients are found to be depressed, or cannot concentrate, the red range is used and the frequency of the flashes increased (beta range). Hyperactivity calls for blue, and a slower delivery speed (in the theta range).

Reactivation of the neurovisual pathway is said to occur in response to the proper colour stimulus, and to have a positive effect on biological balance, learning disabilities (California State University 1989; Kaplan, 1983), hyperactivity in children (Liberman, 1986), and phobic disorders (Ammon-Wexler, 1988).

IRLEN LENS

Irlen (1983) described a new type of visual dysfunction which she named scotopic sensitivity syndrome (SSS), which was claimed to be a major factor in dyslexia that could be treated with coloured lenses. This was the start of a new therapeutic procedure which has attracted much attention and some vociferous critics. The use of Irlen lenses, which filter specific light frequencies and thus change the colour of the page, has been reported to result in a decrease of reading

---

[71] There is a Lumatron now at the UNSW School`of Optometry. It could be made available (if funding were available) for trial runs with NSW school children showing learning disabilities

[72] Ott (1982) mentions that colours have an effect via the pituitary gland.

and learning disabilities (Hannell, Gole et al, 1989; Gole et al, 1989; Whiting and Robinson, 1988; Wilkins and Wilkinson, 1991; inter alia).

Evans and Drasdo (1991) have critically reviewed about 100 experimental studies related to Irlen lens use with underachievers, and found the vast majority of the studies to be wanting in terms of methodology. They found deficiencies in data presentation, lack of statistical analyses, no control groups, and a failure to take the placebo or motivational effect into consideration. Other studies failed to find any significant differences (Winter, 1987; Saint-John and White, 1988). Evans and Drasdo conclude that there is a "small amount of evidence for the existence of a sub-group of dyslexic people who receive a genuine beneficial effect from tinted lenses" (p.214).

Irlen lens research is briefly reviewed here as further evidence of the power of light and colour to influence performance.

Specifically relating to the effects of fluorescent lighting on reading performance, there is some evidence to suggest that lights which flicker may affect accuracy during reading (Wilkins, 1986), and cause headaches and eye-strain (Wilkins and Wilkinson, 1991; Wilkins et al, 1988). Wilkins and Neary (1991) pointed out that the majority of pulsating light from fluorescent tubes has a wavelength less than 550 nm, which would be selectively reduced by most Irlen tints. *Irlen and Lass (1989) also suggested that the symptoms of SSS are increased under fluorescent lights.*

FULL SPECTRUM LIGHTING STUDIES: PRECEDENTS

Several studies over the past 20 years have attempted to evaluate the effects of Full Spectrum artificial lighting on people in light chambers, schools, offices, and indoor training centres. A chronological synopsis follows.

STUDIES RELATING SPECIFICALLY TO SCHOOLS *(AND OTHER STUDENTS)*

Harmon's work in the 1940's (Harmon, 1942; inter alia) was the precursor of the later studies using Full Spectrum lamps. He showed that the *health* of school children was impaired when they were exposed for *long periods* of time to artificial light with a lack of "brightness" due to its *reduced spectrum*.

Maas et al (1974) explored the relationship between spectral differences in environmental illumination and objective fatigue (decrement in performance, measured via the Critical Flicker Fusion Test/CFF) and perceptual fatigue (feelings of weariness etc, as measured by semantic differential tests) in university students. Cool-white and Vita-lite fluorescents were the test lamps used. The subjective variable : Lively-Lethargic proved to be significant. *Subjects under the cool-white light tended to become less lively and more lethargic*, while there appeared to be no changes under the Vita-lites. Flicker fusion evaluation also exhibited significant differences, with the Vita-lites again superior. [73] The *Vita-lites* were found to *enhance visual acuity* (subjects could see more clearly).

Hughes (1980; 1981) researched the effects of *Full Spectrum lights on school children*, and reported increased visual acuity, reduced overall fatigue, improved work performance, and lower rates of illness due to colds. Such findings apparently led to the specification of Full Spectrum lighting for schools and work places in the ex-USSR *ie* ultraviolet radiation has been used in schools (and hospitals and factories) to supplement conventional light. Children apparently grow faster, their *work ability and grades improve* and catarrhal infections are fewer (Birren, 1972a).

John Ott (1982) reported on a number of studies undertaken in the mid-70's relating to fluorescent lighting and the behaviour of children at school. He conducted a study at a school in Florida, USA using Full Spectrum, radiation

[73]of the central nervous system.

shielded lamps, during a two-month period. *Hyperactive children calmed down*, learning disabilities decreased, and academic level increased in children exposed to the Daylight-simulating lamps. A photographic record shows the progression of a distracted and hyperactive boy, initially unable to sit still on his chair, moving closer to the teacher, and finally at the blackboard taking part in the regular classroom activities. A time-lapse film is available from the International Film Bureau, Chicago showing hyperactive children calming down with the use of these special lamps. Ott reported two studies undertaken by California schools which confirmed this relationship (p.130-133); and also mentions an article, in the Ft. Worth Star-Telegram, about a School Board which had voted unanimously to remove the high pressure, sodium vapour lights that had been installed, in the interest of energy efficiency, in about a dozen schools. This was the result of many complaints by teachers and students listing such problems as headaches, eyestrain, nervous tension and nausea. A similar story appeared in the New York Times.

Lindsten and Kuller (reported in Kuller, 1987) studied about 100 school children, aged 8-9, for one year. Similar experimental and control lamps were used, and the children were studied by means of behavioural observation, teachers assessment and analysis of urine samples for cortisol excretion. The results from the study indicated that the *absence of daylight* influences the annual variation in the production of *cortisol*. Children in the classroom which had neither natural daylight (no windows) nor simulated daylight showed a significant deviation. Cortisol levels in this group fell less from early to mid-winter than for the other children, then declined rapidly until February while the levels of the others rose during this period, and finally rose precipitously until May. Presumably, this would indicate that cortisol levels during winter in this group were unnaturally low and that their arousal levels would have been similarly depressed. The report in Kuller (1987) does not elaborate on the meaning of the results.

OTHER STUDIES (OFFICES ETC)

Disturbances in the endocrine functioning of people as a result of exposure to *spectrally unbalanced* and intense artificial light were reported by Hollwich and Dieckhues (1968, 1972). As the intensity of the light increased, *cortisol secretions* (from the adrenal cortex) *increased*. Since the pioneering work of Seyle (1956) it has been known that the adrenal cortex responds to any stress by increasing secretions of stress hormones - this is the "non- specific stress response". While it will be seen from later studies that intense Full Spectrum light has a beneficial effect, intense artificial light which differs markedly from the spectral composition of sunlight has the opposite effect. Cool White fluorescent light does not show the spectral continuity seen in natural light, and is, moreover, broken up by very intense mercury vapour lines at 406 nm, 436 nm and 578 nm. Full Spectrum lamps has noticeably lower mercury lines, particularly in the red range, while the Triphosphor lamp has mercury peaks which are very similar to Cool White lamps.

Following on this work, Hollwich et al (1975) related *low spectral quality* lighting to *fatigue*, while Hofling (1973) found a relationship with *headache* episodes.

Both Elder and Tibbott (1981) and Wineman (1981) reported that the high pressure sodium lamps installed in some offices in the USA, and which produce a yellowier spectrum of light than the standard fluorescent lamps, were found to be unacceptable to the workers in those buildings.

In 1977, Boyce and Simons described several experiments in which older subjects (55 years and more) produced significantly better mean error scores on a hue test with both a higher CRI lamp and increasing illuminance levels. Hughes and Neer (1981) reported on a large number of studies linking Vitamin D synthesis to solar ultraviolet radiation and documenting its deficiency in indoor workers working under artificial light with little or no UVR below 315nm. Such UV radiation emitted by conventional fluorescent bulbs is usually absorbed by the glass (Ott, 1982) and/or the reflectors and diffusers (Thorington & Parascandola, 1967). Some years earlier, Neer et al (1971) had exposed a group of veterans to cool-white lighting, and found their intestinal *absorption of calcium* declined during winter periods.

Greiter et al (1979) documented that natural or simulated sunlight had a positive effect on physical working capacity, decreased heart rate and increased oxygen uptake.

Hollwich and Dieckhues (1980) reported on a study they undertook regarding the influence of two sources of strong artificial illumination (3,200 - 3,500 lux) - one a cool-white, the other a Daylight-simulating tube. They found *stress-like levels of the hormones ACTH and cortisol in the group exposed to the cool-white lamps* for a fortnight, but the stress-like effect was absent in the sunlight-simulating group. The different metabolic and endocrine effects recorded were thus assumed to be due to the spectral components of the two lamps. The researchers believe that these differences *explain the agitated mental and physical behaviour and fatigue of students* under artificial illumination with a strong spectral deviation from sunlight, as reported by Maas et al, in 1974.

Hughes (1983) reports on a number of studies he undertook to determine the psychological impact of simulated natural light and cool-white light. Office workers evaluated their work environment, their work task and their feelings as a function of lighting type, employing an environmental survey composed of semantic differential bipolar scales. The results supported the conclusion that the Daylight-simulating light was *perceived* as significantly more pleasing, natural, bright and stimulating. Observers felt more relaxed, less fatigued and experienced greater eye comfort. They also rated their tasks as being more distinct, easier and satisfying.

Employing the same evaluation techniques and lamps but with modified bipolar items, Hughes (1983) evaluated an indoor training facility, used by rowing crews. Significant differences were found for pleasantness, brightness, feelings of healthiness, and strong physical strength. He also evaluated whether such lighting would influence high-school wrestlers training indoors. Here he employed the Critical Flicker Fusion test too, which proved to be significantly improved under the Daylight-simulating conditions, demonstrating greater activation and decreased fatigue. Again, a large array of survey items proved significant: pleasantness, naturalness, stimulation, and positive effect on strength, *inter alia*.

Erikson and Kuller (1983) compared the effects of a common white tube and a Daylight- simulating tube on 55 office workers in Sweden over a half-a-year period. The results showed that persons working under the Daylight-simulating tube lighting had *fewer vision problems* and reported less visual fatigue (eye-strain $p <.02$). Measures of *melatonin* indicated that secretion was *reduced* under the Daylight-simulating light during the winter. This group also reported feeling more *alert and active* during this time; and scores on the bi-polar mood scales indicated a significantly higher "social mood" ($p <.01$) and "drive" ($p <.03$). To their surprise, the researchers observed a regression in this positive mood, which was later replaced by a more passive and negative mood when daylight hours were again at their longest. Hard-pressed to explain this, they reasoned that the return of long hours of natural daylight must have "meant much less" to this group. Some measure of explanation might be found in the reported tendency of SAD sufferers to experience some degree of manic relief when spring returns (Wurtman & Wurtman, 1989), and this lack of a relief reaction in people who have had sufficient light exposure might be natural.

On a different note, Wilkins et al (1988) studied the influence of High Frequency ballasts, rather than lighting per se, on the weekly incidence of headaches and eyestrain amongst office workers. High Frequency or solid state ballasts attenuate the temporal modulation of the light emitted from a fluorescent tube *ie* light from a fluorescent tube usually fluctuates, and this intermittent light has been associated with headache episodes (Golla & Winter, 1959; inter alia). They reported that the average incidence of headaches and eyestrain were more than halved under the HF lighting conditions. They also reported that headaches tended to decrease with the increasing height of the building - in other words, with increasing natural light.

Finally, Samuels and Ballinger (1992) evaluated the potential social/personal and environmental consequences arising from the use of three different types of fluorescent lighting systems installed on three different floors of an office building (55 respondents), in terms of the relationships between the quality and efficiency of such lighting systems. The 3 lighting systems used were: Standard white or ‘Stds' (CRI [74] 63 CCT [75] 4100K); Triphosphor or 'Tris' (CRI 85, CCT 4000K); and Daylight-simulating/full spectrum or 'Blues' (CRI 98, CCT 5400K). 8 months after the lights were installed a questionnaire was administered, based on issues such as Satisfaction, and the experience of SAD [76] and SBS [77] episodes.

Six significant findings all related to employee evaluations and experiences in the Daylight-simulating lighting condition. They were: higher overall *satisfaction* with artificial lighting; satisfaction with the colour of the light; satisfaction with the level of the light; satisfaction with the clarity of the light; *less headaches* at work (a SBS symptom); and *feeling energetic* rather than lethargic at work (a SAD symptom).

There were also five marginally significant findings, four of which implicated the Daylight- simulating lamps, viz: feeling less fatigue at work; lower incidence of 'feeling less fatigued away from work' and 'headaches being better away from work'; and experiencing the Full Spectrum light as pleasant. The fifth finding relates to having experienced less headaches at work in the Triphosphor conditions.

Findings relating to Feeling Energetic indicated that 60% of respondents in the Std lighting condition felt lethargic as compared to 43% in the Tris condition and only 21% in the Blue condition (ie 79% felt Energetic). Moreover, notably more

[74] CRI = Colour Rendering Index (100 = perfect daylight-simulation)
[75] CCT = Correlated Colour Temperature (>5000=cool)
[76] SAD = Seasonal Affective Disorder
[77] SBS = Sick Building Syndrome

respondents in the Blue conditions recorded high levels on the scales (towards the 7 end of the 1-7 point scales).

Findings relating to feelings of Fatigue (ie feeling tired, worn out etc rather than lethargic, apathetic) indicated that 36% of respondents in the Blue condition did not feel fatigue at all, compared to only 8% in the Tris condition, and *every* respondent in the Standard lighting condition.

