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THE COLORED RADIANCE - A NEW THERAPEUTICAL ARM

The whole approach of the Chinese tradition has been redefined from hypothesis that appeared us logical and roughly in accordance with most Old texts. These hypothesis could have been transcribed into a mathematical trigrammatical scheme.

We found thus six colors that in the texts corresponded to "the fondamental (main) energies of the tradition.

For the Chinese, the cold -, heat -, humidity -, and dryness climates correspond to energies that exist not only at the surrounding world level, but also et our body level.
Whatever they may be in excess or insufficient in our body, they create pathologies. These energies can neutralize themselves. Cold neutralizes heat and invertedly dryness neutralizes humidity.
All these notions seem to be far away from the western medicine. Have they a real and possible therapeutical application ?

The use of light rays in medicine seems to answer favorably to this question. Our trigrammatical calculations lead us to consider that the Red had an anti-cold power by demanding heat, the Orange an anti-heat power by demanding cold, the Green an anti-humidity power by demanding dryness, and the Blue an anti-dryness power by demanding humidity.
Let us take clinical example : a foot with chilblains following a too long presence in the cold environment.
Considering that it is the cold penetration that is responsible for the pathology, we expose it during a precise time at a red ray. The painful manifestations disappear in the following 20 minutes. Three days later, the foot starts to peel off and the recovery is complete.
It seems that the red lead to a heat energy that has neutralized the current cold excess in organism.

Other clinical example : the one of a woman who recived the content of astew full with boiling water on the arm.
Considering that it is the heat penetration that is responsible for the pathology, we expose the blowed area by orange, what implies the pain relief in the following 30 minutes. The third day, a small skin desquamation can be seen. All traces of burn have disappeared.
The orange seems to have well neutralized the heat excess by demanidng locally a cold energy.

A third clinical example : the one of a man working all day long, feets in water. These ones are white, inflated, perspiring excessively with a desagreable flavour. Considering that the pathology was due to a penetration of humidity, we expose the feet to a green ray. In the twenty following minutes, the feet have recovered a normal coloration and the perpirement has stopped.
The green seems tp have well appealed the dryness energy that has neutralized the excess of humidity at the organism level.

These clinical exmaples semm to confirm the existence of the energies of the Chinese tradition. Starting from this probability, we have searched pathologies that can be defined with these criteria.

We have also determined pathologies such as heat that have the particularity of giving to the patient an impression of heat or burn (These elements are not always objectived by the exams) some pains (articularIinflammatory). increased by the movement.

But we can go further in the definition of the pathology type heat. Bacterial diseases or viral disease can be treated by orange. Abscess get thinner and disappear in one night. Zona are relieved and cured in a few hours by the local use of the coloured light.

Samely, pathologies type cold, dryness or humidity can be determined.

As the diagnosis is correct, the therapeutical results seem us good for the following reasons :

1 - The quickness of the answer to the treatment is often higher than the one of the classical chimiotherapy.
2 - The continuance on a long time of the positive obtained results.
3 - The minimum second effect in 15% of cases.
4 - The possibilities of substitution or association with the classical chimiotherapy.
5 - The therapeutical effects in the fields where it is the sole that can act efficiently. (-for example some viral diseases such as zona, but also sequelae of old traumatisms, such as brain traumatism, etc ...)
6 - The material is extremely simple, thus it only needs a lamp, an optical fibre and filters.

An association called C.E.R.E.C., i.e. Center of Study and Research for Chromatotherapy and Colour has been created to transmit to doctors these therapeutical principles.
A questionnaire has been fullfilled by about fourty doctors who have treated by this method three tousands hundred twenty four (3124) patients.
All these doctors recognise that the coloured luminous rays have a positive therapeutcal effect.

Currently the rhumatology is the specialty that react the best to the chromatotherapy (44,8%) followed by the traumatology (34,48%)
65,5% of the doctors consider that the obtained results are very good and 34% find them good.

The use of colored rays for therapeutical views open a "new" research field on the energetic medecines, that are old of several centuries.

The medecines have always been delayed for the application of the most recent scientifical data. Would they be this time in advance ?

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Estimation of the variability in colour appearance using the CIELAB system

Introduction

In a previous work (1) we studied the variability of the appearance of a coloured textile sample when the illuminant D65 was substituted by the illuminant A. The set of colours was obtained from the most used colorants of each hue; because we are concerned in studying the colours that are most employed although they are not uniformly distributed in the chromaticity space.

In the present work, we use the CIELAB system, which is perceptively more uniform than the CIE 1931 system, to test if the results improve working in this system. The intervals of λ_D (dominant wavelength) or lightness that we establish to divide the chromaticity space, are different according to the system used; and therefore the set of colours that they enclose will be different too. Likewise, in this study, we employ coloured samples obtained not only from one colorant, but also from mixtures of colorants; something very usual in the industry.

Finally, on the basis of the results obtained, we attempt an equation relating the variability in the appearance of a colour when the illuminant is changed with different parametres. To do this we calculated different multifactorial regressions for the different set of colours enclosed in each interval of the chromaticity system (CIE 1931 or CIELAB). We will discuss the validity of the results in each case.

Method and results

From 120 colorants, we obtained textile samples of each unmixed colour, as well as a set of samples by subtractive mixing of colours. The primary colours chosen for subtractive mixing were: Red (x=0.48, y=0.34), Yellow (x=0.51, y=0.45) and Blue (x=0.19, y=0.19). The mixtures were made with two or three of these primaries in different ratios. All the samples were measured using a Macbeth 1500/PLUS connected to an IBM PC/XT computer. From the data, the constancy of the colour index (Icc) was calculated as being the addition of the differences between tristimulus values for the illuminants D65 and A.

Table I

Mean values of L and Icc for the samples enclosed in each hue interval of the CIELAB system

Interval of H_D	L	Icc
0º - 90º	56.1	34.8
90º - 180º	54.1	14.1
180º - 270º	43.0	20.6
270º - 360º	33.5	14.7

To present the results, the CIELAB space has been divided in four equal intervals of hue, from 0º to 360º. Table I shows the mean values of L and Icc for each of these intervals. Only unmixed colours are considered in this Table.

Table II shows the results for the mixtures of colour. In this case the colour space has been divided into three intervals of λ_D (dominant wavelength) because in this way we can compare with the three primary colours chosen. Each value of Icc in Table II is the mean over all the samples enclosed in the interval.

Table II

The Icc average for the mixtures of colour enclosed in each interval of dominant wavelength

Interval of λ_D	Icc
400 - 500	28.9
500 - 580	7.0
580 - 675	29.8

On the other hand, as the lightness is a factor which also has an influence on the constancy of colour index, we calculated linear equations relating Icc with λ_D and L. These equations were calculated for both, CIE 1931 and CIELAB systems; since the number of samples enclosed in each interval is different, as mentioned in the introduction. In Tables III and IV, one sees the results of these calculations.

Table III

Equations of multifactorial regression Icc = f(λ_D, L) for different intervals of dominant wavelength CIE 1931 System

$\Delta\lambda_D$	Equation of regression	Coefficient of correlation
400 - 490	$Icc = 10.81 - 0.04\lambda_D + 0.25\ L$	0.87
490 - 530	$Icc = 151.0 - 0.33\lambda_D + 0.63\ L$	0.87
530 - 570	$Icc = 2.24 - 4.0 \cdot 10^{-3}\ \lambda_D + 0.3\ L$	0.80
570 - 675	$Icc = 35.38 - 2.3 \cdot 10^{-3}\ \lambda_D + 3.8\ L$	0.75

Table IV

Equations of multifactorial regression Icc = f (H_D, L) for the different intervals of H_D. Cielab System

ΔH_D	Equation of regression	Coefficient of correlation
0º - 90º	$Icc = 5.85 - 0.04\ H_D + 0.54\ L$	0.95
90º - 180º	$Icc = -19.48 - 2.5 \cdot 10^{-3}\ H_D + 0.63\ L$	0.88
180º - 270º	$Icc = -106.0 + 0.24\ H_D + 1.76\ L$	0.95
270º - 360º	$Icc = 18.87 - 0.087\ H_D + 0.66\ L$	0.92

Discussion

According to Table I, the colours enclosed in the interval 0º - 90º, that is, the colours red and yellow, present the greatest variation of colour when the illuminant changes. Moreover, they usually have a high lightness, and this factor conduces to a high Icc. Therefore, in this respect, the results in he CIELAB system are in agreement with those obtained in the CIE 1931. In another respect, we ıave observed that the highest Icc is obtained for colours with a high value and chroma; and the Icc lecreases as does the chroma and the value.

The colours obtained by mixing present an index, Icc, lower than that of unmixed colours. The blue primary utilized has an Icc of about 38, while the blue colours obtained by mixing have an Icc average of 28.9 (as seen in Table II). The Icc for the yellow primary colour is 33, and 7 for yellow mixed colours. And the index for the primary colour red changes from 40 to 29.8 (the mean value of all the red colours obtained by mixing). That means that the variation in the appearance of colour is smaller for mixtures than for primary colours. This fact could be explained by considering that the chroma and the value are lower in mixtures than in unmixed primary colours and so produce a decrement in the Icc.

Tables III and IV show a good correlation between the Icc and the parametres hue and value. In general, the results are very similar for the CIE 1931 and CIELAB systems, as is to be expected working with the same data. Notwithstanding, the correlation is better using the CIELAB system, since the correlation coefficient is higher than 0.9 in almost all the intervals.

Here we must recall that these equations are deduced from data obtained from textile samples and with certain colorants. Therefore, its application has a practical character and it is limited to a particular case. Nevertheless, we have tested, with satisfactory results, the validity of these equations for data obtained from colorants different to those employed in this work; this verifies the fact that the equations are useful at least for textile samples.

Finally, we must point out that it is easy to obtain the value of Icc from the equations in Table IV, since there are tables which provide the value of Hd with adequate precision (Plaza 7), and the lightness of a sample can be obtained approximately with a photometre. Obviously, this value of Icc will be approximate but, in many cases, it might be sufficient and it avoids the use of expensive apparatus. This method has been verified with good results.

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PHYSIOLICAL EFFECTS OF COLOR ON NORMAL HUMANS.

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Color has become increasingly important as a design element in the human environment. Earlier in this century, color choice was primarily based on preference, habit or cultural bias. However, during the past twenty years, it has become apparent that color can be used as a powerful contributor to man's well-being (1, 2).