Findings relating to Headaches indicate that *all* the Std respondents experienced headaches at work (during the 4-6 weeks prior to the survey), while 46% of the Blues and 41% of the Tris did not. Moreover, 75% of Std respondents reported that headaches were better away from work, while this was true for only 38% of the Blues and 42% of the Tris. The implications of this is that removing themselves from the poor lighting seemed to have more impact than being away from the good lighting. Finally, 42% of the Blues who did report having a headache at work also reported that being away from work did not ameliorate this condition ie it might be assumed that the headache episodes were due to factors other than lighting - personal and personality issues.

VISUAL CLARITY AND FULL SPECTRUM LIGHTING

Samuels and Ballinger (1992) also undertook a chamber experiment, the aim of which was to test a "subjective equivalence" or visual clarity hypothesis, viz. that people appear to rate full spectrum lighting as **equally satisfying** as standard lighting which is nonetheless emitting light at a lux level some 20% higher (Aston and Bellchambers (1969); Boyce (1977); Worthey, 1985, 1991).

Bellchambers and his colleagues first discovered the phenomenon called 'visual clarity' - the *tendency for high spectral quality light to be equally satisfying visually at low illuminance as poor quality light at higher illuminance* (a high quality lamp at 480 lux having equal visual clarity with a poor quality light at 600 lux).

Boyce (1977) subjected their findings to a rigorous re-examination, with some important methodological changes, and established further support for their findings, also showing that the higher the quality the higher the rating for satisfaction with colour, pleasantness and illuminance.

Boyce suggested that the reason was due to issues relating to 'colour saturation' rather than colour rendering. This measure, called the Colour Discrimination Index or CDI relates to the colour of *surfaces* when illuminated by a specific light source. The higher the CDI, the greater the saturation of a colour and the colour difference perceived. Because the standard white lamps have a low CDI (0.0024) respondents would tend to set its illuminance higher in order to increase the colour saturation, in order to match the full spectrum lamps with a CDI of 0.0048.

More recent research has focused on 'opponent-colour theory' (Worthey, 1985) as an explanation of visual clarity; and Berman (1991) explains how satisfaction might be higher when illuminance is lower as a consequence of the 'scotopic/photopic' ratio of different colours. Both hypotheses are referred to below when attempting to explain the findings by Samuels and Ballinger (1992). In the latter experiment, three chambers were setup with exactly similar objects in the same colour setting. Only the lamp types were varied (*ie* standard, triphosphor and full spectrum). Respondents were provided with a dimmer, with which illuminance levels could be adjusted. Respondents also answered a brief questionnaire relating to their satisfactions with the lighting.

The results were partially unexpected, in that the respondents significantly over-estimated the illuminance levels required to match the full spectrum lamps with the standard level.

At the same time, the average settings chosen for the Triphosphor lamps were significantly less than the standard control level. Here the expected relationship was evident *ie* the higher the spectral quality of the light the less is required to meet satisfactory illuminance levels.

Thornton (cited in Worthey, 1985) showed large improvements in visual clarity in experiments at Westinghouse using triphosphor (prime-colour) lamps.

Various explanations are offered to understand the unexpected full spectrum result.

Comments of respondents give some clue to the finding. Despite the fact that the 'blue' chamber was the preferred lighting condition, and the satisfaction with the light was highest, several respondents commented on its "cold" colour, and some referred to it as "gloomy". Respondents might have been trying to warm-up the space by increasing the level of illumination. It is well known from colour theory that there is a subjective feeling of cool in a blue room and of warmth in a red room (Birren, 1982). Itten (cited in Mahnke and Mahnke, 1987) showed a difference of 5 to 7^0C in subjective feelings of hot and cold by subjects in red and blue rooms. Red is also associated with fire, festivity, revolution, passion while blue is linked to sky, water, distinction but also despair and depression. Low illuminance blue does have a tendency to appear gloomy, while a saturated red or blue light appears brighter than a white light of the same luminance (Worthey, 1985). It is possible that the low level of illuminance at which the experiment was conducted (380 lux) might have had an unequal effect on the saturation of the colours in the cooler 'blue' chamber as compared to the warmer red chamber.

The theory of opponent-colours might similarly help explain this finding. Worthey (1985:239): "lamps which give greater visual clarity are those which better reveal the *red- green* contrasts of objects in a scene". This increased perceived brightness is due to "chromatic brightness" and perceived distinctness of the borders formed by the colours of the object.

Cool white colour lamps provide low red-green contrast and blue-yellow colour lamps do not contribute to border distinctness, while triphosphors reveal *red-*

green contrasts and give colourful scenes greater visual clarity, even when light is dimmed by a large factor (Worthey, 1985). This is due to the physiology of the eye. Blue receptors, which are essential for perception of blue-yellow contrasts are the least numerous receptors in the retina; and Thornton (cited in Worthey, 1985) even suggests that visual clarity could be essentially independent of the blue content of the illumination.

Further analysis was undertaken to examine whether it is higher illumination (rather than, or as well as higher CRI/spectral quality) that is linked to satisfaction with level, colour, clarity and pleasantness. Mean responses (on the satisfaction scale) indicated, for both the Blues and the Tris, that where illumination had been set *lower* than equivalence, satisfaction ratings were *higher*.

This tends to contradict most previous laboratory research (Boyce 1977, inter alia), but a recent study by Berman at the Lawrence Berkeley Laboratory (1991) found that reduced light levels may not cause any changes in visual potential and may, in some cases, actually improve vision if the new light spectrum has increased portions of *bluish greens*...which Berman calls "scotopically richer spectral content". The reason for this is that the more optimal spectrum can reduce pupil size with less total energy, and when pupils are smaller, depth of focus and visual acuity (the ability to resolve fine details) are increased. In other words, the richer the scotopic content the less photopic luminance is required to achieve visual clarity.

The scotopic/photopic (S/P) ratio of a warm white fluorescent is 1.0, of an incandescent lamp is 1.41, of a standard cool white fluorescent is 1.46, of a 4000K triphosphor lamp is 1.62, and of a daylight-simulating fluorescent is 2.22. Sun (CIE_{55} illuminant) has a S/P ratio of 2.28, while sun and sky (CIE D_{65} illuminant) has the highest ratio - 2.47.

DAYLIGHT AND INDOOR DAYLIGHT

Daylight-lit interiors seem to be *preferred* by most people (Collins, 1975). They are evaluated as more pleasing, are said to increase the detail and appearance of objects, and also have a different "feel". Furthermore, the short-term variations produced by natural daylighting contribute to the avoidance of monotony. Collins (1975) also reports a wide range of studies confirming the desire of occupants for sunshine in residential buildings, whereas preferences for sunshine in schools, offices and hospitals seems to vary with type of building and type of activity.

The integration of natural and artificial light in solar efficient buildings is an attractive strategy for energy conservation (Warren 1986; Collins, 1975), but is not, however, without its problems. Natural light usually enters a building from side windows (horizontally) while occupants react to the general spatial and temporal distribution of light. Where luminaires (lamps) produce only downward light and window light dominates with its strongly horizontal flow, there is a tendency for room surfaces to be dark, and for there to be some glare, which together produce an overall impression of 'gloom' (Julian, 1987). Other researchers, however, comment that the horizontal directional component of daylight contributes to the "modelling" of objects, thus increasing the apparent detail of an object and improving its appearance (Collins, 1975).

Solar Efficient Design can make important socially responsible (light quality) and environmentally accountable (energy efficiency) contributions. SED can provide a healthier, more natural *indoor climate*, particularly by means of natural ventilation and natural light.

Glazing characteristics of modern buildings are crucial elements in SED, since it is via this envelope that contact is made with outdoor conditions viz: air, temperature, sound; and light, view, time of day, weather conditions, and seasonal variations.

There is an aspect of daylight integration which seems to have gone unnoticed, viz: that the quality of the spectral transmission of these systems is of relevance to human psychobiological well-being.

Suggestions that integrating daylight with artificial lighting in offices would be both environmentally *and socially* responsible must be examined carefully. First, the daylight spectrum itself is not constant, and is influenced by cloud, air pollution etc. Furthermore, *glass does not transmit the full spectrum of daylight*. UVR is largely blocked, and 3mm clear glass permits 86% visible spectral transmission. Only 25% is transmitted through 13mm bronze plate glass (ASHRAE, 1989) - frequently used on high rise office towers.

Clarke (1979) showed these transmittance differences occurring largely in the red and particularly in the blue extremes of the spectrum for 6mm of clear float glass, and called the result : interior daylight, or ID_{65} (which, however, was not accepted by the CIE). In other words, the CIE D_{65} is not equivalent to the daylight experienced indoors, which is perhaps best described as 'attenuated' indoor daylight.

Kok et al (1985) measured the spectral irradiance between 280 nm and 750 nm inside an office, both with and without fluorescent lighting and also with the windows open or closed. They noted higher UV content when the north facing (southern hemisphere) windows were open (the lower figure is a magnification of this region). The impact of closing the windows was quite obvious. Despite having the fluorescent lights on, there was still a noticeable reduction in spectral irradiance compared to when no lights were on but the windows were open.

Kok and Hengstberger (1991) reported on their work examining the influence of glazing and reflectance of building and furniture materials on spectral irradiance characteristics. Their measurements of interior daylight showed that a number of factors - additional to the absorptance of window glass, solar angle, cloud cover, atmospheric ozone and aerosol content - have a marked influence on spectral properties. Most building and furniture materials have a low ultraviolet and blue reflectance (*ie* tend to absorb UVR and blue), which results in a significant lowering of the correlated colour temperature (away from the 6500K of D_{65}) towards the warmer, redder end of the spectrum.

- Given that both glass and materials absorb UV wavelengths, interior daylight is particularly deficient at the shortened wavelengths, the very wavelengths which have a powerful actinic and thus psychobiological effect.

The potential relationship between indoor daylight and psychobiological health has relevance for personal control or at least openability of windows in schools. In other words, the spectral quality of indoor light is different if the available daylight passes through an open or closed window, even if clear glazed. The extent of the impact that this diminished spectral quality might have on health has yet to be determined.

Perhaps systems which beam daylight directly indoors through prisms might lessen this problem in newly designed schools, although some dispersion and absorption will occur, and existing building stock is unlikely to be retrofitted with such systems.

Finally, there is always the possibility that site-restrictions will confound the best laid plans to capitalise on daylight availability - adjacent or neighbouring buildings, or trees casting a shadow over a school. In CBD areas this is very prevalent (where some schools are located - albeit mostly private ?), and where skylights or atria cannot ameliorate this overshadowing effect, the availability of daylight might well be severely diminished, irrespective of the intelligence of the building design.

In sum, although daylight integration is an obvious energy efficiency strategy, we cannot assume that daylight transmitted indoors is of sufficient quality to have a positive psychobiological effect.

The following **Arousal and Attention Table** is a summary of major issues relating to the *physiology of light and colour*.

Issues relating to light have, by and large, been dealt with already.

The colour side of the table is not complete *ie* the full range of colours is not dealt with. It is only a reflection of information available to the researcher at the time. Information contained in the section on Syntonics complements the colour information given here.

AROUSAL AND ATTENTION TABLE

LIGHT	***COLOUR***
 Natural/daylight/sunlight:- all colours equally visible; 5 balanced peaks in spectrum; CRI =100 (*ie* way colours look under a specific light source).	***red*** arousing, alerting, excitation (Wilson, 1966); attention drawing (to envir, away from task) distracting (attention to envir) [Birren, 1979b]; GSR (galvanic skin response) stimulated in decreasing order from red through green and yellow to blue [Jacobs & Hustmeyer, 1974]; attention narrowed to cope with distracting env/stimulation - at start, = stimulating, but threshold, and detrimental eventually impairment in efficiency of performance in intellectual tasks requiring accuracy and concentration tension, anxiety [Jacobs & Suess, 1975]; office: distracting, but less errors, less confusion; more stress, anxiety [Kwallek & Lewis, 1990]

	visual cortex aroused autonomic nerv syst aroused blood pressure up
indoor daylight attenuated spectrum [Clarke, 1979]; glass absorbs UV; furnishings [Kok et al, 1985/91]	***pink*** = strength up, positive mood [Hamid & Newport, 1989] aggression/adults/prolonged exposure [Ott, 1982]
artificial *cool-white fluoro* = lethargy [Samuels & Ballinger, 1992; *inter alia*]	
full spectrum fluorescent Balanced light = all colours, no peaks & UV CRI = 90+ hyperactivity down [Ott, 1976; 1982] [O'Leary et al, 1978] disputes; Crit flicker fusion down, acuity up [Hathaway, 1987]; less headaches less fatigue more energetic [Samuels and Ballinger, 1992 -offices; *inter alia*]	***colour perception*** Perception of colours under artificial lighting will be closest to natural colour where daylight-simulating fluorescent lighting ie full spectrum lighting is employed
cool-white fluoros poor CRI (60) melanoma link ? lethargy (offices)	***white*** arouses visual cortex [Gerard, 1958] glare; most errors (office) but least distracting, but= (habit/expectation ?) [Kwallek & Lewis, 1990]; headaches/nausea
	yellow relatively high anxiety [Jacobs/Suess, 1975]
	 ***green-yellow*:**

	more arousing than blue
incandescent orange/yellow, so human complexion looks good; hyperactivity down in the emotionally disturbed and autistic {Painter, 1976]	***green*** psychomotor performance more precise lower anxiety but...more confusion [Goldstein, 1942; Nakshian, 1964] Yellow-Green =555nm on visual spectrum, and is most 'effective' range for human eye, thus green = 'efficient' in fluorescent lamps.
	***blue-green*:** operating theatres (eyes acute to red of flesh, blood) [Birren, 1972a]
	blue relaxing least arousing cool negative mood eyes less sensitive to blue so perceived as dimly lit [Birren, 1972a] nervous system and visual cortex are less aroused (than with red or white); and heart rate, blood pressure, respiration rate and galvanic skin responses (GSR) also decrease (Gerard, 1958).
	pale blue melancholy
X-rays radiation shielded cathodes (ElectroMagRad) (in fluoros) = (OTT lites) school performance ⇑ [Ott, 1982] [Ingraham, 1983]	***cool colours*** greenish look under white fluorescent lighting [Birren, 1972a]

UV kills bacteria less tooth decay increased weight and growth [Hathaway, 1987] increased levels of working ability resistance to fatigue improved academic performance clear vision [Zamkove et al, 1966] adolescence and pubescence implications: metabolism, hormones, immunological, CNS [Neer et al, 1971; Birren, 1972a] stimulates calcium absorption	***Chromatic & Achromatic Stimuli*** [Brechsler, 1960] Coloured stimuli elicit more emotional responses than do gray stimuli (with red being the most stimulating). Tested via evaluations of 'word-association disturbances' (*ie* reaction times)under green, red and gray conditions. Results interpreted in terms of the Intrusion Hypothesis : bright colours intrude on the perceiving person in such a way that their thought processes are interrupted or disrupted (see Schachtel, 1943).

LIGHT <u>AND</u> COLOUR

psychodynamic shades :-

(yellow in student vision and blue in teachers vision; blue desks/board)

x full spectrum lighting (blue colour light):-

= less noise in library, more positive mood.

UV supplemented light = less dental cavities & less absenteeism;

warm colours (yellow) = blood press up slightly

<u>no</u> effect on mental abilities/achievement/behaviour/attitudes to work

(but controls for natural daylight missing)

[Wohlfarth, 1986]

full spectrum + shades of blue

handicapped kids

= systolic blood pressure down [20 pts], aggressive behav down [56%]

non-attentive behav down [23%], teachers more relaxed, and more work completed

[Wohlfarth & Sams, 1981]

high illumination + warm colours

= arousal, attention directed into envir (red, pink, orange, yellow);

lower illumination and cooler colours

= more relaxed (aqua, turquoise, blue) (Birren, 1972b)

lower illumination and cooler colours

= more relaxed (aqua, turquoise, blue) [Birren, 1972b]

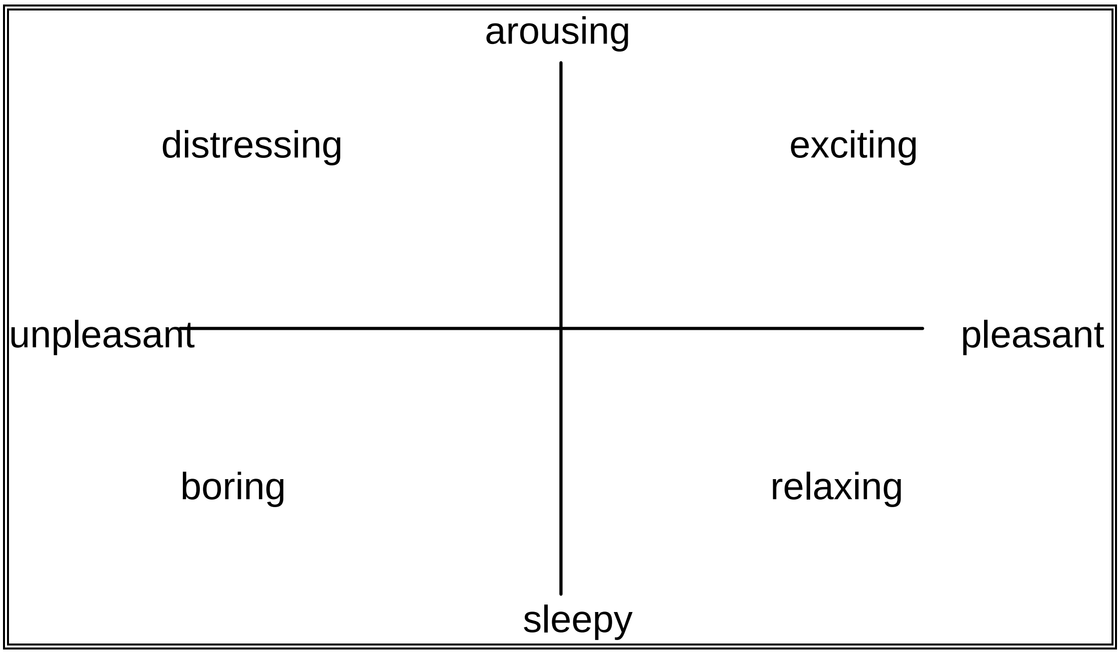
variety NB or attention ⇓

[Vernon, 66]

sensory deprivation ⇒ disorganisation

Alexander Schauss, Director of the American Institute for Biosocial Research (Sydney Morning Herald report, source undated/& The Nature of Things: Living Colour, with David Suzuki, Canadian TV Series) compared 2 groups of school children. In one classroom, the front and side walls were painted bright yellow (stimulating colour), while the front of the students desks and the back wall (in the teachers vision) were painted light blue. He found in the students in this classroom: an increased heart rate, respiration rate, and stimulation of the left hemisphere of the brain - the side which controls judgment, reasoning, logic and writing skills; and an increase in IQ of 12 points. Teachers also reported feeling more relaxed.

AFFECTIVE MEANING OF ENVIRONMENTS



Ordering of eight affective descriptors Source: Russel, Ward and Pratt, 1981

The above diagram indicates a clustering of affective descriptors of environments, based on semantic differential analyses of terminology used by people describing their feelings about places. The emotional quality of environments - or the affective response - expressed in language is a measure of the ‘meaning’ of that place.

Environmental Psychologists, similarly, use affective concepts to characterise behaviours occurring in places, eg satisfaction, comfort, stress, annoyance and arousal.

The two-dimensional system devised and tested (by factor analysis) (shown above) is an attempt to unify this person-environment set of relationships, showing how the parts are integrated in the whole.

- *Exciting is both pleasant and arousing, relaxing both pleasant and unarousing distressing is both arousing and unpleasant etc*

It is important to recognise that the word Arousal here is a dimension of verbally reportable feelings and not a physiological arousal, or behavioural intensification. However, there might well be some utility in applying such a relationship structure in order to evaluate the influence of light and colour in school environments.

CONCLUSION and RATIONALE

FOR COLOUR PRINCIPLES MODEL AND MATRIX

In conclusion it must be noted that the literature of colour, while it is indeed vast, does not include any clearly articulated well documented and authoritatively supported research which deals with the application of ***all*** of the principles discussed herein. Whilst there are a number of general “rules” which the colourist ought to follow, most of these being adequately covered in the section of this report dealing with psycho-biological aspects of light and colour selection, very little has been done to systematically look at the *symbolic and cultural significance of colour in the classroom*. Yet all of the most authoritative sources agree that this aspect of colour is crucially important.

This is not to say that at the moment we have no means of determining roughly appropriate colour environments within the classroom. We do. There have been many colourists who have gone into print to explain the principles they use and whilst none of them have addressed all of the issues in the depth that is argued for herein, the best of them have been able to demonstrate how it is possible for others to emulate their work and achieve "workable" results. And there are good colour designers, drawing on a wealth of personal experience, who are able to work with colour in a creative manner producing satisfactory colour environments and yet be unable to adequately express in words the principles that have been employed, or relate them to physiological states such as attentiveness. There is often a considerable degree of intuition in the work of such people and it will always to some extent defy empirical analysis.

FURTHER RESEARCH

For such colourists and in the interests of building as solid an empirical basis for making colour decisions as possible, further work needs to be done to come to an understanding of the role played by symbolism and culture in determining colour preference and colour response in school students and staff. In the culturally rich environment that the Australian classroom has become, we have a powerful resource from which it ought to be possible to learn much through a well structured program of investigation.

The departure point of such a program would accept that the built fabric of the school has the potential to be a positive influence on the performance and well being of the students and the staff and on educational objectives and outcomes and that this positive influence is intimately connected to the choice of light conditions and colours, as well as materials and finishes. It would accept that light and colours have a direct cultural significance to each person and to groups of individuals, but will depend upon a wide variety of factors ranging from age, to ethnic origins, through processes of acculturation to life goals, aims and aspirations of groups and individuals.

A HYPOTHETICAL SCHOOL COLOUR & LIGHT MODEL

Given the lack of a wide empirical base and the consequent inadequacy of previous colour theorist's models for school colour design guides, a hypothetical model - evolving from empirical work that has been uncovered in this research - is proposed here, for inclusion in the guideline general principles.

This model provides a basis for the development of the dynamic and interactive ***matrix*** which is presented later, itself ***intended as a basis on which colourists and educational managers could rationalise and cross-check decisions regarding the colours to be applied to schools***. The model is not prescriptive, but is performance based *ie* it depends on the interaction of light quality, activities or spatial behaviours, physiological states of arousal, and psychological, cultural and symbolic responses to colour. It is intended to be *adapted* by colourists and education managers according to a further *wide range of* ***context-specific variables***. These variables, it is suggested, will tend to shift the colour band, which runs diagonally across the matrix, towards the warm, arousing, active,and energetic pole or the cool, calming, attentive and sedentary pole, as the case may be. Nonetheless, the shift in the colour band (largely those *wavelengths of light from about 450nm to 600nm*) is expected to be marginal overall. Included in this range of variables are those that will rely on the discretion, experience and priorities of the colourist and education managers, issues such as suburban-cultural majorities, heritage buildings, urban-rural symbolism etc, which, if evoked, could cause a larger shift.

The Interactive/Dynamic Matrix is presented as a tool that could be incorporated in the principles guideline as a basis for colour scheme selection, since it is grounded in activity/behaviour and arousal/attention factors, and is adjusted by any number of variables, from symbolicand cultural interpretation of colours to geographic location.

The matrix is *interactive* in the sense that it includes behaviours, psychological meaning, symbolism and physiological states of the body and brain; and that the colours suggested are not necessarily single colours but could well be a mixture of colours which themselves interact. This, of course, complicates the issue enormously, and is not accounted for by the matrix. It is here that designer experience will be most crucial. The model is *dynamic* in the sense that it changes according to a range of variables which impinge on these interacting elements; and because colour combinations are not excluded *ie* there is an implied ‘porosity’ of the ‘boundaries’ between activity spaces.

To attempt to generate a guideline from ***all*** these interacting and dynamic variables almost defies possibility. The guideline matrix is, thus, a simplified version of only major elements. Although the matrix presented seems relatively simple at first glance this belies the extraordinary complexity underlying its interrelating elements, which of course cannot be predicted.

ELEMENTS OF THE MODEL AND MATRIX

- The guideline matrix is based, first, on an understanding that wherever feasible the **highest quality light** should be provided**.**

The literature in unequivocal about this. Full spectrum light with a natural UV component, be it daylight or artificial fluorescent light, is shown time and again to have positive effects on humans, be they adults or children. In sum: headaches, lethargy, non-attentive behaviour, hyperactivity and physiological stress seem to be reduced, while IQ, visual acuity, positive mood and behaviour seem to be enhanced.

This research recommends without hesitation the provision of full spectrum light. It should be remembered that daylight that has passed through a window is impoverished - it is UV deficient and only a percentage of the full spectrum is available, at most 86%. The psycho-*biological* benefits of impoverished daylight are not equivalent to that of natural daylight outdoors.

This implicates management policies, possibly ensuring that students are outdoors in the mornings (the most crucial period for setting the biological clock and suppressing the secretion of the hormone melatonin, linked with depression and other symptoms) and the use of open windows - where full spectrum daylight is allowed to penetrate indoors.

The argument that daylight-simulating fluorescent tubes are less energy efficient than other, lower quality fluorescent tubes can be countered by the fact that lights are not in constant use - given the amount of daylight which usually enters classrooms, the time of day that school takes place, and the time it ends. Moreover, energy management (either electronically or through teacher intervention) would be a rational way to lower energy consumption *ie* when spaces are unoccupied no artificial lighting should be on in any event. Finally, research suggests that the higher the quality of the artificial light the less light is required to achieve an equivalent visual satisfaction as compared with lower quality light at higher illuminance levels. In other words, it might be acceptable to install less fluorescent lamps (always avoiding generating dark and light areas, notwithstanding) and attain the same level of visual clarity or 'subjective equivalence' while simultaneously reducing energy consumption.

The installation of triphosphor lamps, which are very efficient and which also provide a good quality light, albeit not daylight-simulating, might be considered as a possible alternative, since some studies indicate that they have similar effects (sometimes superior) to full spectrum lamps, at least in terms of visual acuity/clarity - but other positive effects associated with truly daylight-simulating lamps are not evident. It would be shortsighted to favour efficiency over quality where it is the health and performance of the nation's 'future' that is at stake, especially where energy management and 'subjective equivalence' strategies are included in the equation.