It has been well established that specific wavelengths of light entering the eyes can regulate biological rhythms (3), metabolism (4), and hormones (5) in both animals and humans (6, 7). These biological effects are modulated by a neural pathway which originates in the retina. However, unlike the visual system, this pathway projects from the retina into the suprachiasmatic nucleus (SCN) of the hypothalamus. This part of the brain (the SCN) in turn projects to a variety of nonvisual control centers in the brain and appears to be responsible for controlling many of the biological effects of different wavelengths of light.

There is a diverse literature on the physics and measurement of color. Some of this literature is very suggestive that color has an effect on mood, behavior and emotion in humans. A study on the physiological effects of color is currently in progress at Thomas Jefferson University. This Univeristy is an independent academic-medical center dedicated to educating health care professionals and conducting biomedical research. The project is being conducted within a fully equipped sleep laboratory by members of the departments of Neurology and Psychiatry.

The primary aim of this research is to measure changes in heart rate, respiration, blood pressure, blood oxygen, electrical skin potentials, muscle tension and body temperature relative to specifically defined color stimuli. These physiological parameters are measured objectively with surface electrodes and transducers attatched to physiographic recording equipment and data storage computers.

The color stimuli are produced by a monochromatic light system composed of a xenon arc lamp with a grating monochromator and collimated optic system. The color stimuli are measured by a scanning spectrophotometer for spectral distribution curves. In addition, radiometric, photometric, and chromaticity measures are taken of the stimuli immediately before and after each test session.

More than one set of subjects will be studied with this methodology. Selection criteria will be rigorous for each subject group studied. Specifically, all subjects will be in good physical and mental health, have normal color vision, normal visual acuity, and be free of drugs or prescribed medication. Subjects will be grouped according to variables such as sex, age, educational and cultural background, and psychological profiles. It is anticipated that the strict selection and subgrouping of subjects will result in data that is more reliable and usable by the design community for the optimum provision of color in human environments. Additionally, this study may yield further information on how the nervous sytem processes environmental stimuli.

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RÉALISATION D'ÉCHANTILLONAGES CHROMATIQUES À L'AIDE DE LA MODULATION THETA.

INTRODUCTION

La vision des couleurs étant caractérisée par une grande quantité de paramétres, elle ne peut pas être étudiée à l'aide d'un seul test. Selon le paramètre que l'on désire évaluer il est nécessaire d'utiliser des techniques expérimentales adaptées: anomaloscopes, colorimètres, test pseudo-isochromatiques,...(1).

Une technique permettant de manipuler, d'une façon simple, le plus grand nombre de paramètres photomètriques et chromatiques aiderait à résoudre ce problème Parmi les différentes possibilités, nous avous étudié l'application de la modulation theta et des systèmes achromatiques pour la réalisation d'un échantillonage chromatique.

MÉTHODE EXPÉRIMENTALE

La technique de modulation theta est bien connue depuis quelque temps (2). Il s'agit d'introduire des réseaux aux orientations diverses dans les différentes parties de l'objet. La figure de diffraction de Fraunhofer correspondante à chacun des réseaux apparaît dans la direction perpendiculaire à celle du réseau. Cette rédistribution spatiale permet de manipuler chaque partie de l'objet de façon indépendente. Les ordres de diffraction peuvent être considérés des sources ponctuelles de lumière dont le poids dépend de la transmittance du réseau. L'introduction de filtres colorés sur les différents ordres conduit à une image dont les coordonnées chromatiques peuvent être calculées.

Dans les dispositifs classiques, l'usage de sources polychromatiques conduit à un brouillage des figures de diffraction dû à la dépendence de la diffraction avec la longueur d'onde. L'utilisation de systèmes achromatiques évite cet inconvénient. Nous avous utilisé un de ces systèmes (3) constitué par une combinaison de lentilles de phase de Fresnel (4) et d'objectifs achromatiques.

Le test à employer est obtenu, après filtrage, à partir de l'objet montré dans la figure 1. La luminance et les coordonnées de chacune des plages sont déterminées par le filtrage réalisé. Avec des réseaux de phase de fréquence élevée le filtrage peut être réalisé aisement et la présence des traits dans l'image ne perturbe pas la vision du test.

L'image d'un réseau de transmittance t, éclairé par une source de distribution spectrale E_λ, et traité avec les filtres j=1,2,3 de transmittance τ_j, a les suivantes coordonnées chromatiques:

$$x_i = \frac{\sum_j x_{ij} C_j}{\sum_j C_j} \qquad (i=x,y,z); \qquad C_j = P_j \tau_j E_j \sum_j \bar{x}_{ij}$$

$$Y = \sum_j Y_j = \sum_j P_j \tau_j E_j \bar{x}_{2j}$$

Où $P_j = \sum_k P_k$ et P_k est le poids des différents ordres de diffraction filtrés par j.

La condition $\tau_j E_j x_{2j}$ = cte assure la même luminance pour tous les échantillons.

RÉSULTATS

Nous présentous deux exemples d'application inmédiate qui montrent quelques possibilités du système décrit.

La figure 2 montre un ensemble de droites qui convèrgent au centre de confusion des protanopes. Ces droites ont été obtenues avec le système décrit auparavant. En conséquence il est possible d'obtenir dans champ bipartite un test de confusion pour ce type de dichromates. Egalement ou pourrait obténir un test du même type pour les tritanopes.

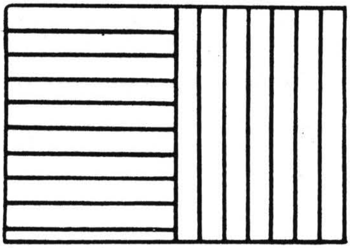

Figure 1. Objet theta-modulé. Les deux réseaux ont la même transmittance.

L'autre exemple est montré dans la figure 3. Les points représentés se situent autour de la courbe d'egale pureté d'excitation p_e = 0,25 avec une tolérance de 0,04. La valeur de la tolérance détermine le nombre de points obtenus. Ce type d'échantillonage peut être utilisé pour l'évaluation des seuils de tone pour des différents niveaux de pureté.

La combinaison de filtres pour obtenir un échantillon déterminé est calculée, à l'avance, à l'ordinateur. Pour cela le software necessaire a été développé.

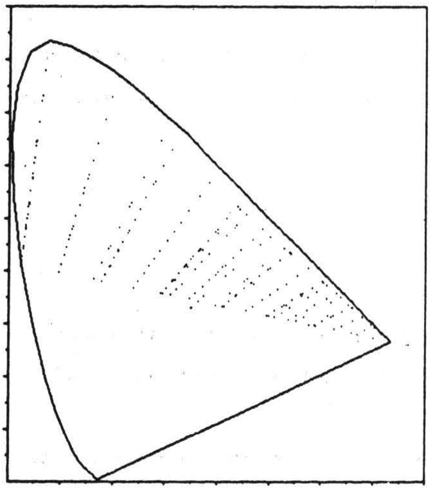

Figure 2.

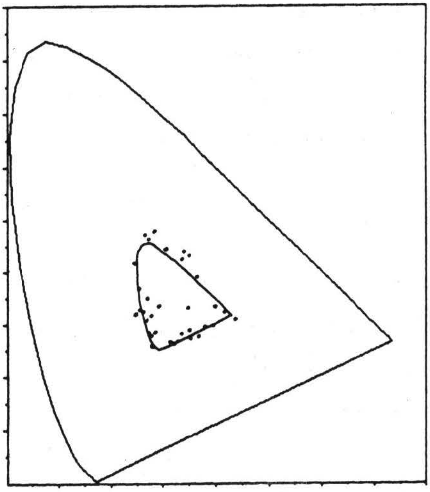

Figure 3.

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THE OBSERVED APPEARANCE OF SURFACE COLOURS UNDER A RANGE OF ARTIFICIAL LIGHT SOURCES

INTRODUCTION

The term Colour Appearance Analysis is used in the context of Illumination to describe the study of the colour of illuminated objects and the extent to which their colour appearance changes when the source of illumination is changed. It is thus intended to be used to provide a fundamental measure of the colour rendering properties of different lamps. Other applications for Colour Appearance Analysis are the assessment of Colour Reproduction Systems, Illumination for Colour Reproduction, and Chromatic Adaptation (Pointer 1983).

With regard to the colour rendering capabilities of light sources, it can be argued that the CIE Colour Rendering Index is a somewhat artificial measure, and that what is really required is an overall "average" assessment of the appearance of a number of test colour samples under the test lamp as compared with the appearance of those same samples in some defined, and realisable, reference situation. To a large extent, what the lighting engineer is interested in is the effect of different light sources on colour constancy. In other words, how constant is the colour appearance of the test samples under one light source, compared with their appearance under another? Deviations from colour constancy can be assessed using colour appearance analysis.

The purpose of this paper is thus to describe some recent colour-scaling experiments carried out at the University of Natal with these objectives in view, and to discuss the significance of the results achieved to date.

THE EXPERIMENT

Magnitude estimation techniques were used to provide subjective assessments of the appearance of a range of test colours, in terms of hue, colourfulness and lightness, in specified viewing conditions (source colour, illuminance level, size of test colour, surround conditions, etc.). The Appendix contains the set of instructions issued to observers for their guidance in scaling the hue, colourfulness and lightness of the test colour samples. It will be noted that a reference blue sample was provided to assist each observer with the estimation of colourfulness.

Three sets of test colours were employed. Set No.1 contains 28 samples in a variety of hues, at different degrees of colourfulness, but all at approximately the same level of lightness. Set No.2 contains a further 28 samples varying in lightness as well as in hue and colourfulness. Set No.3 contains the 14 CIE test colours as used in the present method of specifying the colour rendering index (CIE 1974).

In the colour scaling work being carried out at the University of Natal, all three sets of test colours have been scaled by all the observers (5 to date) under a range of 13 different light sources (Table 1).

It is clear, therefore, that a large volume of colour scaling data has been accumulated; and the statistical analysis of this data is currently in hand. For the present purposes, however, this paper will be confined to the data obtained with sample set No.3 by one of the observers only.

RESULTS

One of the test sources used in the colour scaling experiment was a "Daylight" type fluorescent lamp with a nominal correlated colour temperature of 6500K and a nominal colour rendering index R_a of 75. For convenience, this was chosen as the reference source. The differences in the estimated values of Hue, Colourfulness, and Lightness have been calculated to represent the change in colour appearance of each test colour sample when the illuminating source is changed from the reference lamp to the test lamp. These can be represented by the following equations:

Hue change: $\Delta Hue = Hue)_t - Hue)_r$

Colourfulness change: $\Delta Col = Col)_t - Col)_r$

Lightness Change: $\Delta Lit = Lit)_t - Lit)_r$

where symbols$)_t$ and $)_r$ refer to the observations under the test and reference sources respectively.