In any event, the ubiquitous cool-white fluorescent lamps used in schools *are* detrimental to both health and performance, and some studies even link their use with melanoma (Beral et al, 1982). There is no justification for continuing to submit children in schools to such poor quality light when superior alternatives are available.

THE ATTENTIVE-INATTENTIVE MODEL

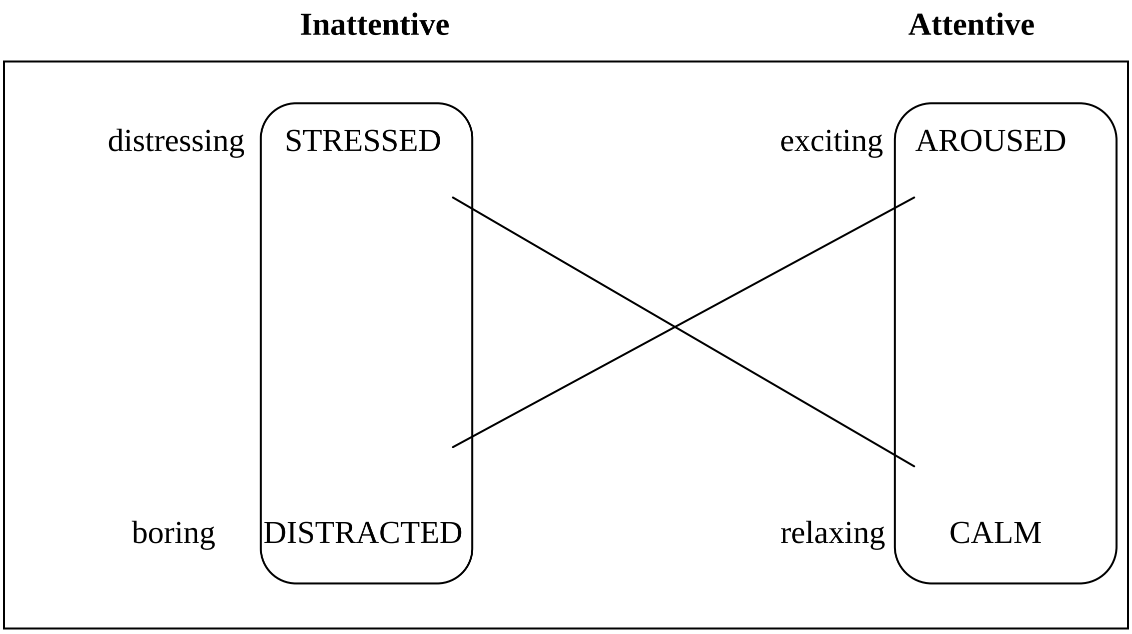
- The model is based on work by Russel, Ward and Pratt (1981), which indicated a **clustering of affective descriptors** based on **people describing their feelings about places**.

Russel et al found that:-

- Exciting is a synthesis of Pleasant and Arousing stimuli
- Boring a synthesis of Unpleasant and Unarousing stimuli
- Distress a synthesis of Unpleasant and Arousing stimuli, and
- Relaxing a synthesis of Pleasant and Unarousing stimuli.

From the above research, and an understanding gleaned from both the colour symbolism and physiological arousal literature evaluated in this research project, a <u>*model*</u> - more appropriate for schools - has been produced, below. Here the elements of *arousal and distraction are introduced*, as well as a stress-calm axis. Attentiveness can be located on the right-hand side of the diagram, and would range along the *aroused-calm* axis depending on the activity appropriate to a specific time and place.

The element which is common to both aroused attentiveness and calm attentiveness is the *pleasantness* of the stimuli. From this realisation it can be deduced that colour preferences could play a major role in colour appropriateness, in other words, the psychological and experiential elements are at least as important as the physiological and physical.



COLOUR, LIGHT AND ATTENTION

Generally researchers posit that, if *colour* has an *effect*, it may be viewed as based on the performance and *arousal* curve (Hebb, 1955) with *increases in performance* *related to increases in arousal up to some optimum for each individual*. Beyond the optimum, increases in arousal (generally) are followed by decreases in performance (Mehrabian & Russell 1974; Wilson, 1966).

Where the task requires that *attention* be paid *to the environment*, high levels of illumination and brightness will be appropriate, since the attention and interest will focus outwards - a good principle to apply in manual tasks. Where the task requires *concentrated visual and mental attention* at fixed points (desks, eg) *softer illumination and subdued brightness* are more appropriate. Here attention will be focused away from the environment and *to the task* at hand (Schachtel, 1943; Birren, 1972b). With the general quickening of autonomic functions associated with stimulation due to colour, greater work productivity is to be expected (Birren, 1972c).

- A monotonous environment can engender boredom, restlessness, inability to concentrate (Vernon, 1966);

- A preponderance of white walls is visually and emotionally sterile (Birren, 1972c);

- Vision seems to degenerate unless stimulated (Birren, 1972c). What is required is variety and contrast i*e* to treat the eye and mind to a change of pace throughout the day. This is consistent with the dynamic approach embedded in the colour matrix presented below.

It is possible to further hypothesise which colours (influenced by which artificial light sources) are arousing[78], and some work showes ‘bright’ environments to be conducive to physical activity (Harris and Bills, 1953-54). Generally, with *reds and light colours are associated with activity,* and *deep cool colours with calmness*. Similarly, the psycho-dynamic work of Wohlfarth (1981; 1986) and colleagues showed the varying impacts *on attentiveness and calmness* of warm yellow in the line

[78] See: Goldstein, 1942; Gerard, 1958; Brechsler, 1961; Nakshian, 1964; Plack and Shick, 1974; Kwallek & Lewis, 1990; see also Arousal and attention Table.

of sight of children in a classroom, with cool blue visible to the teacher - a truly dynamic system. This latter research provides the rationale for the inclusion of at least *two* colours in the matrix cell corresponding to classrooms - the core of the school [79].

COLOUR DYNAMICS AND SPATIAL BEHAVIOUR AT SCHOOL

Given that school children have to be variously *alert or calm*, depending on the *activity* they are engaged in, and in which *spatial setting*, and at which *time of day* the activity takes place, ***a variety of colours would seem appropriate*** - within the constant ambient conditions provided by full spectrum light and natural daylight.

Activities should be matched with appropriate colours. A wide range of activities take place in schools, and even within the same room. This element forms one of the axes of the colour matrix presented below. A group of colours, or more saturated, brighter hues of the same colour - possibly used as accents in the room (around window frames, or even doors themselves, eg), might well generate a better fit in psycho-physiological terms *ie* an appropriate mood and consequent performance, than one colour alone

In primary schools children are often assigned to one classroom in which the majority of activities occur, with trips to special spaces such as music rooms, libraries or gymnasiums at appropriate times. This primary homebase could reflect its multi-functional nature in the colour scheme chosen for different *zones* in the setting. Activities could be correlated with areas, which are painted appropriately.

In secondary schools, most activity happens in different rooms, as students move to where appropriate teachers are located. This impacts on colour design, and in many ways simplifies the task of choosing appropriate colours.

---

[79] An evaluation of a management process that had children turn to face different colours at different times and activities would be a valuable field experiment to undertake.

The underlying assumption built-into the model and matrix is that both attention and relaxation, arousal and calm, are valued in classrooms (and in the library). In staffrooms, assembly halls, corridors and stairwells, art and music rooms relaxation might be most appropriate; while arousal would be more likely to be valued in gymnasiums, and workshops for manual activities.

PREFERENCE FOR COLOURS AND PERFORMANCE

- Young children apparently *prefer* bright (saturated) warm colours, and adolescents prefer less saturated and cooler colours (Harris and Bills, op.cit.).

In early research on work situations adults have been found to prefer cool colours - *ie* find them pleasant (Pierce and Weinland (1934). And some early experimental evidence shows that very young children prefer certain colours because of certain pleasurable experiences associated with them (Staples and Walton, 1933). Further research could establish children's preferences for different colours (under particular light sources), and which situations are considered pleasant at school, and attempt to correlate such findings with attentiveness, mood and performance. It is worthwhile to reiterate here that pleasantness, thus preference, seems to be a central element in attentiveness.

LIGHT, COLOUR AND TIME OF DAY

While daylight sources and daylight simulating sources, including ultraviolet radiation could be used all of the time, as a general rule, it might also be possible to *programme activities to match colours and intensities of light at certain times and in certain places*: warm light in the morning at a relatively low intensity being replaced with increasing intensity of light and cooler colours as the day progresses. This would mimic the natural evolution of light throughout a daily cycle, but is complicated and probably unnecessary.

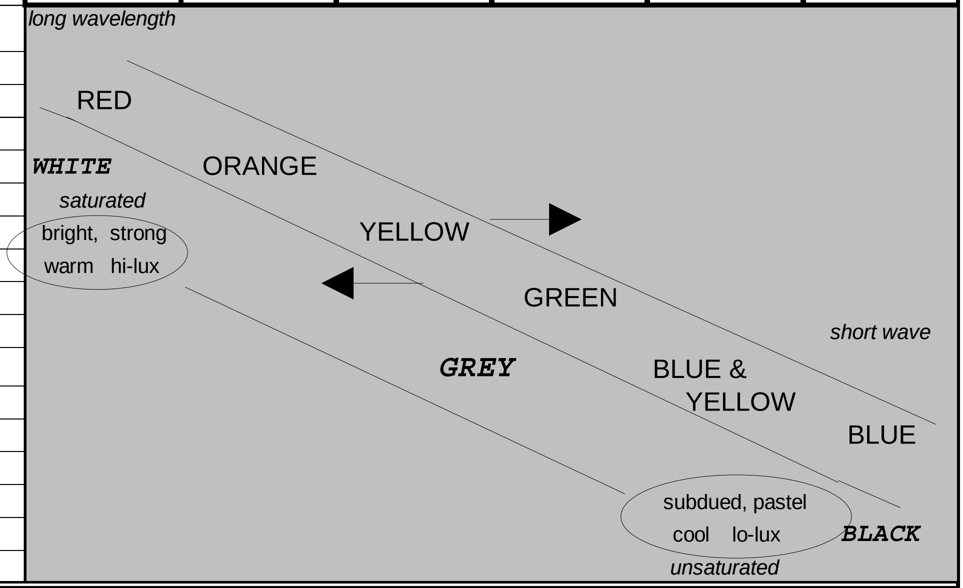
THE INTERACTIVE/DYNAMIC COLOUR MATRIX (OVERPAGE)

is proposed as an informational baseline for application
in the critique of colour schemes,
along with consideration of a range of context-specific variables -
ie incorporating a basic set of principles
by which colour designs can be evaluated

The colour band can shift
according to the variable selected

	ACTIVITY/SPATIAL BEHAVIOUR					
AROUSAL, ATTENTION	*outdoors*	*workshops*	*verandah*	*assembly*	*classrooms*	*library*
	courtyards	*canteen*	*entry*	*corridors*	*staffrooms*	*computer*
		gym		*stairwells*	*music/art*	

Stimulated
Energetic, Noisy
Active, Dynamic
Hi-Metabolic Rates
▲ ▼
Contemplative
Concentration
Sedentary, Silent
Attentive, Calm
Lo-Metabolic Rates



Archetypal Symbolism ▶	passion		joy	knowledge		wisdom
[Chromatic/positive]	emotion		spirit	hope		mystery

LIGHT : FULL SPECTRUM/DAYLIGHT-SIMULATING FLUORESCENT LIGHT & UV

INTERIOR/ATTENUATED DAYLIGHT

NATURAL DAYLIGHT/OPEN WINDOWS

Performance guideline, not prescriptive (activity x spatial design x Variables)
Designer also chooses hues, shades of colours
Dynamic and Interactive: More than 1 colour per space x activity patterns
Colour Band can shift (indicated by ▶)

Variables:
Age of students (primary/secondary)
Materials & Finishes
Furnishing, Carpeting
Patterns (stripes, patches, multi-coloured cloth/wallpaper, etc)
Interior displays (posters, artwork, graphics...) add colour/variety/spice
Colour of edging, door and window frames, detailing, adds variety
Not rainbow : saturation can mimic colour properties (cool-warm)
Climate (warmer ▶ cooler colours)
Multi-Culturalism x Suburban Majority x Ethnic Colours ?
Urban x Rural (sophistication; regional flavours)
Time of day x activity (cool to warm light: morning to afternoon)
Geography, (coastal symbolism etc)
School Colours; school uniform colours
Optics (direction of daylight, silhouettes, glare, receeding/advancing colours)
Spatial Form (shape of room - elongated, rotund etc, & linearity emphases)
Heritage Building x Heritage Colours

Where elements overlap *eg* younger children with naturally higher levels of activity and greater preference for warmer colours with a cooler climate, or secondary students with a warmer climate, the variables are relatively easily reconciled.

Where there is a conflict between issues, such as primary schools and warm climates, the experience of the education managers and colourists, and the situational context of the particular school, will be most crucial.

Where more variables are included the complexities multiply rapidly.

Indoor climate (temperature) can, however, be managed in a wide variety of ways without having to resort to colour *ie* to *perceived* warmth/coolth. Other aspects, such as symbolism and attentiveness are far more relevant, and influencing temperature sensations (‘cool’ blues for a hot climate, eg) should not predominate over other considerations.

The impacts of many other elements/variables are likely to be averaged out, for example, multi-culturalism, regionalism, materials and finishes, given the wide range of individuals amongst the school going population. Where, however, extreme cases stand out in the context, eg a landlocked school in a hot region, or an overwhelming majority of an ethnic/sub-cultural group in a school, the individual colourist should emphasise this in their rationale and scheme presented to the evaluating panel.

It is suggested here that the overriding elements for consideration
should be the relationships of colour
to *age, attentiveness, activity and context-*
within a full spectrum environment.

BIBLIOGRAPHY

Allen, G. (1879), *The Colour-Sense: Its Origin and Development,* Houghton Osgood and Co, Boston.

Ammon-Wexler, J. (1988), *"An investigation of the influence of visually-perceived coloured light stimulation on subjects with DSM-III phobic disorders. A Preliminary Report"*, Innerspace Body/Mind Therapy Center, California.

Arendt, J. (1979), *"Radioimmunoassayble melatonin: circulating patterns in man and sheep"*, in J.A. Kappers & P. Pevet (eds), The Pineal Gland of Vertebrates Including Man, Progress in Brain Research, 52:249-258, Elsevier.

ASHRAE Fundamentals, (1989), *Fenestration,* Chapter 27.

Aston, S.M. and Bellchambers, H.E. (1969), *"Illumination, colour rendering and visual clarity*", Lighting Research & Technology, 1, 4: 259-261.

Australian Standards Association, (1980), *AS 2310 - 1980, Glossary of Paint and Painting Terms,* (Australia).

Banov, A. (1973), *Paints and Coatings Handbook for Contractors, Architects, Builders and Engineers,* Michigan: Structures Publishing.

Beck-Friis, J., Von Rosen, D., Kjellman, B.F., Ljunggren, J.G. & Wetterberg, L. (1984), *"Melatonin in relation to body measures, sex, age, season and the use of drugs in patients with major affective disorders and healthy subjects"*, Psychoneuroend. 9.

Beral, V., Evans, H., Shaw, S. and Milton, G. (1982), *"Malignant melanoma and exposure to fluorescent lighting at work"*, Lancet, 2: 290.

Berlin, B. and Kay, P. (1969), *Basic Color Terms,* University of California Press, Berkley and Los Angeles.

Berlyne, D.E. (1960), *Conflict, Arousal and Curiosity,* McGraw Hill, New York.

Berman, S. (1991), *"Energy Efficient Consequences of Scotopic Sensitivity"*, paper presented at the IESNA Annual Conference (see also Journal of the Illuminating Engineering Society, 22, 1: 3-14, Winter, 1992).

Bickford, E.D. (1980), *"Biological effects of full spectrum lighting*", in M.L. Wolbarsht and D.H. Sliney (eds), Ocular effects of non-ionizing radiation, 229: 2-6, Proc. Soc. Photo. Opt. Inst. Eng.

Birren, F. (1949), *"Functional Color in the Schoolroom",* Magazine of Art, 4: 136-8 (April).

Birren, F. (1961), *Color, Form and Space,* Reinhold Publishing Corporation, New York.

Birren, F. (1969), *Principles of Color,* Van Nostrand Reinhold, New York.

Birren, F. (1972a), *"Color and man-made environments: The significance of light*", *AIA Journal*, 15-19, August.

Birren, F. (1972b), *"Color and man-made environments: Reactions of body and eye", AIA Journal*, 35-39, September.

Birren, F. (1972c), *"Color and man-made environments: Reactions of mind and emotion", AIA Journal*, 37-40, October.

Birren, F. (1979), *"Human response to color and light",* Hospitals, July 16th, 93-96.

Birren, F. (1982) (rev. ed.), *Light, Color and Environment,* Van Nostrand Reinhold, New York.

Boxall, J. and Von Fraumhofer, J.A. (1977), *Concise Paint Technology,* Chemical Publishing, New York.

Boyce, P.R. and Simons, R.H. (1977), *"Hue discrimination and light sources",* Lighting Research and Technology, 9, 125-140.

Boyce, P.R. (1977), *"Investigations of the subjective balance between illuminanace and lamp colour properties",* Lighting Research and Technology, 9, 1, 11-24.

Brechsler, R.J. (1960), *"Affect-stimulating effects of colours"*, Journal of Abnormal Social Psychology, 61, 323-338.

Brown, B. (1974), *New Mind, New Body: Bio-Feedback: New Directions for Mind,* Harper and Row, New York.

Bultmann, R. (1948), *"Zur Geschichte der Lichtsymbolik im Alterum",* Philologus, 97, 1-36.

Burckhardt, T. (1967), *Alchemy: Science of the Cosmos, Science of the Soul,* Stuart and Watkins, London.

Burckhardt, T. (1976), *Sacred Art in East and West*, Perennial, UK.

California State University, Sacramento, (1989), Services to Students with Disabilities, *Letter addressed to the Downing Institute,* San Francisco.

Catherwood, D. (1990), *"New findings on perceptual development: Implications for early childhood education",* Links, 3, 14-17.

Cayless and Marsden, (1983), *Lamps and Lighting*, 3rd. edition, Edward Arnold, Vic.

Chevalier, J. & Gheerbrant, A. (1982), *Dictionnaire des Symboles*, Laffont/Jupiter, Paris.

Cirlot, J.E. (1984), (rev.ed.) *A Dictionary of Symbols*, 2nd edition, trans. from Spanish by Jack Sage, Routledge and Kegan Paul, London.

Clarke, F.J.J. (1979*), "Practical standard illuminant representative of interior daylight"*, Proceedings of CIE 19th Session, Kyoto, 73-78.

Cockrill, I.M. and Miller, B.P. (1983*),* "Children's Colour Preferences and Motor Skill Perfomance with Variation in Environmental Colour", Perceptual and Motor Skills, 56, 845-46.

Cole, C., Forbes, P.D., Davies, R.E. and Urbach, F. (1985), *"Effect of indoor lighting on normal skin"*, The Medical and Biological Effects of Light, Annals of the New York Academy of Sciences, 453, 305-316.

Collins, B.L. (1975), *"Windows and people; a literature survey, Psychological reactions to environments with and without windows",* NBS Build. Sci. Ser., 70, U.S. Dept. of Commerce, Nat. Bur. of Stands.

Commonwealth Department of Productivity, Physical Working Environment Branch, (1980), *"Colour at work: planning colour schemes*", AGPS, Canberra.

Commonwealth Dept. of Science and Technology, (1981), *Artificial Light at Work,* Occup. Safety and Health Working Envir., Series 6.

Concar, D. (1992), "The resistible rise of skin cancer", New Scientist, 16 May, 23-28.

Conklin, H.C. (1973) *"Color categorization"* (review of Berlin and Kay, 1969) American Anthopologist 75, 931-42.

Cowen, P. (1979), *Rose Windows,* Thames and Hudson, London.

Danger, E.P. (1987), *The Colour Handbook: How to use colour in commerce and industry,* Gower Technical Press, Worcester.

Dantsig, N.M., Lazarev, D.N. and Sokolov, M.V. (1967), *"Ultraviolet installations of beneficial action",* CIE Publication P.67.20.

Dawkins, Kate & Furnham, A.,(1989), "The colour naming of emotional words", British Journal of Psychology 80, 3, 383-389, Aug.

Deutsch, F. (1937), *"Psycho-physical reactions of the vascular system to influence of light and the impressions gained through light"*, Folio Clin. Orient, 1, Fasc. 3 and 4.

Downing, J. (1988), *"Downing technique of neurosensory development"*, The Downing Institute, San Francisco, Calif.

Drechsler, R.J. (1960), *"Affect-stimulating effects of colours"*, Journal of Abnormal and Social Psychology, 61, 3, 323-328**.**

Eames, T.H. (1936), *"Restrictions of visual field as handicaps to learning"*, J. Educ. Research, 19, 460-463.

Elder, J. and Tibbott, R.L. (1981), *User acceptance of an energy efficient office building: A study of the Norris Cotton federal office building,* U.S. Government Printing Office, Wash D.C.

Ellinger, F. (1957), *Medical Radiation Biology*, Charles C. Thomas, Springfield, IL.

Erikson, C. and Kuller, R. (1983), *"Non-visual effects of office lighting"*, Proceedings of the CIE, 20th Session, D602/1-/4, Amsterdam.

Evans, B.J.W. and Drasdo, N. (1991), *"Tinted lenses and related therapies for learning disabilities - a review"*, Ophthal. Physiol. Opt. 11, 206-217.

Facts of Light, (1989), Publication of Ott Light Systems, Santa Barbara, California.

Faulkner, W. (1972), *Architecture and Color,* Wiley-Interscience, New York.

Fodor, J.A. (1987), *Psychosemantics: The Problem of Meaning in the Philosophy of Mind,*.Bradford, Cambridge, Mass.

Gage, J. (1978), "Colour in history: relative and absolute", *Art History*, 1, 1, 104 ff. March.

Gage, J. (1993), *Colour and Culture,* Thames and Hudson, London.

Gerard, R.M. (1958*), Differential effects of colored lights on psychophysiological functions,* Unpublished doctoral dissertation, Univ. of Calif. at Los Angeles.

Gerritsen, F. (1982), *Evolution in Color,* Schiller Publishing, West Chester, Penn.

Gerstner, K. (1986), *The Forms of Color,* MIT Press, Cambridge Mass. & London.

Gibson, J.J. (1966), *The Senses Considered as Perceptual Systems,* Houghton Mifflin, Boston.

Goethe, J.W. von, [1840] (1970), *Theory of Colours*, trans. by Charles Lock Eastlake, MIT Press, Cambridge, Mass.

Goldstein, K. (1942*)*, "Some experimental observations concerning the influence of colour on the function of the organism", Occupational Therapy and Rehabilitation, June.

Golla, F.L. and Winter, A.L. (1959), *"Analysis of cerebral responses to flicker in patients complaining of episodic headache",* Electroenceph. Clin. Neurophysiol. 11, 539.

Green-Armytage, P. (1981), *"Color in schools: a bridge between art and science",* Paper presented at International Society For Education Through Art, World Congress (24th 1981, Rotterdam) Official Journal of the Institute of Art Education, 5, 17-39, Dec.

Greene, T.C., Bell, P.A. and Boyer, W.N. (1983), *"Colouring the environment: Hue, arousal and boredom",* Bulletin of the Psychonomic Society, 21, 4, 253-254.

Greiter, F. et al. (1979), *"The influence of artificial and natural sunlight upon various psychological and physical parameters of the human organism",* Annual Meeting Am. Soc. Photobiology, June 1979.

Grieve, K.W. (1991), *Traditional beliefs and colour perception",* Perceptual and Motor Skills, 72, Part 2, 1319-1323, June.

Guénon, **R.** (1950), *Aperçu sur l'Initiation,* Paris.

Halse, A.O. (1978), *The Use of Color in Interiors,* McGraw- Hill, New York.

Hamburg, H.R. and Murzans, W.M. (1979) (eds), *Hess's Paint Film Defects: Causes and Cure*, Chapman and Hall, London.

Hamid, P.N. and Newport, A.G. (1989*), "Effect of colour on physical strength and mood in children",* Perceptual and Motor Skills, 69, 179-185.

Hanlon, H. (1979), *"A learning, working environment",* Educational Horizons, 58, 2, 89.

Hannell, G., Gole, G.A., Dibden, S.N., Rooney, K.F., Pidgeon, K.J. and McGlinchey, N.D. (1989), *"Reading improvements with tinted lenses: a report of two cases*", Clin. Exp. Optom. 72, 170-176.

Harber, L.C., Whitman, G.B., Armstrong R.B. and Deleo, V.A. (1985), "*Photosensitivity diseases related to interior lighting*", Annals of the NY Academy of Sciences, op. cit, 317-327.

Hardin, C.L. (1988), *Color for Philosophers: Unweaving the Rainbow,* Hackett Publishing Company, Indianapolis,Cambridge.

Hargreaves, J.A. and Thompson, G.W. (1987), *"Ultraviolet light and dental cavities in children",* Faculty of Dentistry, University of Alberta, Edmonton, Canada.

Harmon, D.B. (1942), *Illumination and child development*, Illum. Eng. Soc., Ft. Worth.

Harris, F.E. and Bills, R.E. (1953-54*), Psychological considerations of colour selection",* The American School and University, 25, 157-160.

Hathaway, W.E. (1987), *"Light, colour and air quality: important elements of the learning environment ?",* Education Canada, 27, 3, 35-44.

Hebb, D.O. (1955), *"Drives and the C.N.S. (Central Nervous System)",* Psychological Review, 762, 243-254.

Henning, W. (1936), *"The fundamentals of chrome-orthoptics"*, Actino Laboratories, Inc.

Hevner, K. (1935), *"Experimental studies of the affective value of colors and lines",* Journal of Applied Psychology, 19, 385-398.

Hofling, G. (1973), *"Can fluorescent lamps cause headaches?",* in Schilling, Verlag fur Informationstechnik, Herne.

Hollwich, F. and Dieckhues, B. (1968), *"Eosinopenie-reaktion und sehvermogen",* Klin. Mbl. Augenheilk, 152, 11.

Hollwich, F. and Dieckhues, B. (1972), *"Effect of natural and artificial light on animals and human organism",* Fortschr. Med., 90, 25.

Hollwich, F. and Dieckhues, B. (1980), *"The effect of natural and artificial light via the eye on the hormonal and metabolic balance of animals and man",* Ophthalmologia 180, 188-197.