Averages of the absolute values of these three quantities for the 14 samples in set No.3 are included in Columns (6), (7) and (8) of Table 1 to show the extent to which these parameters were influenced by the different light sources used in the experiment.

CONCLUSIONS

It would be premature to attempt to attach too much significance to the data presented in Table 1, partly because these results have been derived for only 14 test colours, and also because they represent the findings of only one observer. There is, however, some evidence of a correlation of increases in ΔHue with decreasing values of R_a for the light source. The distributions of ΔCol and ΔLit, however, appear to be of a more random nature. Changes in illuminance level have not been properly investigated at this stage, and it is not clear whether illuminance had any influence on the present set of data. It is intended that further data, with more detailed statistical analyses, will be provided in the presentation of this paper.

ACKNOWLEDGEMENTS

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APPENDIX

Hue Scaling: Any colour can be defined in terms of two of the psychological primaries : red, yellow, green and blue. These four colours can be represented as points on a hue circle. Hues lying at opposite ends of a diameter of the circle cannot be, experienced simultaneously. You are asked to name the dominant hue present, and estimate its amount as a percentage, and then estimate the amount of secondary hue present; e.g. an orange may be 60% yellow and 40% red. This would be recorded as 60Y 40R. There are thus 400 subdivisions in the hue circle.

Colourfulness Scaling: You are asked to consider the blue test colour labelled 'colourfulness scaling' and decide on a number which you feel, in the knowledge of your everyday experience of colours, fairly represents its colourfulness. A neutral test colour would have no colourfulness and will be represented by zero on your scale. You are asked to scale all subsequent test colours using a similar scale. This will be an open ended scale since no top limit is set. The blue test colour can be present all the time that you are scaling and you are asked to give it the same number of your scale for all experimental conditions; i.e. every time that you scale colourfulness. Some colours will be more colourful than this test colour and others less colourful.

Lightness Scaling: Any colour has a lightness within the range of black (0) and white (100). You are asked to assign a number between 0 and 100 to the sample, that you feel represents its lightness, e.g. a mid-grey would be 50.

TABLE 1 : OBSERVED CHANGES OF HUE, COLOURFULNESS & LIGHTNESS OF 14 COLOURED SAMPLES UNDER DIFFERENT LIGHT SOURCES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TEST NO.	TEST SOURCE DESCRIPTION	NOMINAL COLOUR PROPERTIES		ILLUMINANCE (LUX)	AVE $\|\Delta HUE\|$	AVE $\|\Delta COL\|$	AVE $\|\Delta LIT\|$
		R_a	T_c				
	Fluorescent Lamps:						
1.	Daylight (Ref.Repeat)	75	6500	700	7.1	5.4	9.3
4.	Warm White	52	2900	500	12.5	2.5	4.3
5.	Warm White (Repeat)	52	2900	1000	16.1	2.5	1.8
10.	White (Med. Eff.)	75	4000	500	10.4	3.2	2.9
2.	White (High Eff.)	66	4100	900	7.9	5.4	11.4
3.	White (Hi Eff. Rpt)	66	4100	450	9.3	3.6	4.6
6.	CW Triphosphor	85	4100	700	8.6	1.8	5.0
7.	CW Triphosphor (Rpt 1)	85	4100	500	10.0	2.1	2.1
13.	CW Triphosphor (Rpt 2)	85	4100	1000	10.7	5.0	2.9
	Incandescent Lamp:						
11.	GLS	100	2800	600	8.9	3.2	3.6
	Gas-Discharge Lamps:						
9.	Coated Metal-Halide	68	4000	500	12.1	3.9	3.2
14.	Tubular Metal Halide	68	4000	500	5.0	1.8	3.6
15.	Mercury (Type 1)	45	4000	400	11.4	4.6	3.2
17.	Mercury (Type 2)	45	4000	450	11.4	2.9	4.6
12.	Mercury Deluxe	52	3800	500	14.6	3.6	2.9
8.	H.P. Sodium (Type 1)	25	2000	650	21.4	5.3	5.0
16.	H.P. Sodium (Type 2)	25	2000	750	13.4	4.6	3.2

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A TELEVISION ILLUMINANT CONSISTENCY FIELD TRIAL EMPLOYING SUMMER DAYLIGHT AS THE REFERENCE SOURCE

INTRODUCTION

The CIE Technical Committee 1-11 on Illumination for Colour Reproduction has recommended the adoption of a Consistency Index (Taylor 1988) that is intended to be used to classify the colour properties of electric lamps for television lighting.

To the authors' knowledge, there have, to date, been three field trials of television illuminant consistency, one in South Africa (Chalmers & Holmes 1981) and two in the United Kingdom (Taylor & White 1987) in all three of which the reference illuminant (used in the assessment of colour consistency) was the incandescent tungsten-halogen lamp, chosen on account of its widespread use in television studio lighting.

The other light source widely regarded as a working standard among television engineers is natural daylight; and it is, of course, widely used in the context of outside broadcasts. There is thus an interest in ascertaining the consistency of various light sources relative to natural daylight (as opposed to filtered sources or gas discharge lamps which may be capable of simulating daylight chromaticities but not their spectral distributions). The present experiment has therefore been designed as an attempt to provide this knowledge.

THE EXPERIMENT

It was decided to investigate the television colour consistency of eight different types of electric lamps using natural summer daylight as the reference illuminant. The spectrum of daylight at Durban has been measured in an earlier experiment (Kok and Chalmers 1978) and it is thus known that, at the time that the consistency experiment was performed (near mid-day on a clear day in late spring), there would have been an air mass close to unity, giving a known global spectral power distribution with a colour temperature of approximately 5800 K.

A test scene was constructed using furnishings and backgrounds of medium tones and low saturation, but including some splashes of highly saturated colour in the form of flowers as the centre piece on a table. Two human subjects were included in the scene, seated one on either side of the table. The one was a fair-haired female wearing a uniformly-coloured pink dress, and the other a dark-complexioned male wearing blue trousers and a multicoloured shirt.

Video recordings of the test scene were first made under daylight and then after dark, without repositioning, under each of the other test sources in turn. A single camera was used throughout and its colour balance was realigned so as to yield a neutral grey scale with each test source. An evaluation tape was subsequently produced, in which the test pictures (taken under each of the test illuminants) are presented alongside the reference picture (taken under daylight) using a vertical split-screen effect. One of the scenes includes a "test" picture taken under daylight, as a measure of the consistency of the observers, who are asked to rate the test pictures in terms of colour consistency as judged against the reference picture.

The ten test scenes were edited into two random sequences which are presented as a series of twenty (supposedly different) test scenes for evaluation purposes.

This test tape of twenty scenes has, to date, been evaluated by 55 observers, representing a random sample of the television-viewing population. They had been invited primarily to express an opinion on the programme content of a proposed new television series, after which they were also asked to take part in the television consistency evaluation.

Each observer was expected to rate, on a scale from 1 to 5, the extent of the difference perceived in the colour of each test picture as against the reference picture (1 = no difference; .... 5 = extremely different) and a statistical analysis of their responses has been carried out.

RESULTS

The arithmetic mean of the numerical responses of the 55 observers was calculated for each test scene. This number has been multiplied by 100 to yield the rating for that scene (Rating 1 and Rating 2 in Table 1). The ratings obtained by each test source in the first and second cycles of test scenes were averaged to yield the Average Rating, also given in Table 1.

CONCLUSIONS

(i) There is a remarkable degree of consistency in the 1st, 2nd and Average data sets, both in terms of the numerical ratings, and in the rank order within each set.

(ii) The order of presentation of the test scenes does not appear to have had a noticeable effect on the ratings, except perhaps in the case of the Metal Halide (type 2) source which appears to have an unexpectedly low value for Rating 2 (scene 19) when it was presented between the two High Pressure Sodium scenes (18 and 20).

(iii) The observers evidently found Tungsten-Halogen and 3-band Fluorescent Lighting to give "more consistent" television colours than Daylight itself. The only simple explanation for this effect would appear to be some form of observer inconsistency.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of the SABC in Durban, in particular Mr Jack Downie of TV Outside Broadcasts, for their contribution to the production of the colour consistency video tape, and the staff of the SABC and HSRC in Johannesburg for the collection of the subjective data from the viewer panel. We also wish to express our gratitude to our on-screen subjects, Miss Cherine Cridick and Mr Premlal Ramnarain, for their patient cooperation, and to the University Research Committee of the University of Natal for their financial assistance.

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TABLE 1 : TELEVISION CONSISTENCY OF VARIOUS LIGHT SOURCES, WITH REFERENCE TO DAYLIGHT (LOWER RATING = HIGHER CONSISTENCY)

TEST SOURCE DESCRIPTION	1ST SCENE CYCLE			2ND SCENE CYCLE			OVERALL	
	SCENE NO.	RATING 1	RANK ORDER	SCENE NO.	RATING 2	RANK ORDER	AVE RATING	RANK ORDER
Tungsten-Halogen	5	211	1	14	189	1	200	1
Fluorescent (3-band)	10	224	2	15	213	2	219	2
Daylight	1	225	3	16	238	4	232	3
Metal Halide (Type 1)	7	234	4	11	238	4	236	4
Metal Halide (Type 2)	8	247	5	19	233	3	240	5
Fluorescent (Halophos.)	9	248	6	12	262	6	255	6
Metal Halide (Type 3)	4	249	7	17	291	7	270	7
Mercury Vapour (Col.Cor.)	2	300	8	13	331	8	316	8
High Pressure Sodium: (a) Operational Line-up	6	372	9	18	416	10	394	9
(b) Technical Line-up	3	375	10	20	415	9	395	10

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THE INFLUENCE OF SPECKLE CHROMATICITY ON FLICKER SENSITIVITY

INTRODUCTION

When a diffusser test is illuminated with coherent radiation its aspect is degraded by the presence of the speckle, that appears independently from the wavelength used just as long has the radiation is coherent. As we know the numerous advantages that come from the use of coherent illumination, it is important to know how the speckle of that light affects the Temporal Modulation Transfer Function (TMTF) of the visual sistem.

Our purpose in this experiment is to study about the influence that the TMTF of the human visual system has on the speckle size and its variation with the chromaticity of the stimulus.