Hollwich, F. (1948), Ber. Dtsch. Ophthal. Ges., 54, 326, Heidelberg.

Hollwich, F. (1979), *The Influence Of Ocular Light Perception On Metabolism In Man And Animal*, Springer Verlag, New York.

Hollwich, F., Dieckhues, B. and Meiners, C.O. (1975), *"Physiological importance of light to man",* Licht-technik 27, 388.

Horne, J.,(1992), "Stay awake, stay alive", New Scientist, 4 January, 20-24.

Hughes, P.C. and Neer, R.M. (1981), *"Lighting for the elderly: a psychobiological approach to lighting"*, Human Factors, 23, 65-85.

Hughes, P.C. "School Lighting for the Total Person: A Psychological Approach", CEFP Journal, 19, 2, 5.

Hughes, P.C. (1980), *"The use of light and color in health"*, in A.C. Hastings, J. Fadiman and J.S. Gordon (eds), Health for the Whole Person: The complete guide to holistic medicine, Westview Press, Boulder, Col.

Hughes, P.C. (1981), *"School lighting for the total person: A psychobiological approach"*, Council of Educ. Facility Planners Journal, 4-6, (March-April).

Hughes, P.C. (1983*), "An examination of the beneficial action of natural light on the psychobiological system of man"*, Proceedings of CIE 20th Session, Amsterdam.

Ingraham, L. (1983*), "Electromagnetic Radiation and Student Off-Task Behaviour",* Edmonton Planning Services Branch, Alberta Education.

Irlen, H. and Lass, M.J. (1989), *"Improving reading problems due to symptoms of scotopic sensitivity syndrome using Irlen lenses and overlays",* Education, 109, 413-417.

Irlen, H. (1983), *"Successful treatment of learning difficulties",* Presented at The Annual Conference of the Am. Psych. Assoc., Anaheim, Calif.

Itten, J. [1961] (1973), *The Art of Color,* Van Nostrand Reinhold, New York.

Izutsu, T., (1972), *"The Elimination of Color in Far Eastern Art and Philosophy",* ERANOS, p.429.

Jacobs, K.W. and Hustmeyer, F.E. (1974), *"Effects of Four Primary Colours on GSR, Heart Rate and Respiration Rates"*, Perceptual and Motor Skills, 38, 763-66.

Jacobs, K.W. and Suess, J.F. (1975), *"Effects of four psychological colours on anxiety states",* Percept and Motor Skills, 41, 201-210.

Jacobsen, F.M. and Rosenthal, N.E. (1986*),* "Seasonal affective disorder and the use of light as an antidepressant", Directions in Psychiatry, 6, Lesson 3, Hatherleigh, N.Y.

Julian, W.G. (1987), *"Lighting : An urgent case for a major research effort in architectural science"*, Build. and Environ, 22, 3, 155-161.

Kaplan, R. (1983), *"Changes in form visual fields in reading disabled children produced by syntonic (coloured light) stimulation"*, Int. Jour. of Biosocial Research, 5, 1, 20-33.

Kok, C.J. and Hengstberger, F. (1991), *"The effect of indoor environment on the spectral and colorimetric characteristics of daylight"*, Proceedings CIE 22nd Session, Melbourne, 85-86.

Kok, C.J., Monard, L.A.G. and Hengstberger, F. (1985*), "The Radiospectrometry of actinic radiation indoors"*, Paper prepared from CIE TC-1.7, report presented at the *20th CIE Session*, Amsterdam (1983).

Kollar, L.P.(1987), *On The Architectural Idea*, 2nd. edition, Sydney.

Krauss, R.N. (1968), *"Language as a symbolic process in communication"*, American Scientist, 56, 265-278.

Kruithof, A.A. (1941), *"Tubular Luminensence Lamp"*, Philips Technical Review, March.

Kuller, R, (1981), *"Non-visual effects of light and colour: Annotated bibliography"*, Swedish Council for Building Research, Doc. D 15,81, Stockholm.

Kuller, R. (1987), *"The effects of indoor lighting on well-being and the annual rhythm of hormones"*, CIE proceedings, 21st Session, Vol 1, Venice.

Kuller, R and Lindsten, C. (1992), *"Health and behaviour of children in classrooms with and without windows"*, Journal of Environmental Psychology, 12, 305-317.

Kuller, R. and Wetterberg, L. (1993), *"Melatonin, cortisol, EEG, ECG and subjective comfort in healthy humans: Impact of two fluorescent lamp types at two light intensities"*, Lighting Res. Technol., 25, 2, 71-81.

Kwallek, N. & Lewis, C.M. (1990), *"Effects of environmental colour on males and females: a red or white or green office"*, Applied Ergonomics, Dec, 21, 4, 275-278.

Lerner, A.B., Case, F.D. and Heinzelmann, R.V. (1958), J. Am. Chem. Soc. 80, 2587.

Lewy, A.J. and Sack, R.L., (1986), *"Light therapy and psychiatry"*, Proc. Soc. Exp. Biol. Med., 183, 11-18.

Lewy, A.J., Kern, H.E., Rosenthal, N.E. and Wehr T.A. (1982), *"Bright artificial light treatment of a manic-depressive patient with a seasonal mood cycle"*, Amer. J. Psychiat., 139, 1496-1498.

Lewy, A.J., Wehr, T.A,. Goodwin, F.K., Newsome, D.A. and Markey, S.P. (1980), *"Light suppresses melatonin secretion in humans"*, Science, 210, 1267-1269.

Liberman, J. (1985), *"Looking at colors widens visual field"*, Brain/Mind Bulletin, August.

Lindsten, C. and Kuller, R. (1987*),"Health impact on school schildren from lack of natural daylight",* cited in Kuller, (1987), *op. cit.*

Linton, H. (1991), *Color Consulting: A Survey of International Color Design,* Van Nostrand Reinhold, New York.

Logan, H. L. (1970), *"Outdoor Light for the Indoor Environment"*, The Designer, Nov.

Lüscher, M., (1956), *The Lüscher Colour Test,* trans. by Ian Scott, Pan Books, London.

Lynch, H.J., Ozaki, Y,. Shakal, D. and Wurtman, R.J. (1975), *"Melatonin excretion of man and rats: Effect of time of day, sleep, pinealectomy and food consumption"*, Int. J. Biometeor. 19, 267-279.

Maas, J.B., Jayson, J.K. and Kleiber, D.A., (1974a), *"Effects of spectral differences in illumination on fatigue"*, J. of Applied Psychology, 59, 524-526.

Maas, J.B. et al, (1974b), *"Quality of light is important - not just quantity"*, American School and University, 46, 12, 31.

Mackay, J. (1995), *"Paint and the Environment"*, Specifier, 4, 1, 74-75.

Mahnke, F.H. & Mahnke, R.H. (1987), *Color and Light in Man-made Environments,* Van Nostrand Reinhold, New York.

Mamid, P. et al, (1989), *"Effect of colour on physical strength and mood in children"*, Perceptual and Motor Skills, 69, 1, 179-185, Aug.

May, H.G., (1939), *"The creation of light in genesis"*, Journal of Biblical Literature, 58, 203 ff.

Mayron, L.W., Ott, J., Nations, R. and Mayron, E.L. (1974*), "Light, radiation and academic behaviour",* Academic Therapy, 10, 1, 34-47.

McLaughlin et al, (1982), *"Spectral character of sunlight modulates photosynthesis of pre-vitamin D3 and its photoisomers in human skin",* Science, 216, 1001-03.

McLaughlin, K.J. (1980), *Pupil control ideology in eleven state and catholic schools in metropolitan and rural areas of south east queensland,* Masters Thesis MEdAdmin, University of New England, Armidale NSW.

Mehrabian, A. and Russel, J.A. (1974), *An Approach to Environmental Psychology*, M.I.T. Press, Camb, MA.

Mestel, R. (1995*)*, "Escape from the Zombie Zone", New Scientist, 21 Jan, 7.

Mikellides, B. (1989), *"Emotional and behavioural reaction to colour in the built environment",* unpublished PhD dissertation, Oxford Polytechnic, Oxford and Lund Institute of Technology, Lund.

Moore-Ede, M.C., Czeisler, C.A. and Richardson, C.S. (1983), *"Circadian timekeeping in health and disease",* Part 1 and 2, New Engl. J. Med., 309, 469-476 & 530-536.

Munsell, A.H. [1905] (1961), *A Color Notation: An Illustrated System Defining All Colors and Their Relations by Measured Scales of Hue, Value and Chroma,* Munsell Color Company, Baltimore.

Munson, P. and Ferguson, R. (1988), *"The influence of fluorescent illumination on the behaviour of school children",* unpublished manuscript, School of Child Care, University of Victoria, Victoria, B.C.

Murphy, D.L., Campbell, I. and Costa, J.L. (1978), *"Current status of indoleamine hypothesis of the affective disorders",* in M.A. Lipton, A. Dimascio and K.E. Killam (eds), Psychopharmacology: A Generation of Progess, Raven Press, N.Y, 1235-1247.

Nakshian, J.S. (1964), *"The effects of red and green surroundings on behaviour*", Journal of General Psychology, 70, 143-161.

Nasr, S.H. (1981), *Knowledge and the Sacred*, Edinburgh University Press, Edinburgh.

Neer, R.M., Davis, T.R., Walcott, A., Koski, S., Schapis, P., Taylor, I., Thorington, L. and Wurtman, R.J. (1971*), "Stimulation by artificial lighting of calcium absorption in elderly human subjects",* Nature, 229, 225.

Nourse, J.C. and Welch, R.B. (1971*), "Emotional attributes of color: a comparison of violet and green",* Perceptual And Motor Skills, 32, 403-406.

O'Leary, K.D., Rosenbaum, A. and Hughes, P.C. (1978), *"Fluorescent lighting: a purported source of hyperactive behaviour",* J. of Abnormal Child Psych. 6, 3, 285-289.

Oil and Colour Chemists' Association, (1989), *Manual of Oil and Colour Chemists Association,* (Australia).

Osborne, H. (1968), *"Colour Concepts of the Ancient Greeks"*, The British Journal of Aesthetics, 8, 3, July.

Osborne, R. (1980), *Lights and Pigments: Colour Principles for Artists,* Harper and Row, New York.

Ostwald, W., [1916] (1969), *The Color Primer,*ed. by Faber Birren, Van Nosrand Reinhold, New York.

Ott, J. (1965), *"Effects of Wavelengths of Light on Physiological Functions of Plants and Animals",* Illuminating Engineering, April.

Ott, J. (1976), *"Influence of Fluorescent Lights on Hyperactivity and Learning Disabilities",* Journal of Learning Disabilities, 9, 7, 22-27.

Ott, J. (1982), *Light, Radiation and You: How to stay healthy,* Devin-Adair.

Painter, M. (1976*), "Fluorescent lights and hyperactivity in children: An experiment",* Academic Therapy, 12, 2, 181-184.

Panofsky, E. (1979), *Abbot Suger, on the Abbey Church of St.-Denis and its Art Treasures,* ed. trans. and annotated by Panofsky, 2nd Edition, Princeton Uni. Press, Princeton, NJ.

Paul, P. (1991), *"Colour in Intercultural Communication",* Australian Journal of Communication, 18, 1, 40-51.

Pelham, R.W., Vaughan, G.M., Sandox, K.L. and Vaughan, M.K. (1973), *"Twenty-four hour cycle of a melatonin-like substance in the plasma of human males",* J. Clin. Endocrinol. Metab. 37, 341.

Pertsovskiy, A.I. and Kunitsyna, L.A. (1977*), "Biochemical assessment of the effectiveness of different ultraviolet irradiation modes on patients with cerebral atherosclerosis",* Vopr Kurortol Fizioter Lech Fiz Kult, 3, 821.

Plack, J.J. and Schick, J. (1974), *"The effects of color on human behaviour",* J. of the Assoc. for Study in Perception, 9, 4-16.

Plato, *The Republic*, trans. by Desmond Lee, (1974), Penguin, London.

Plato, *Timaeus and Critias*, trans. by Desmond Lee, (1979), Penguin, London.

Portal, F. (1844), *"Symbolic Colours",* Neale's Quarterly Papers in Architecture, Vol. 2-3.

Porter, T. & Mikellides, B. (1976), *Colour for Architecture,* Studio Vista, London.

Portmann, A. et al, (1977), *Color Symbolism: Six Excerpts from the Eranos Yearbook, 1972,* Spring Publications, Dallas.

Potkin, S., Zetlin, M., Stamenkovic, V. et al, (1986), *"Seasonal affective disorder: prevalence varies with latitude and climate",* Clin. Neuropharm. 9, Suppl. 4, S-74.

Putnam, H. (1988), *Representation and Reality,* A Bradford Book by The MIT Press, Cambridge, Mass.

Quay, W.B. (1966), *"24-hour rhythms in pineal 5-hydroxyindole-O-methyl-transferase activity in the macaque",* Proc. Soc. Exptl. Biol. Med., 121, 946.

Reid, D. & Wicks, Sheila, (1988), *"Young children's perception of colour on a school microcomputer",* Programmed Learning and Educational Technology, Nov., 25, 4, 348-53.

Rice, A.H. (1953), *"Colour: What research knows about the classrooms",* Nation's Schools, 52, 1-8.