METHOD

The experimental device and the method used for measuring flicker sensitivity can be found in previous studies[1,2]. The light source was or a Spectra Physics 25 mw He-Ne laser that provide us a red radiation of 632.8 nm and $\Delta\tau = 4.3 \times 10^{-3}$ nm bandwidth or a Spectra Physics 2 w Argon laser of which we chose the corresponding lines in green 514.5 nm ($\Delta\tau = 5.3 \times 10^{-3}$ nm) or in blue 488.0 nm ($\Delta\tau = 4.3 \times 10^{-3}$ nm). Light from the source goes through optical system with two channels, S_1 and S_2, which illuminates the same test by means of a beam splitter. Flicker stimulation is achieved by means of a modulator interrupted the beam S_1, made with a black metallic disc with four openings regulary separated of 45° each, that was driven by a motor whose rotation speed is controlled by a monophasic changer. The modulator produced a stimulus wave form that was practically square.

Subjects were two men trained, graduates, ametropics but with corrected vision. Both were "color-normal" as determined by Ishihara test plates (Ishihara, 1972). Head position was held stacionary by means of a head and chin rest. Measurements are carried out with artificial pupil of 3.0, 1.1 and 0.5 mm diameter. The values of the speckle sizes obtained appear in Table I.

Table I : *Variation in retinal speckle size s (μm) as a function of wavelength λ(nm) and the diameter of the artificial pupil d(mm).*

	λ(nm)		
d(mm)	**488.0**	**514.5**	**632.8**
0.5	19.1	20.1	24.8
1.1	9.0	9.5	11.7
3.0	3.3	3.5	4.3

The retinal illumination used was 103 td. All observation were foveal and left monocular.

In each experimental session we determine the sensitivity curve to flicker for one given colour and artificial pupil size obtaining at about 11 different points of the curve.

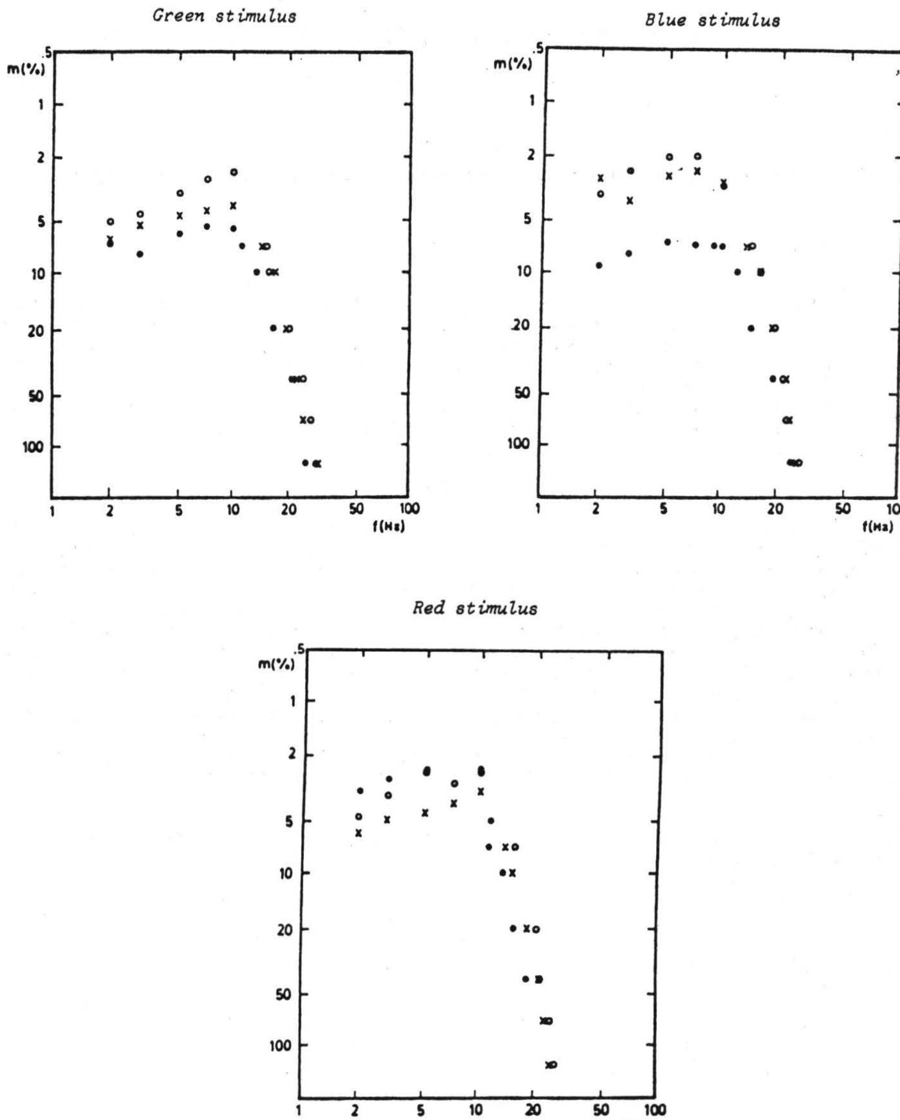

Figure 1: Flicker sensitivity as a function of frequency. Artificial pupil of (o) 3.0 mm; (x) 1.1 mm and (•) 0.5 mm diameter. 103 trolands. Observer J.P.

RESULTS AND DISCUSSION

The results for observer J.P with tests of 1°, monocular and foveal vision, retinal illumination of 103 td, three different chromaticities and pupil size of 3.0, 1.1 and 0.5 mm diameter are ploted in Figure1.

In general, the analysis of the given data reveals that for all two subjects:

In the low frequency regions and with blue and green radiations the flicker sensitivity decrease as the speckle size increase. The same behaviour is obtained for red radiation with the two smaller speckle sizes.

The higher differences between the curves corresponding to the extreme speckle sizes are achieved for blue radiation.

In the high frequency region and for the three radiations the frequencies corresponding to the different modulations increase as the speckle size decreases.

The explanation for this reduction in sensitivity is, at low frequencies, in the presence and size of a speckle which affects the lateral neural inhibition. In accordance with Kelly[3,4] when a low frequency flickering input spreads out through the lateral inhibition networks, as these have their TMTF with cut-off frequencies of a lower range to those on the cones the sensitivity of the system is reduced below that corresponding to the individual cones; however, a high frequencies, Kelly says, that the cones are the ones that limit the response, by now the lateral network cannot follow the inputs.

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GENERAL PURPOSE NON-COMBINATORIAL SOFTWARE FOR COLOR REPRODUCTION

1. Introduction

Computer color matching generally relies on the solution of simultaneous equations to achieve the goal of calculating colorant formulations. This approach leads to the development of combinatorial algorithms in which all possible combinations of colorants are calculated and selected afterwards. Different interesting ideas to formulation systems have been previously discussed [1-3]; they allow to find directly, both the colorants to be used and their concentrations. The purpose of this work is to describe the implementation of these non-combinatorial algorithms into a standard color software package, Linear-Programming Color Software (LPCS), and the results obtained.

2. Software characteristics

The program has been designed in order to allow the user to select the specific industry application: textiles, printing inks, paints, plastics and ceramics, applying one- or two-constant Kubelka-Munk theory with suitable empirical corrections.

Linear-Programming is used to optimize colorant mixtures subjected to preset color-difference tolerances. The same LP algorithm can be used either for color matching or color correction.

Main features of the proposed software package are :

a) The tolerance in CIELAB system for either ΔL, Δa, Δb or ΔE for all illuminants of interest can be established. No exact matching is required a priori under any illuminant.

b) There is no restriction in the number of colorants used in each recipe. If it would be necessary to restrict the number of illuminants, it could be accomplished through the application of Mixed-Integer Programming techniques.

c) The allowance of special user requirements, e.g. infrared spectral reflectance curve matching needed for camouflage coatings.

d) The possibility of inclusion of non-standard constraints derived from color matching under two different standard observers, or including/excluding specular component, simultaneously.

e) The option of calculating a recipe for goniochromatic materials (e.g.:metallized car paints) in such a way so as to match two sets of tristimulus values, obtained from measurements under two different viewing angles.

f) The inclusion of fixed limits on the maximum load for each dye of the whole inventory. Chemical incompatibilities between dyes can also be taken into account.

Numerical tests were made in order to evaluate the behavior of the described software package. Performance criteria are:

a) closeness between the predicted match and the standard

b) formulation cost savings

c) flexibility to find suboptimal recipes according to specific needs

d) speed of calculation

3. Comparison between LPCS and combinatorial based software

Outstanding differences between a typical combinatorial color matching software [4] (CCMS) and LPCS are summarized :

a) CCMS : Up to 15 dyes used for each match.
LPCS : Virtually no limit in the number of dyes.

b) CCMS : Metameric tolerance for three light sources can be specified.
LPCS : There is no distinction between principal and secondary illuminants for which metameric tolerances are preset.

c) CCMS : Negative amounts of dyes might appear in the recipe.
LPCS : Recipes have a priori non-negative amounts of dyes.

d) CCMS : The possibility to search for recipes including two, three or four dyes
LPCS : Suboptimal recipes containing any preset number of dye combinations can be found.

e) CCMS : Calculates and prints all recipes matching the objective within specified tolerances.
LPCS : No need to search all possible combinations in order to determine the best one.

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EINIGE BEISPIELE UEBER DEN WERT DER PSYCHOCHROMOTHERAPIE

Es werden zuerst geklärt einige theoretische Grundfragen der Psychochromologie mit Analyse auf Models von Man und Frau.

Die wichtige Farben der Psychochromotherapie fuer Autiste, Mongoloide und Mental Behinderte Leute werden gezeigt worden.

Weiterhin werden noch Beispiele mit Farben fuer Asthmakranke Leute, noch ueber Farben des Aufenthaltsrämen fuer Taubstummen und fuer Krankenhaus Bekleidung gesprochen worden.

Zum Schluss es wird ein Versuch gemacht worden, ob es an die Psychochromotherapie die moderne Farbmetrik zu nutzen werde.

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The brightness of signal-lights of different colour depending on different surrounding luminances

Introduction

The brightness of a signallight of different colour as seen by a testperson, appears to be depending as well from the luminances, directly surrounding the signallight as from the luminance of the background. The influences of these parameters were investigatet in a downscaled experiment (1:10) in the laboratory and in outdoor experiments in a normal scale (1:1). During these experiments the background luminance and the surrounding luminence were choosen in luminence areas typical for different traffic situations e.g. traffic signs in area of railways, shiptransport and streettraffic.

Investigation

The experiments were made in the laboratory and outdoor for different signalareas with different backgrounds and different surrounding fields. The size of the lightsignal was choosen typical for a pointsource and areasources. As criterion for the raiting of the coloured lightsources the brightness of the signallight and the "impression of colour" was chosen.

Conclusions

The luminances surrounding a signallight influences as well the brightness as the impression of the colour for an observer. For daytime and nighttime observation the changing of the brightness and the colourimpression can be shown from the experiments.

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A practical study of changes in the appearance of colour when the light source is changed

Introduction

The constancy in the appearance of colour when the illuminant changes is very important in industry. The textil industry is, in particular a familiar example in bibliographies about this subject. For a coloured textile sample, the most usual change in illuminant (and so that which has a greater practical importance) arises when daylight (illuminant D65) is substituted by light from an incandescent lamp (illuminant A). Although this change produces different colours for the same object, the effect on the appearance of colour might go unnoticed in most cases.

In other respects, we have remarked that a certain confusion exist in the industrial circle about the terminology in colour subjects. For instance, one uses the term "metameric" for "one" colorant (instead of a pair) when its appearance, on a textile sample, changes noticeably using illuminant D65 or illuminant A. This application of the term "metameric"is not quite correct, however it does indicate the importance of this effect from an industrial point of view.

In the present work, we have employed a wide number of colorants in textile samples. The purpose was to illustrate which of them present a noticeable change when the illuminant is changed; and to study the possible existence of some similar characteristics between them (hue or value).

Method and Results

The chromaticity coordinates x, y, Y and L*, a*, b* of 120 samples, for both illuminants D65 and A, were measured using a Macbeth 1500/Plus connected to an IBM PC/XT computer. To prepare the samples we employed the most usual colorants and a normal colouring method. As the selection of the colorants was conceived following a practical criterion (all the colorants selected are used in industry), the colours present, in general, a moderate chroma and value, and they do not cover all the chromaticity space. In this way, the results of this work will be useful from a practical point of view although it will not necessarily have a general theoretical strength.

From the definition of metameric index, analogously, we define the "constancy of the colour index", Icc, as the addition of the differences between tristimulus values for the illuminants D65 and A. That is:

$$Icc = (X_D - X_A) + (Y_D - Y_A) + (Z_D - Z_A)$$

Thus, a small value of Icc indicates a small change of colour when the illuminant is changed, and vice versa.

The results are shown in Tables I and II. In these tables the samples are distributed within different intervals either of dominant wavelength (I) or of lightness (II). There are a similar number of samples enclosed in each interval.

Table I

λ_D ,dominant wavelength; L, value; Icc constancy of the colour index; $\Gamma_{\lambda,I}$ linear correlation coefficient λ_D-Icc; $\Gamma_{L,I}$ linear correlation coefficient L-Icc.

λ_D(interval)	L (average)	Icc (average)	$\Gamma_{\lambda,I}$	$\Gamma_{L,I}$
400-490	40	18.3	0.13	0.81
490-530	48	12.6	0.38	0.85
530-570	52	15.3	0.40	0.73
570-675	62	36.3	0.42	0.44

Table II

L, value; λ_D , dominant wavelength; Icc, constancy of the colour index; $\Gamma_{\lambda,I}$,linear correlation coefficient λ_D-Icc; $\Gamma_{L,I}$ linear correlation coefficient L-Icc

L interval	λ_D(average)	Icc (average)	$\Gamma_{\lambda,I}$	$\Gamma_{L,I}$
0-40	510	11.8	0.09	0.59
40-60	540	23.8	0.54	0.47
60-90	570	30.0	0.81	0.21

Discussion

From Table I one deduces that the Icc takes a similar value (about 15) for all the intervals of wavelength except for the highest wavelengths, which also have the highest lightness, and where the Icc is twice the value. Therefore the colours yellow and red present a greater variation of colour when illuminant D65 is substituted by illuminant A.

The results on Table II confirm the previous ones. Since the interval of highest lightness has the highest Icc. And the mean wavelength is also highest in this interval.

The concordance between both tables is logical, because for the colorants employed (the most usual) it generally results that the yellow and red have a higher lightness than the colours blue and green.

In conclusion, when the illuminant is changed, we can expect small changes of colour, for colours with a short wavelength, as well as colours with low lightness. And, to the contrary, the colours with a long wavelength and high lightness (these two characteristics coincide, in general, in our samples) will be the least constant.

Notwithstanding, we must take into consideration that the same change in chromaticity coordinates, for two different colours, does not mean an equal or similar change in appearance for these two colours. From MacAdam, we know that a certain change in chromaticity coordinates produce a more noticeable variation in appearance of colour within the blue area of the chromaticity space than elsewhere. This fact might compensate in part for the difference found in the constancy of colour index between long and short wavelengths.

In order to establish some relation between the variation of Icc and the other parametres (dominant wavelength and lightness) we have calculated the linear correlation coefficient between Icc and each of these two parametres. Table I and II show the value of these coefficients for each interval. In Table I all the values are very low. Only for short wavelengths is there a certain correlation between Icc and lightness. In Table II, only the last interval (60-90) which corresponds to high lightness colours, presents a certain correlation between Icc and λ_D. In general, no correlation exists between the Icc and the two parametres considered; except the above mentioned cases which have no significance.

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MONITORING DYSCHROMATOPSIA IN THE POPULATION OF SCHOOL-GOERS IN BOLOGNA (EMILIA), IN CENTRAL ITALY.

Summary

Ischihara pseudo-isochromate plates were administered to 1203 adolescents of both sexes in a school of Bologna, in Central Italy: 653 males and 550 females. The total percentage of dyscromates resulted to be 3,07±0,49% (n.= 37).: 5,66±0,91% for the males and 0% for the females.
The resulting value for the students in Bologna (5,66%) is in line with the percentages presented by KHERUMIAN et al. (1959) for the various European populations (from 4 to 9%).
The analysis for defining the various forms of dyschromatopsia revealed 11 protane subjects (1,68%) and 16 deutane subjects (2,45%).
The questionnaire submitted to the dyscromate subjects revealed, among other things, that a large percentage (70,3%) had no idea of having such defect.

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COLOUR'S THIRD DIMENSION

Although there is a place for every non-fluorescent surface colour in each of the three-dimensional colour order systems in current use, there are more than three dimensions or aspects of a colour's appearance that are of concern to people who work with colour, especially artists and designers. The different structures of the different systems reflect different decisions about what aspects are most important. Underlying these structures, however, is a basic set of relationships which are common to all systems. For example the lattice structure of the OSA UCS system could be deformed and the colours could be realigned according to the principles of some other system. The connecting lines of the lattice might be stretched, compressed or bent in the process but they would not be broken. The relationships are best described by polar co-ordinates. All models have a central axis of the achromatic colours from White through greys to Black. Around this axis is what can be called the "chromatic circuit" a continuous sequence of the most vivid colours that can be produced or imagined in the order of the spectrum with reddish then bluish purples to connect spectral red to spectral violet.

As with a building, the three dimensions of a colour system can be shown in plans and cross sections. In plan the central axis of achromatic colours appears as a point in the middle of the chromatic circuit. Radiating outward from this point are sequences of increasingly vivid colours. A colour's position in relation to the circuit (its hue) is its first dimension and its position between the central axis and the line of the circuit is its second dimension (fig.1)

Fig.1 Plans of a typical colour order system showing the first and second dimensions.

The circuit has been presented in many configurations; there has also been debate about spacing and the status of individual colours as "primary" (fig. 2).

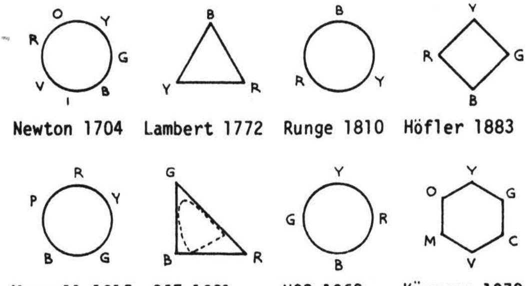


Fig.2 Representative configurations of the chromatic circuit. The sequence (clockwise or counter clockwise) is the same in each case, but different colours in the sequence are variously singled out as primary: Red Orange Yellow Green Cyan Blue Indigo Violet Purple Magenta.

Relationships in the first dimension are variously about colour perception, colour mixing and matching and colour harmony (1). In the second dimension, debate is largely focused on definitions. A word commonly used for this dimension is "saturation", but there is also debate about whether equal increments of saturation should be presented on concentric cylinders or cones (2, 3) (fig.3).

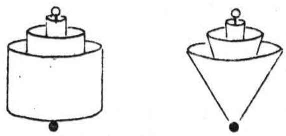
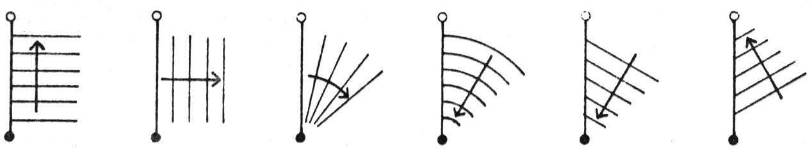


Fig.3 Colours of the same saturation are presented on concentric cylinders in some systems, on concentric cones in others.

The extent of the 3rd dimension is fixed by the achromatic line. The different principles by which systems are constructed are seen clearly in cross sections which show the relationships between the 2nd and 3rd dimensions. In a working draft of ISO TC 187 are definitions proposed for some of the colour variables that can be shown on cross sections. Some of these correspond with the variables embodied in different systems. These variables can be shown simply in relation to the achromatic line (fig.4).



Value: 1 Lightness: 3 5 7 8 (also 4 6)	Chroma: 1 Chromaticness: 6 8 Saturation: 5 7	Saturation: 3 4 8	Darkness degree: 4	Blackness: 2 6	Whiteness: 2 6

1. Munsell, 2. Ostwald, 3. Hesselgren, 4. DIN, 5. ACC, 6. NCS, 7. Coloroid, 8. ISO/TC 187 (draft)

Fig.4 Schematic cross sections showing relationships between the achromatic line and colour variables in the 2nd and 3rd dimensions as embodied in representative systems.

All systems have at least two of these variables and these combine to fix the relationship between the achromatic line and the maximally vivid colours on the chromatic circuit. With scales of blackness and whiteness (or blackness and chromaticness) this relationship is the same for each hue on the circuit. With scales of lightness, the maximally vivid colours are located opposite greys of the same lightness on the achromatic line. These "grey partners" vary from hue to hue (fig. 5)

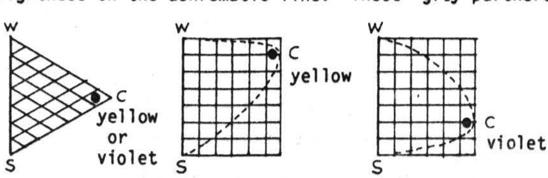


Fig.5 The choice of variables (blackness, lightness etc.) determines whether the relationship between vivid colours and the achromatic line are constant or whether they differ according to hue.