Ronchi, L.R. and Bodmann, H.W. (1983), *"Fluorescent lighting, skin cancer and malignant melanoma",* CIE Journal, 2, 2, Dec.

Rosenthal, N.E., Joseph-Vanderpool, J.R., Levendosky, A.A., Johnson, S.H., Allen, R., Kelly, K.A., Soutre, E., Shultz,P.M. and Startz, B.K. (1990), *"Phase-shifting effects of bright morning light as treatment for delayed sleep phase syndrome",* Sleep 13, 354-361.

Rosenthal, N.E., Sack, D.A., Gillin, J.C., Lewy, A.J,. Goodwin, F.K., Davenport, Y., Mueller, P.S., Newsome, D.A. and Wehr, T.A. (1984), *"Seasonal affective disorder: A description of the syndrome and preliminary findings with light therapy",* Arch. Gen. Psychiat., 4.

Rosenthal, N.E., Sack, D.A., James, S.P., Parry, B.L., Mendelson, W.B., Tararkin, L. and Wehr, T.A. (1985), *"Seasonal affective disorder and phototherapy",* in Wurtman et al (eds), Annals of the NY Academy of Sciences, op cit, 260-269.

Rossotti, H. (1983), *Colour: Why the world isn't grey*, Penguin, UK.

Rowe, C.E. (1972*), "Conceptions of Colour and Colour Symbolism in the Ancient World",* ERANOS, 327.

Russell, J.A., Ward, L.M. and Pratt, G. (1981), *"Affective quality attributed to environments: a factor analytic study"*, Environment and Behaviour, 13, 3, 259-288.

Saint-John, L.M. and White, M.A. (1988), *"The effect of coloured transparencies on the reading performance of reading disabled children",* Aust. J. Psychol., 40, 403-411.

Samuels R. and Ballinger J. (1992), *"Quality and efficiency in lighting: Social and environmental responsibility",* Final Report to Pacific Power, Solarch, UNSW.

Samuels R. (1978), The Psychology of Stress: The impact of the urban environment, unpublished Ph.D. dissertation, University of Reading, U.K.

Samuels R. (1994*), "Developments in environmental lighting: Energy efficiency and environmental responsibility, psychobiology and social responsibility,"* The Australian and New Zealand Journal of Person-Environment Studies, No. 45, 21-32.

Samuels R. (1995), *"Design and planning for urban safety and security"*, Prepared for the NSW Department of Housing, Final Report.

Samuels R., (forthcoming*), "Defensible design and security - university campuses",* Prepared for the Department of Employment, Education and Training, Evaluations and Investigations Program, Final Report, AGPS.

Sauer, J. (1902), *Die Symbolik des Kirchengebaudes*, Frieburg.

Saunders, Barbara, (1994), *"The Ignis Fatuus of Colour"*, a review of Gage, J., 1993, Colour and Culture in Art History, 17; 3, 494 - 504, Sept.

Savides, T.J., Messin, S., Senger, C. and Kripke, D.F. (1986), *"Natural Light Exposure of Young Adults"*, Physiology and Behavior, 38, 571-574.

Schachtel E. (1943), *"On color and affect"*, Psychiatry, 6, 393-409.

Scholem, G. (1979, 1980), *"Colours and their symbolism in jewish tradition and mysticism",* Diogenes, no.108, winter 1979, 84-111, and no.109, spring 1980, 64-76.

Schoun, F. (1956), *Spiritual Perspectives and Human Facts*, Faber and Faber, London.

Segall, M.H., et al, (1966), *The Influence of Culture on Visual Perception: An Advanced Study in Psychology and Anthropology*, Bobbs-Merrill, New York.

Selye, H. (1956), *The Stress of Life*, McGraw Hill, New York.

Sharpe, DT. (1976), *The Psychology of Color and Design*, Nelson-Hall Company, Chicago.

Sloane, P. (1989), *The Visual Nature of Color,* Design Press , New York.

Spitler, H.R. (1941), *The Syntonic Principle*, College of Syntonic Optometry.

Staples, R. and Walton, W.E. (1933), *"A study of pleasurable experience as a factor in colour preference"*, J. Genet. Psychol., 43, 217-223.

Stewart, K.T., Gaddy, J.R., Benson, D.M., Byrne, B.M., Doghramji, K. and Brainard, G.C. (1990), *"Treatment of winter depression with a portable head-mounted phototherapy device"*, Prog. Neuro-psychopharm. Biol. Psych., 14, 569-578.

Sydoriak, D.E. (1984), *"An experiment to determine the effects of light and color in the learning environment"*, unpublished doctoral dissertation, University of Arkansas, Little Rock.

Taylor, H.D. et al, (1950), *Descriptive Color Names Dictionary,* Container Corp. of America. Chicago.

Terman, M. and McCluney, R. (1987), *"Counteracting daylight deprivation"*, CIE Proceedings of the 21st Session, Venice.

Terman, M., Terman, J.S., Quitkin, F.M., McGrath, P.J., Stewart, J.W. and Rafferty, B. (1989), *"Light therapy for seasonal affective disorder: A review of efficiacy"*, Neuropsychpharm., 2, 1-22.

Thorington, L. and Parascandola, L.J. (1967), *"Ultraviolet emission from light sources used as general illuminants"*, Illuminating Engineering, 62, 674-681.

Thorington, L. (1980), *"Actinic effects of light and biological implications"*, Photochem. and Photobiol., 32, 117-129.

Thorington, L. (1985), *"Spectral irradiance and temporal aspects of natural and artificial light"*, Annals of the NY Academy of Sciences, 453, 28-54.

Unisearch Ltd. (1975), *Colour in the School Environment*, UNSW.

Varley, H. (ed) **(**1980), *Colour*, Mitchell Beazley Artists House, London.

Vernon, M.D. (1966) (ed), *Experiments in Visual Perception: Selected Readings*, Penguin, Harmondsworth.

Warren, M., Benton, C., Verderber, R., Morse, O., Selkowitz, S. and Jewell, J. (1986), *"Instrumentation for evaluating integrated lighting system performance in a large daylighted office building"*, Presented at the National Workshop on Field Data Acquisition, Dallas.

Waterhouse, J. (1991), *"Light dawns on the body clock"*, New Scientist, 26th October, 22-26.

Wever, R.A. (1985), "Characteristics of circadian rhythms in human functions", in Wurtman, R.J. and Waldhauser, F. (eds), Melatonin in Humans, Center for Brain Sciences and Metabolism Charitable Trust, Cambridge, MA, 291-352.

Wever, R.A., Polasek, J. And Wildgruber, C.M. (1983), "Bright light affects human circadian rhythms", Pflugers Arch, 396: 85-87.

Whitemead, A. (1992), *"Teaching in a Steiner School: My favourite colour? All of them except grey"*, Classroom, 12, 9, 18-19, Oct.

Whiting, P.R. and Robinson, G.L.W. (1988), *"Using Irlen coloured lenses for reading: A clinical study"*, Australian Educational and Development Psychologist, 5, 2, 7-10.

Wilkins, A.J. and Wilkinson, P. (1991), *"A tint to reduce eye-strain from fluorescent lighting? Preliminary observations"*, Ophthal. Physiol. Opt., 11, 173-175.

Wilkins, A.J. (1986), *"Intermittent illumination from visual diplay units and fluorescent lighting affects movement of the eye across text"*, Human Factors 28, 75-81.

Wilkins, A.J., Nimmo-Smith, I., Slater, A.I. and Bedocs, L. (1988), *"Fluorescent lighting, headaches and eye-strain"*, National Lighting Conference, U.K.

Wilson, G.D. (1966), *"Arousal Properties of Red versus Green"*, Perceptual and Motor Skills, 23, 947-49.

Wineman, J. (1981), *"Office evaluation research: Issues and applications"*, Paper presented at the Center for Building Technology Federal Workshop Series on Building Science and Technology.

Winter, S. (1987), *"Irlen lenses: An appraisal"*, Austr. Educ. Develop. Psychol., 1-5.

Wohlfarth, H. (1958), *“Psychological evaluation of experiments to assess the effect of colour-stimuli upon the autonomous nervous system”,* Exerpta Medica, Neurology and Psychiatry, II, 4.

Wohlfarth, H. (1986), *Colour and Light Effects on Students' Achievement, Behaviour and Physiology,* Planning Services Branch, Alberta Department of Education, Edmonton, Canada.

Wohlfarth, H. and Sams, K. (1981), *The effects of colour psychodynamic environment modification upon psycho-physiological and behavioural reactions of severely handicapped children,* Edmonton: Planning Services Branch, Alberta Department of Education.

Worthey, J.A. (1982), *“Opponent-colours approach to color rendering”*, J. Opt. Soc. Am., 72, 74-82.

Worthey, J.A., (1985), *“An analytical visual clarity experiment*”, *Journal of IES*, 239-251, Fall.

Wurtman, R.J. (1969), *“The Pineal and endocrine function”*, Hospital Practice, January.

Wurtman, R. J. (1971), *“Biological implications of artificial illumination”*, Illuminating Engineering.

Wurtman, R.J. (1975), *“The effects of light on man and other mammals*”, Annual Review of Physiology, 37,467-483.

Wurtman, R.J., Axelrod, J. and Fisher, J.E. (1964), *“Melatonin synthesis in the pineal gland: Effects of light mediated by the sympathetic nervous system”*, Science, 143, 1328.

Wurtman, R.J. and Weisel, J. (1969), *“Environmental lighting and neuroendocrine function: relationship between spectrum of light source and gonodal growth*”, Endocrinology, 85, 6, December.

Wurtman, R.J., Baum, M.J. and Potts Jr., J.T. (1985) (eds), *“The Medical and Biological Effects of Light”*, Annals of the New York Academy of Sciences, Vol 453, Sept 20, 1-407.

Wurtman, R.J. and Wurtman, J.J. (1989), *“Carbohydrates and depression”*, Scientific American, 50-57, Jan.

Yau, V. (1994), *"Use of colour in china"*, British Journal of Aesthetics, 34, 2, 151-162, April.

Zahan, D. (1972), *"White red and black: colour symbolism in black africa"*, ERANOS, 365.

Zamkova, M.A. and Krivitskaya, E.E. (1966), *"Effect of irradiation by ultraviolet erythema lamps on the working ability of children"*, Gigiena I Sanitariya, 31, 41-44.

Zimmer, H. (1946), *Myths and Symbols in Indian Art and Civilization*, ed. by Joseph Campbell, Pantheon Books, New York.

Zolla, E. (1981), *Archetypes*, George Allen and Unwin, London.

APPENDIX I[80]

MAINTENANCE ISSUES

Introduction

We tend to expect that bricks and mortar or steel and wood last a long time. **A paint film** is an organic material usually derived from carbon compounds which is normally thinner than a page of newsprint.

When we paint a piece of steel we should not endow it with the same aura of permanence as metal. We should see paint for what it is and relate it's cost to that of the building.

Modern paints are remarkably tough and if you have applied the original coating properly it pays to try cleaning them down with a mild household cleaner. These dowdy walls may suddenly disappear and you may find that you don't really need a new paint after all.

Functions of a Paint System

Paints must perform many different functions. Few paints can satisfactorily perform all of them, so various paint formulations must be applied in separate layers, or coats, and these are collectively known as a paint system.

We should expect our paint to perform the following tasks without difficultly:

- **It must adhere firmly to the surface it covers and should not flake off.**
- **It may be needed to seal porous material.**

[80] Appendix 1 was prepared for The Building Research Centre by Ron Beckett.

- **It may have to protect different materials from weather and UV exposure.**
- **It must hide existing marks or stains.**
- **It should give colour to the painted surface as desired.**
- **It should provide the specified finish and texture.**
- **It must resist wear and tear that may result from the elements or from other chemical or aggressive agents.**
- **It must be elastic enough to resist knocks and scrapes and normal movements due to expansion and contraction within the surface it covers.**

it must have the necessary coating thickness to last as all paints deteriorate when exposed to the atmosphere.

by specifying the best features of a particular paint compound a perfectly satisfactory coating system can be built up layer by layer.

THE CRITICAL PAINT ZONES

Primers have several functions. they cling to a surface and protect it, sealing porous materials such as wood or brick. they protect metal surfaces from corrosion. generally, they dry with a roughish surface(matt finish) to help the next layer of paint, the undercoat, to cling to the primer.

The undercoat has three main functions. it masks any discolouration on the surface to which it is applied. it helps to provide a thickness build up that lengthens the life of the paint system and it too, generally dries with a matt surface for grip.

sometimes more than one undercoat may be desirable. the colour should preferably not be exactly the same colour as the final coat. a slightly different colour makes it easier to ensure that the final coat has properly covered it’s backing.

The topcoat provides colour, texture and resistance that protects the paint film from damage. the surface of the topcoat is not always suitable to take another coat of paint. attempts to paint over finished work often result in failure.

Primers, undercoats or finishing paints each contain some or all the basic ingredients, pigment, binder, drier and solvent. it is important to purchase a complete marketed system by one manufacturer as the very wide range of chemicals used may not be compatible with other paint formulations.

CLASSIFICATION OF PAINTS

Water based emulsions, (ie compounds suspended in water) sometimes called plastic or latex paints. **this group includes:**

Polyvinyl Acetate (PVA)
Acrylics (formulated from ester resins)
Maleates (Promoting adhesion to metals)
and various other co-polymers. (Vinyl chloride to vinyl acetate ratios)

These paints are popular because they are water dispersable before setting. This quality enables them to be thinned easily. They are alkali resistant and can be applied to cement. They are somewhat porous when dry enabling them to "breathe" and consequently are less likely to be pushed off a surface by water vapour. They also provide little protection against moisture unless applied over a non porous sealer.