The whiteness-blackness of a colour and its lightness are each significant for artists and designers. Two colours of the same whiteness-blackness look comfortable together in a way that colours of the same lightness-chromaticness do not (4) but for legibility, and for clarity of form and pattern, lightness relationships are crucial (5).

Two systems embody the means to read both kinds of relationship. The NCS is constructed on scales of blackness and chromaticness. In the atlas an auxiliary scale for each hue makes it possible to draw lines to connect colours of equal lightness(fig.6)

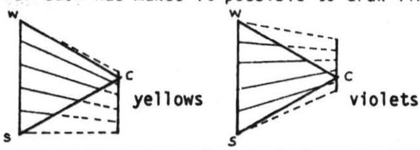


Fig.6 In the NCS atlas auxiliary scales make it possible to draw lines to connect colours of equal lightness.

In the DIN system colours of the same darkness degree and saturation will look comfortable together in the same way as colours of the same whiteness-blackness. The structure is often shown distorted so that colours are brought into position opposite their grey partners and each colour's lightness can be read as well as its darkness degree and saturation (fig. 7).

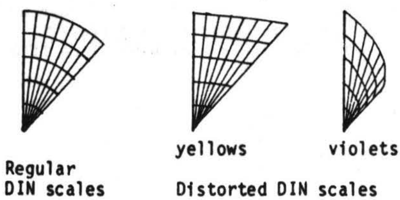


Fig.7 In the DIN system the scales of darkness degree and saturation can be distorted to bring colours into position opposite their grey partners on the achromatic line.

The situation is further complicated by people's different understanding of what is meant by "lightness" and by the common use of another term for describing colour - "brightness" (6). Brightness can be understood as the equivalent of chromaticness or lightness or a combination of both. A combination would be the opposite of darkness degree and might be described better as "brilliance", a term proposed by Evans (7). More serious for students of art and design is that many judge a colour's "lightness" in terms of its whiteness. This can lead to a reversal of the true order of lightness-a pale violet might be judged to be lighter than a vivid yellow (Fig.8). This can lead in turn to designs where forms and patterns are ill defined and lettering is difficult to read.

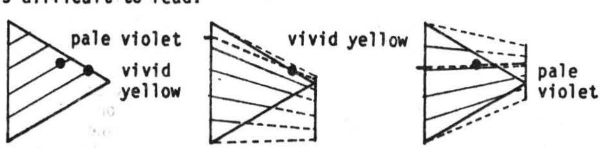


Fig.8 Scales of whiteness and lightness in the NCS triangle show how a pale violet is whiter while vivid yellow is ligher.

For artists and designers, clear understanding of the variables in the 3rd dimension is the way to mastery of colour.

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MEASURING GEOMETRY FOR COLOUR MATCHING BETWEEN GLOSSY AND MAT OBJECTS

INTRODUCTION

There is no simple objective answere to what should be ment by the expression *"same colour but different gloss"*. If one half of a mat colour sample is coated with an colourless film there is no doubt that the two halfes will appear different. Some would say that the two halfes are of the same colour but differ in gloss and other would say that they have different optical properties and therefore must differ in colour. And instrumental measurements will give different answeres depending on which measuring geometry is used.

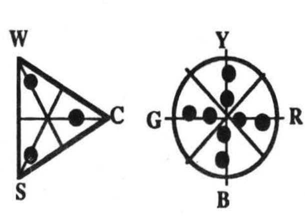
From a phenomenological point of view, it is appropriate to consider colour and gloss as two visual dimensions of the appearance of a surface. A reasonable definition of *"same colour but different gloss"* could be: "TWO OBJECTS OF DIFFERENT GLOSS HAVE THE SAME PERCEIVED COLOUR IF THEY MATCH WHEN VIEWED SO THAT THE DIFFERENCE IN GLOSS IS ELIMINATED".

Measuring colour stimuli , different geometries will indicate a variety of colour differences between a glossy and a mat object. The aim of the experiments reported here, is to find out which measuring geometry that best simulates the difference in colour appearance of glossy and mat objects in an illuminating and viewing situation where difference in gloss is eliminated.

MAIN EXPERIMENT

Colour samples

Twelve different sets of mat NCS colour samples were used in the experiment.One highly chromatic, one pale and one dark nuance of each of four hues close to the four elementary (unique) hues as shown in the figure. A glossy version of these colour samples was produced by coating with a "colourless" glossy laquer. Around each sample were selected the 8 nearest neighbours in the NCS Colour Atlas varying in chromaticness, blackness, whiteness and hue. Thus we had 9 mat colour samples at each set which could be compared with the glossy sample.



The samples were measured in a Zeiss spectrophotometer in diffuse illumination with specular component included (t/8°), excluded (d/8°) and for strong greens in a 45°/0° geometry. For eac set was calculated the CIE L*a*b* differences ΔE* between the glossy and the 9 mat samples.

Visual determination

For each set, the perceived differences between the glossy and the 9 mat samples was judged by 32 observers with normal colour vision. The samples were observed in a light booth with diffused illumination with main direction from above. The walls were painted grey with Ycie≈56. The samples were inclined at 45° to horizontal line and viewed at 8° from normal so that a grey board in front of the observer, and not his body or face, should be "mirrored" in the glossy .

All 36 possible pairs of differences between the mat samples and the glossy were presented to the observer who judged in which pair the difference appeared to be greatest. By using Thurston's Law of Comparative Judgements, scale values of the 9 perceived differences were obtained. The interval scale was made compatible with measured differences ΔE* by giving the lowest and the highest visual differences the same values (R) as the calculated ΔE* values in the t/8° geometry.

For one of the twelve sets, strong greens, with nominal NCS notation 3060-G10Y of the mat version (M,1) of central colour sample, the results are shown in the following table for the measuring geometries t/8° (specular component included), d/8° (excluded) and 45°/0°. G,1 represents the glossy version of the same sample as the mat called M,1.

Sample		G,1	M,1	M,2	M,3	M,4	M,5	M,6	M,7	M,8	M,9
Gloss value		80	13	9	17	20	18	14	15	11	13
t/8° Specular component included											
CIE coordinates	x	0,274	0,273	0,283	0,274	0,269	0,269	0,273	0,282	0,251	0,297
	y	0,447	0,449	0,431	0,441	0,480	0,482	0,447	0,432	0,435	0,466
	Y	17,6	17,6	22,1	27,8	21,6	16,6	12,2	14,6	17,4	20,1
NCS coordinates	s	32,5	32,2	30,4	20,4	22,2	28,5	41,1	41,2	31,3	29,6
	c	56,1	56,6	50,2	59,0	68,2	66,5	53,4	47,6	57,2	58,6
	Ø	-G 9,4Y	-G 9,5Y	-G10,1Y	-G 8,1Y	-G10,8Y	-G11,6Y	-G 9,7Y	-G11,0Y	-G 2,0Y	-G18,9Y
d/8° Specular component excluded											
CIE coordinates	x	0,256	0,270	0,281	0,271	0,263	0,263	0,267	0,278	0,247	0,296
	y	0,506	0,459	0,435	0,450	0,494	0,501	0,461	0,442	0,442	0,475
	Y	14,0	17,3	22,4	27,9	21,2	16,0	11,7	14,1	17,3	19,9
45°/0° geometry											
CIE coordinates	x	0,255	0,262	0,277	0,267	0,256	0,251	0,253	0,272	0,235	0,293
	y	0,510	0,486	0,448	0,461	0,518	0,548	0,504	0,469	0,464	0,499
	Y	13,5	14,8	19,9	25,4	19,0	13,7	9,5	12,0	14,8	17,7

Differences to glossy sample G,1:

Perceived R	0,45	7,27	12,32	11,92	7,95	9,06	6,96	8,97	9,77
Calculated ΔE* from t/8°	0,45	6,09	12,32	13,39	8,30	8,87	8,79	6,35	8,03
Calculated ΔE* from d/8°	10,22	17,48	16,25	9,79	2,92	14,46	17,86	12,02	13,34
Calculated ΔE* from 45°/8°	4,72	14,29	14,18	11,06	8,60	9,36	13,00	8,95	10,90

Correlation analyses

For each of the twelve sets of colour samples the correlation coefficients r was calculated for the visually determined (R) and the calculated colorimetric (ΔE*) colour differences between the glossy sample and the nine mat samples at the used measuring geometries as shown in the table.

Colour sets with approximate NCS notation		Correlation coefficients r for visual R and colorimetric ΔE* differences ^{r}R ; t/8°(spec.incl)	^{r}R ; d/8° (spec.excl)	^{r}R ; 45°/0°
Strong yellow	1070-Y10R	0,714	0,144	
Strong red	2060-R10B	0,871	0,091	
Strong blue	3050-B10G	0,879	0,449	
Strong green	3060-G10Y	0,924	0,119	0,365
Dark yellow(-brown)	6020-Y10R	0,737	0,417	
Dark red(-brown)	6020-R10B	0,780	0,208	
Dark blue	7020-B10G	0,778	0,317	
Dark green	7010-G10Y	0,849	0,475	
Pale yellow	1020-Y10R	0,672	0,554	
Pale red	1020-R10B	0,791	0,742	
Pale blue	1020-B10G	0,890	0,742	
Pale green	1020-G10Y	0,792	0,667	

Without exception the t/8° geometry, with specular component included, is higher correlated with visually determined differences between a glossy and nine mat colour samples than is the d/8° geometry and also in the comparison with the 45°/0° geometry for the strong greens.