Solvent based alkyd resin paints (polyesters), are synthetic compounds produced by chemically treating normal drying oils. they fall into these broad categories.
Drying (soluble in aromatic solvents)
Semi-drying (binders in air drying finishes)
Non-drying (binders in decorative finishes, normal air drying)
Modified resins (improved chemical resistance and drying)
They are found in most gloss enamel paints. alkyds can also be used to produce paints with matt and flat finishes. they are compounded to produce primers, undercoats and topcoats and can be thinned with mineral turpentine.

Polyurethanes are resin polymers containing urethane formed by the reaction of isocyanates with hydroxyl compounds. there are two broad classifications, one component or single pack system and the two component or two pack systems.

Single pack coating systems commonly form urethane resins by air curing, moisture curing and heat (stoving). they are characterised by good abrasion resistance and high resistance to water and mild corrosives.

Two pack systems produce in situ polymerisation films of high chemical resistance, good durability, high film strength and excellent adhesion to a variety of substrates.

Epoxy paints are among the hardest known resins. they cling tenaciously to most surfaces. they can be loaded with pigment and fibre to form the basis of the successful one-coat painting systems. serious adhesion problems may exist, however, if they are used with a second coat or are painted over.

Lacquers are dissolved in a solvent and hardens as the solvent evaporates. no oxidisation or chemical curing takes place. their properties are greatly improved with the addition of modified alkyd resins or similar compounds.

Cement based paints. this system differs from those already included. cement based "paints" are made from pigments and cement mixed with water. they set quickly into a hard waterproofing skin and perform best when applied to cement based surfaces. they are unaffected by alkali agents.

Preparing the Substrate Surface

Preparing the surface correctly is an essential step to getting good adhesion and a satisfactory performance.

Wood should be sanded smooth and care taken to fill cracks, splits and nail holes. A base coat which seals the grain should be used.

Metals should be free of grease, dust and moisture. A stiff wire brush followed by a rub from a steel pot scourer is needed. The metal primer must be applied as soon as possible on a dry day. Moisture condensation from dew must be avoided.

Concrete or plastered walls should be washed down thoroughly with water and detergent then rinsed and dried off before painting. Old powdery finishes must be removed with a stiff brush. All surface irregularities, cracks and holes must be filled and rubbed down before paint is applied.

Old paint. Where the surface is in good condition, a good clean is necessary to give the paint a key.

For a gloss paint, all grease or wax should be removed with detergent and then rubbed down with wet emery paper. remove all loose dust and scratchings.

Matt finishes should be rubbed down with paint solvent.

Oil paints require washing with water and detergent before rubbing down with solvent.

For all paints remove any chalky material present.

Durability

The durability of paint films is dependent upon a number of factors. These can be divided into “internal” factors such as formulation details and “external” factors such as the substrate preparation, location effects, industrial exposure and weather.

Paint systems require to withstand severe exposure conditions have to possess the highest durability. Polyurethane, vinyl, chlorinated rubber or epoxide resins must be used when cost considerations dictate a long maintenance free service.

The durability of alkyd paints is not considered to be of a high order but improved performance is achieved through extra film thickness.

Paint systems for milder exposure conditions are typically alkyds, emulsion resin binders (acrylics) and oleoresinons varnishes for indoor use.

The pigmentation of paints can also be adversely affected by pollutants, ultramarine blue is stable to alkalis but sensitive to acids. Prussian blue is stable to acids but unstable in the presence of an alkali. The chemical resistance of synthetic inorganic pigments is thus variable. Synthetic organic pigments also tend to be variable depending on their chemical composition.

The covering powers of paint vary with the purosity of the surface and type of paint used.

The covering areas of primers vary between 5-15 m^2 per litre. Undercoats and finishing coats from 12 m^2 for non drip to 14-15 m^2 per litre for conventional types.

Health Aspects

Paints, resins and adhesives contain formaldehyde which together with isocyanates are a powerful allergen as well as a probable carcinogen.

Epoxy compounds can cause central nervous system depressions. Vapours from these compounds cause severe irritation to eyes, skin and respiratory system.

Di-isocyanates found in two pack polyurethane products are also powerful allergens especially toluene substances.

A combination of two relatively harmless chemicals may produce a more toxic compound such as epoxy resin dilutant styrene.

Sealing and waterproofing compounds, adhesives and paints often contain organic solvents such as xylene, turpentine toluene and thinners which causes headaches, drowsiness or dizziness. Dermatitis may also result from skin contact.

Manufacturers instructions for use or storage should be carefully followed. A water based paint may be a safer substitute for one containing organic solvents.

What Can Go Wrong With Paint

Lifting and flaking occurs if applied over a powdery or damp surface. Crazing is caused when previous coat was not allowed to dry before the next application.

Blistering is an indication of trapped damp or resin beneath the paint film. **Cratering** results from rain or condensation droplets on wet paint. **Wrinkling or shrivelling** on horizontal surfaces is due to too thickly applied coating.

Running, sagging or curtaining on vertical surfaces is also due to paint applied too thickly.

Remedial action requires the removal of the paint and work redone.

Waterproof Membranes

The problem of securing a water tight structure unfortunately embraces most of the field of concrete engineering, including characteristics such as cement content, water, type and grading of aggregate, the control of construction procedures, (i.e. quality control), such as mixing, handling, compaction and curing, together with the avoidance of structural defects and knowledge of the local environmental effects producing degradation.

Permeability is attributed to the presence of voids such as gel and capillary pores in the cement paste, aggregate pores, channels and cavities caused by bleeding, voids due to poor compaction, expansion or shrinkage and cracks or discontinuities in the concrete structure.

Environmental factors such as temperature change, wind, wet-dry cycling or ground movement cause surface cracking, particularly in flat concrete slabs. Not only in the appearance of the structure affected, but cracks provide the ingress of water, chlorides, acidity and carbon dioxide from sources of industrial pollution. The inherent alkalinity of the concrete is reduced leading to corrosion.

Where ponding of rainwater is permitted on flat or low profile concrete roofs, the problem of leakage or corrosion is compounded and various waterproofing systems must be employed. Given the choice, however, the concept of flat roof construction in our climate and conditions is best rejected since it has already caused enormous difficulties in the maintenance of our building stock.

SURFACE TREATMENT PRODUCTS OR MEMBRANES

Penetrants

Penetrants are generally low viscosity liquids which penetrate the hardened concrete and line the pores. The majority of commercially available penetrants are based on either silane, siloxane or silicone resins which are hydrophobic and thus repel water which not only causes corrosion but enhance the acidic attack of chloride and acid gases.

These resins do not block the pores of the concrete and so allow the evacuation of potentially harmful elements such as water vapour and other gases which may otherwise remain trapped.

Sealers and Coatings

Sealers rank between penetrants and coatings and block the pores of the concrete substrate. They are more viscous than penetrants and generally form a film on the surface of the concrete. Silicates, silica fluorides and linseed oils are used but their effectiveness as a barrier against environmental attack is very limited.

Coatings are still more viscous than sealers and provide protection by forming a relatively thick film on the surface. They generally consist of a binder, pigments, fillers and a carrier. The binder is a polymer which can be of various types and which dictates the major properties of the system including anti-carbonation of resistance and flexibility.

A degree of flexibility is essential to ensure that carbonation does not occur in areas of the structure which are subject to movement or crack formation. Polymer types such as, chlorinated rubbers, urethanes, epoxies and acrylics are used frequently.

Chlorinated rubber coatings suffer from poor UV resistance and dirt shredding properties.

Polyurethanes have limited "breatheability" and are sensitive to water. Epoxies tend to chalk and yellow and have limited "breatheability" and flexibility.

Acrylic and meth acrylic resins, while popular, need to be pigmented and although they show good durability, inevitably demonstrate a lack of cured film flexibility in this climate and environment.

Flat Roof Membranes

Traditional waterproofing membranes create a resilient and solid envelope over the entire roof surface. Water penetration is prevented by careful detailing around projections, joints and gutters and special attention to seams, fixing pins, overlaps and welds. Water vapour is allowed to escape.

Membranes range from unreinforced acrylics to polyurethane increasing in sophistication to high tech polyester reinforced PVC's.

Synthetic rubber based products - EPDM (ethylene propylene diene monomer membranes) are also available from major rubber producers. Butynol membranes (isobutylene, isoprene combines with low temperature petroleum gases) are also available.

Torch-on membranes (reinforced polymer/polyester AP modified bituminous) known as APP - atactic polypropylene products, are widely available at the lower end of the market, although successive layers of waterproofing can be built up and top layer protected with impregnated sand or slate chips.

Generally, the **more expensive systems** will last longest and owners seeking a maintenance free product should consider the initial cost against future liabilities, inflation and performance in use over 10 to 15 years or more.

From an assessment of basic material properties, it is widely accepted that, in most applications, PVC performs longer and better than bituminous or rubber based products. Some formulations (**monomers**) may be subject to plasticiser loss due to UV or oils. **Acrylic type** membranes (reinforced or unreinforced) have a limited life as they are susceptible to cracking and blistering in critical locations such as folds and turn-ups.

Polyurethane based membranes are more resilient to building movement and temperature variations but can be difficult to apply.

The concept of a warranty on products and/or workmanship is a healthy development within the industry. Care should be taken to determine whether the system will be completely replaced if failure occurs, or whether financial cover is reduced over the life of the membrane.

Only those manufacturers who have complete faith in their system and applicators offer a comprehensive cover including labour and materials. Some systems may underwrite cover from an independent insurance company. All these warranty schemes should be carefully reviewed before a decision is made.

APPENDIX II

PAINT AND ENVIRONMENTAL HEALTH OF SCHOOL CHILDREN

[Mackay, J, 1995]

Issues: lead, Isocyanates, solvents (VOC's), off-gassing

Presumably all lead-based paints have been removed from all schools, and none are used at present. [81] [Red pigment lead paint has previously been employed as a rust inhibitor]. Given the tendency over the past 50 years to apply lead based paints to industrial structures and infrastructure such as bridges, a thorough evaluation of areas surrounding schools should also be conducted, to determine whether or not neighbourhood influences could be playing an insidious role in lead inhalation. We know that lead-poisoning leads to behavioural disruptive episodes in children.

Isocyanates are used to manufacture prepolymers, used in turn in paint manufacture, specifically in polyurethane coatings. Respiratory, eye and skin problems are known to follow exposure to isocyanate-containing vapours. Presumably once dry and stable there is no off-gassing. However, if such surfaces are disrupted (weather-affected, scratched, decay) a potential problem might exist. Isocynante-free technology is now available (see, for instance the acrylic coatings used on the Olympic stadiums).

Volatile Organic Compounds (VOC's) are hydrocarbons contained in the solvents in paints. In Europe and the USA the paint industry is being targeted as a key area for legislative attention regarding VOC's. These volatile substances contained in solvents evaporate into the air and are then oxidised by photodegradation. On a larger scale, VOC's in car exhaust fumes interact with

---

[81] Any tendency or policy to keep windows closed where schools are located in dense traffic zones, in order to reduce the amount of air-borne lead inhaled by students, would have an indirect impact on light quality inside schools. Daylight attenuated by transmission through glass is inadequate psychobiologically.

the UV in sunlight and nitrogen oxides to generate photochemical smog (actually low level ozone or O_3). VOC's are thought to cause asthma and irritation of the eyes.

Suggestions:

- It should be a standard policy to leave freshly painted schools to stand before occupation. This allows a large percentage of the solvents to evaporate, which, although detrimental to the environment (in terms of smog, acidification of rain and waterways, ozone depletion (due to chlorinated solvents) and global warming (solvents trap heat)) at least protects children and teachers from the off-gassing of these toxins. In some places, buildings are 'baked' to accelerate the off-gassing of such toxins.

- Water-based paints do not contain solvents. They should be employed as a matter of policy, albeit that such a procedure would necessitate more frequent maintenance and implicate a shorter life-cycle - hence more costs.

    - [Dust-mite concentrations in housing, particularly in carpeting and bedding (and also soft furnishings, and curtaining, linen etc) have been conclusively associated with asthma episodes. Carpets in schools should be re-evaluated. The tendency to soften hard surfaces with carpeting might not be advisable. Wooden flooring might be superior (treated with Isocynante-free polyurethane)].

A further consideration relates to the degree of reflected diffuse light *ie* from the sky, which is required for adequate illumination, and the contribution which a light coloured, wooden floor can made in this regard - a light floor having a reflection value of between 30 and 40%.

APPENDIX III

REDUCTION OF POTENTIAL AND FOR GRAFFITI AND VANDALISM

Crime Prevention Through Environmental Design (CPTED) literature suggests that where environments are carefully designed to reflect community values, are well maintained and beautified, and where local ‘stakeholders’ (in this case school children) are invited to participate in the design and decoration of common property, a sense of care and defensibility is likely to be enhanced. This translates as a tendency to protect rather than deface or abuse this property *ie* enhances proprietary attitudes. It is suggested here as a viable anti-vandal and anti-graffiti technique. Anti-graffiti paint can also be applied to the exterior of buildings - a form of target hardening (see Samuels, 1995 and Samuels, forthcoming).