A qualitative analyses

Of interest is how the colour of the glossy sample would appear according to the colorimetric data at the actual measuring geometries, to be compared with the visually perceived colour of it.To determine the colour coordinats for the colour percept of the glossy sample from the visual differences (R) out of the experiments, a special "forking" method was used. For this purpose the CIE L*C*h* diagram was used, as it is assumed that it is eucledian and that differences can be set off as straight lines. From the the points representing the nine mat samples, the perceived differences were set off as arcs and the points in the diagrams representing the visual percept of the glossy sample was derived. A comparison with the colorimetric position of the glossy sample in the two measuring geometries indicates which one is closest to the perceived colour in the three dimensions of the CIE L*C*h* space. In the following table is shown how much the colorimetric values in the L*,C* and h* dimensions deviates from the determined perceived values. These deviations are of approximately the same dignity as corresponding NCS figures in Lightness value v, Chromaticness c and Hue Ø.

	t/8°(spec incl)			d/8°(spec excl)		
	ΔL*	ΔC*	Δh*	ΔL*	ΔC*	Δh*
Strong yellow	+1,6	-0,0	-0,3	-0,2	+10,0	-0,0
Strong red	-0,7	+1,0	-0,3	-4,5	+5,4	+0,4
Strong blue	-0,4	+1,3	-2,0	-4,1	+4,7	-2,1
Strong green	+0,3	+0,7	+0,3	-4,1	+9,3	-0,6
Dark yellow(-brown)	+0,6	-0,1	-1,0	-5,0	+6,2	+0,3
Dark red(-brown)	+0,3	+0,3	+0,5	-5,9	+3,8	+2,1
Dark blue	-1,3	-0,1	-2,4	-11,1	+4,9	-8,9
Dark green	-1,1	-0,5	+0,8	-10,5	+8,4	-2,1
Pale yellow	+1,1	+1,7	+1,4	-0,7	+3,4	+1,1
Pale red	+1,8	+1,1	-0,4	-0,5	+1,7	-0,2
Pale blue	+0,1	+0,8	-2,3	-1,7	+1,5	-0,5
Pale green	+0,2	+2,0	-6,1	-1,7	+3,1	-6,2
Mean of absolute values	*0,8*	*0,8*	*1,5*	*4,2*	*5,2*	*2,0*

It is clear that measures of the glossy samples with specular component included (t/8°) lies much closer to the perceived colours (and also to the mat version of the samples) than does the measures with specular component excluded (d/8°) with the exception of the h* values (hue) for which the differences are not significant.

A CONTROL EXPERIMENT

For each of all pairs of five blue samples of varying gloss, the observer had to judge which sample appeared to be the darker and which appeared to be the most chromatic. The scales were made compatible with corresponding CIE L*a*b* values so that perceived lightness and chromaticness could be expressed in terms of L* and C* as shown in the table.

Sample with gloss value:	3	13	43	75	91	Rank correlation to perceived values
Perceived lightness R_{L*}	44,2	44,1	43,9	44,7	45,1	
Measured L* at t/8°(spec incl)	43,4	43,8	43,9	44,3	44,6	0,6
Measured L* at d/8°(spec excl)	44,1	42,8	39,9	38,5	38,6	–0,5
Measured L* at 45°/0°	41,8	39,2	37,7	37,8	37,8	–0,2
Perceived chromaticness R_{C*}	36,3	36,9	36,7	36,7	36,7	
Measured C* at t/8°	36,3	36,6	36,1	36,4	36,6	0,3
Measured C* at d/8°	37,3	38,9	40,8	42,6	42,9	0,0
Measured C* at 45°/0°	36,5	40,2	41,6	41,6	42,1	0,0

CONCLUSION

The control experiment veryfies what was found in the main experiment that measures with specular component included (t/8°) of samples of different gloss lies much closer to perceived colours than does measures with specular component excluded (d/8°).

Refering to how we perceive the colour of objects in our surround it is reasonable to believe that illumination in most cases is rather diffuse and that a glossy surface mirrors more or less of the "diffusing" areas (the sky, the walls, other objects etc.) as in the t/8° measuring situation. It seems not probable that we in nature perceive a glossy surface as if it was mirroring a black hole as in the d/8° measuring case.The conclusion is that the t/8° geometry best simulates the color appearance of samples of different gloss, both from a common sense of view and also as shown in these reported experiments.

RESEARCH REPORT

A complet research report on the experiments will be published as Färgrapport/Colour Report F 33, by Scandinavian Colour Institute, PO Box 49 022, S-100 28 Stockholm, Sweden

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THE COLOUR HOUSE - CASA DA COR (Identity, Goals and Functions)

IDENTITY

1. An entity that sees colour as an instrument for interdisciplinary argumentation with a view to reorganizing the categories of human thought.
2. An entity open to the various currents of thought, forum for debate.
3. An independent, international, culturally oriented entity, set up as a public service, initially addressing itself to the opinion makers (business, the arts, intellectuals, the academy, and the press).
4. An entity without professional involvement in the economy, but...
5. ... an interdisciplinary laboratory open to the public.

GOALS

1. To treat colour as a highly cultural phenomenon without ignoring its "technical aspects", such as optical and physiological.
2. To view under a new light some traditional themes and approaches related to colour.
3. To discuss everything that comes under man's influence.
4. To formulate and to promote the elaboration of vanguard projects from the point of view of colour.
5. To stimulate, catalyse and disseminate interdisciplinary research in the field of colour.
6. To establish, according to needs, public centers to further the aims of the Casa da Cor.
7. To strive, within the scope of its identity, for a constant dynamic and qualitative renewal of itself and of its goals.

FUNCTIONS

COLLECT (Primary Processing). To discover, select and mantain contact all over the world with individuals, institutions, projects and informations which might be of interest to itself.

STORE. To store, classify and keep available such collected informations.

DISSEMINATE (Final Processing). To promote, through projects and public events, the knoweledge obtained through its Collecting Activity, and to place it at the disposal of individuals, institutions, projects and businesses.

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RELIABILITY OF THE SPANISH OFFICIAL METHODS FOR COLOR OF RED WINES IN COMPARISON WITH THE CIE 1931 (x,y) METHOD

Spanish regulations[7] adopted the OIV Recommendations[6] and the so-called Rapid Method[8] for the chromatic characterization of red wines. This approach is a simplification from the more rigorous CIE procedure[1] based on the weighted ordinate method.

Some authors[5] have made clear that for some "Rioja" wines significative differences were found when the above chromatic methods were applied to the same wine samples. In this study the reliability of the OIV method in comparison with the CIE method is discussed. This reliability is dependent on some chromatic parameters shown by the analyzed red wines.

1 MATERIALS AND METHODS

1.1 Materials

1.1.1 Samples. Forty seven representative samples of Spanish red wines from twelve "denominaciones de origen" ("Alicante", "Ampurdán-Costa Brava", "Campo de Borja", "Cariñena", "Jumilla", "La Mancha", "Navarra", "Ribeiro", "Rioja", "Valdepeñas", "Valencia", "Yecla") have been considered in this study. The samples were selected at random, following the criterion of representativity according to their production and consumption. All the wines were bottled and commercialized samples, and the preservation conditions were the adequated for bottled wines. All the samples studied showed no turbidity, so previous centrifugation or filtration process was no necessary.

1.1.2 Apparatus. Experimental absorbances were measured in a Bausch & Lomb "Spectronic 2000" spectrophotometer provided with a continuous X-Y recorder 333508. Hellma precission glass cells with 1, 2, 5, 10 mm pathlengths were used. Chromatic parameters were obtained applying a Fortran program on a Digital VAX-11/785 computer. The data were treated employing BMDP statistical software.

1.2 Methods

The method proposed for computing chromatic parameters were the Reference Method and the Rapid Method[6,8], valid in Spanish Regulations[7], the CIE 1931-(x,y) Colorimetric System[3], CIELUV and CIELAB Uniform Color Spaces[2]. Absorbance measurements were carried out within a time interval of an hour, avoiding in this manner color unestability with time elapsed[4].

2 RESULTS AND DISCUSSION

The differences (δ) between the respective chromatic parameters obtained by both methods have been chosen as objective indices of reliability of the OIV method. In Table 1 chromatic parameters for the wine samples are offered, such as luminance (Y_{CIE}), lightness (L^*), saturation (S_{CIE}, s^*_{uv}), dominant wavelength (λd), chroma (C^*_{uv}, C^*_{ab}), hue angle (h_{uv}, h_{ab}), tint (Tn) and color intensity (CI). Table 2 lists limits values for δ, the mean values and the standard error. From the plot of each δ value versus each of chromatic parameters listed in Table 1 it was infered that in some instances samples behave according to two distinguishable patterns: an interval of chromatic parameter values where δ oscillated within a narrow interval (Set I), and other interval where a linear increase of δ values was observed (Set II). A cutpoint was found between

Table 1

Chromatic parameters of wine samples

Chromatic parameter	Mean	Standard deviation	Standard error	Coeff. of variation	Smallest value	Largest value
max	500.930	29.064	4.2394	0.05802	380.000	524.200
A_{max}	2.592	2.068	0.3017	0.79792	1.004	15.100
Y_{CIE}	9.967	5.260	0.7673	0.52778	0.200	24.650
S_{CIE}	85.312	11.571	1.6878	0.13563	55.106	100.000
d_{CIE}	611.313	10.632	1.5508	0.01739	598.003	649.026
CI	4.698	3.406	0.4969	0.72512	2.044	25.400
Tn	10.842	18.735	2.7328	1.72801	-23.025	78.230
L*	35.846	10.574	1.5424	0.29499	1.806	56.733
C^*_{uv}	104.238	16.774	2.4468	0.16092	9.729	118.259
C^*_{ab}	75.070	15.759	2.2987	0.20992	14.103	97.367
s^*_{uv}	3.140	0.815	0.1188	0.25946	1.550	5.389
h_{uv}	14.441	3.582	0.5225	0.24803	6.526	22.966
h_{ab}	44.824	9.319	1.3594	0.20791	12.752	59.404

the two sets. The results for $\delta_{chromaticity}$ (δ_c) are shown in Table 3. Although most of the samples were situated within set I, where the symplified method (OIV) might b applied with sufficient reliability, a considerable percentage of the samples (set II) were submitted to an appreciable error. It was observed (Table 3) that this error was present as a linear function of the chromatic parameter value that was being considered. The conclusions infered from these experiences will be taken into account for later experiences with the different treatments, origin and circumstances of the wines.

Table 2

δ values relating to several parameters

Chromatic parameter	Mean	Standard error	Smallest value	Largest value
δ_x	0.007	0.0015	0.000	0.053
δ_y	0.007	0.0015	0.000	0.053
δ_z	0.001	0.0002	0.000	0.008
δ_C	0.010	0.0022	0.001	0.075
δ_Y	0.297	0.0301	0.006	0.867
δ_S	0.349	0.0509	0.000	2.180
$\delta_{\lambda d}$	0.007	0.9752	0.019	35.430

The subscript refers to the parameters taken into account (tricromatic coordinates, chromaticity, luminance, saturation, and dominant wavelength, respectively)

Table 3

Behaviour of samples for δ_c values

Chromatic parameter	Cutpoint	Set I			Set II		
		N	δ mean	δ range	N	Regression line	r*
Y_{CIE}	5.0	38[a]	4.56	13.35	9[b]	$y= 7.49\cdot10^{-2}-1.19\cdot10^{-2}\cdot x$	-0.980
S_{CIE}	93.0	34[b]	4.40	13.16	13[a]	$y=-6.26\cdot10^{-1}+6.73\cdot10^{-3}\cdot x$	0.732
λd_{CIE}	612.0	30[b]	3.61	9.04	17[a]	$y=-1.11+1.83\cdot10^{-3}\cdot x$	0.926
L*	28.0	38[a]	4.56	13.35	9[b]	$y= 8.23\cdot10^{-2}-2.35\cdot10^{-3}\cdot x$	-0.974
s^*_{uv}	3.6	35[b]	3.97	10.51	12[a]	$y=-1.26\cdot10^{-1}+3.68\cdot10^{-2}\cdot x$	0.991
h_{uv}	13.1	30[a]	3.61	9.04	17[b]	$y= 1.24\cdot10^{-1}-9.42\cdot10^{-3}\cdot x$	-0.905
CI	5.0	35[b]	4.44	13.11	12[a]	$y= 3.60\cdot10^{-3}+3.09\cdot10^{-3}\cdot x$	0.833
Tn	12.0	30[b]	3.90	9.6	17[a]	$y=-3.42\cdot10^{-3}+8.78\cdot10^{-4}\cdot x$	0.804

[a] Samples with a chromatic parameter > cutpoint
[b] Samples with a chromatic parameter ≤ cutpoint

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CUBIC MODEL OF THE JAPANESE INTERIOR COLOR COORDINATION SYSTEM & IMAGE

In Japan, western-style housing has rapidly developed during the last 40 years and accordingly, interior color has become very important.

Therefore, a manual for color coordination offering understandable information became necessary to present good color harmony for interior color planning. In order to accomplish this, the Japan Interior Industry Association established a technical committee for interior color in 1985. The members of the committee undertook a study on the creation of an interior color coordination system

The purpose of the study was to survey colors used in Japanese housing interiors and also to create an interior color matrix. As a result of this study the image structure for interior color coordination was established according to the analysis of image tests created by the committee and given to interior designers.

In this report, we describe the outline of this study and the new concept of the cubic model for interior color coordination corresponding to the image structures shown as follows.

1, Primary study for the interior color code (matrix)

We collected and measured the color of 1297 recent products and materials which sold well and were used in housing interiors. These samples were then categorized into the percentage of each hue group and each tone group using the color naming system of Japan Color Research Institute.

After completing the process, 700 color samples were chosen for the interior color matrix, and at the same time, the range of recent Japanese interior colors in use was obtained.

2, Basic image axis of interior color coordination

2・1 Test 1, (an abstract model case using color chips)

The image test was executed by the SD method using 50 interior designers as subjects. They were shown 47 samples of two color combinations which they were to consider as interior wall and floor color samples. Another 55 samples of three color combinations (wall, floor, sofa) were shown as well.

Factor analysis test results are shown in table 1.
The four main factors are as follows:

factor 1: friendliness (material, friendly, Japanese — artificial, urbanic, high-tech)
factor 2: potency (masculine, cold, hard — feminine, warm, soft)
factor 3: activity (light, gay, light-hearted — dark, quiet, dignified)
factor 4: evaluation (smart, harmonic, modern, serene — rustic, inharmonic, restless)

2・2 Test 2, (a more concrete model case using illustrations and photographs)

As the stimuli of the test,24 schematic interior illustrations and 24 interior photographs were used for the second image test in order to study whether the tendency of test2 was in accordance with the result of test 1. The three major factors were drawn as follows:

factor 1, friendliness (cold, hard, masculine, artificial — warm, soft, feminine, natural)
factor 2, activity (light, gay, light-hearted — dark, quiet, dignity)
factor 3, evaluation (serene, smart, harmonic — restless, rustic, inharmonic)

3. Cubic model of color image

As for "activity" factor, there is an accordance between the abstract model (#1)and the concrete model (#2) The "potency" factor in test 1, however, has been absorbed into the "friendliness" factor in test 2.
Further more the "evaluation" factor (#4) in test 1 has been shifted to the (#3) position in test 2.
Therfore, the three major factors in the concrete model cover the mean scales. The committee then adopted these three factors for the basic image of the color coordination system.

Figure 1 shows 2 image maps.
(A) shows Axis 1 (natural—mechanical) to Axis 2 (dark—light) and (B) shows Axis 1 to Axis 3 (strong—mild). The descriptive interior image terms used in the maps were chosen by the interior dasigners tested.

These image Axis correspond to the categories of hue and tone combination. The cubic model (Fig.2) shows the interior color combination concept and image.

4. Basic Interior Color Coordination Model Concept

8 quadrants of color combinations (Fig-2) are formed by Axis 1,2,3, according to factor Ⅱ (light—dark).

The upper half forms an image of "light" and the lower half "dark".
Four categories of color combinations can be obtained and we have listed them as, "unity", "variety", "soft" and "hard".

These four categories can be placed in both the upper (light) and lower (dark) areas as shown in table 3.

Table 1 Image Factor Analysis of Abstract Color Combinations
(3 color combinations -wall,floor,sofa-)

group	evaluation scale	F 1	F 2	F 3	F 4
friendliness	natural - mechanical	0.886	0.389	-0.073	-0.114
friendliness	high-technical	0.615	0.555	-0.002	0.453
friendliness	natural	-0.897	-0.175	-0.168	0.212
friendliness	dynamic	0.640	0.306	-0.254	-0.081
friendliness	japanese-style	-0.739	0.008	0.087	-0.277
potency	cold - hot	-0.447	-0.751	-0.128	-0.315
potency	hard - soft	-0.636	-0.704	-0.124	-0.165
potency	masculine - feminine	-0.144	-0.883	-0.184	-0.061
potency	elegant	-0.080	-0.829	0.100	0.346
activity	light - dark	0.016	0.226	0.834	-0.143
activity	gay - quiet	-0.539	0.046	0.730	0.149
activity	dignified - light hearted	0.002	-0.067	-0.908	0.042
activity	classic	-0.234	-0.441	0.669	-0.053
activity	casual	-0.126	-0.050	-0.706	-0.230
evaluation	serene - restless	0.554	0.118	-0.500	-0.591
evaluation	smart - rustic	-0.115	0.068	0.089	-0.955
evaluation	harmonic - inharmonic	0.194	0.096	-0.167	-0.907
evaluation	modern	0.581	0.341	-0.129	0.652
	eigen value	4.613	3.507	3.482	3.205
	contribution(%)	25.6	19.5	19.3	17.8
	accumulation(%)		45.1	64.4	82.2

Table 2 Image Factor Analysis of Concrete Color Combinations

group	evaluation scale	F 1	F 2	F 3
friendliness	cold - hot	0.320	-0.128	0.165
friendliness	hard - soft	0.974	-0.067	-0.082
friendliness	masculine - feminine	0.792	-0.418	0.089
friendliness	natural - mechanical	-0.873	-0.203	0.304
activity	light - dark	-0.217	0.878	0.076
activity	gay - quiet	0.257	0.746	-0.501
activity	dignified - light hearted	0.167	-0.851	-0.076
evaluation	serene - restless	-0.349	-0.437	0.733
evaluation	smart - rustic	0.325	0.257	0.848
evaluation	harmonic - inharmonic	-0.084	-0.026	0.929
	eigen value	3.562	2.594	2.516
	contribution(%)	35.6	25.9	25.1
	accumulation(%)	35.6	61.5	86.6

Table 3 Basic Interior Color Combination Names and Contents
-Table 3 represents both light (upper) and dark (lower) areas- * H:Hue,T:Tone

color combination name of quadrant	combination [hue/tone]	color combination name of axis	synthetic image
unity	H*	identity	natural harmonic chic
	T*	analogy	japanese-style modern
soft	H	variety	hot soft classic
	T	analogy	elegant feminine
variety	H	variety	gay restless inharmonic
	T	contrast	casual dynamic
hard	H	identity	mechanical cold masculine
	T	contrast	high-tech modern

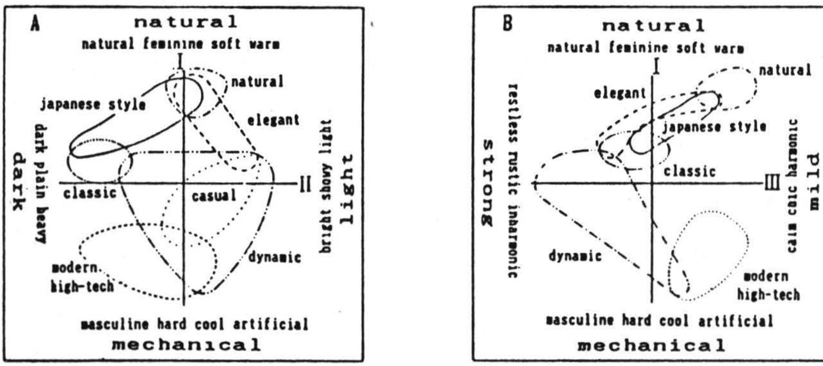

Fig. 1 Interior Image Map

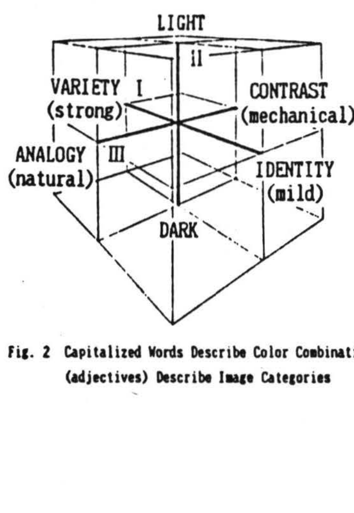

Fig. 2 Capitalized Words Describe Color Combinations
(adjectives) Describe Image Categories

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How Reflectance Measurements of Interference and Metallic Pigments as well as of Mixtures with Absorption Colourants depend on Different Measuring Angles

Colour styling and the perception of colour are important elements of man's communication with his environment.

Today three groups of pigments are known which basically differ by their optical behaviour:

Absorption pigments
Metallic pigments
Interference (mica) pigments (figure 1)

The characteristic features of the absorption pigments are mainly determined by their molecular and crystal structure. Colour shade and intensity primarily depend on the absorption wavelength range and the molar absorption coefficient of the pigment. The particle size has a great influence on the colouring features of a pigment and produces light scattering.

Metallic pigments create a "metallic" effect. Their colour shade is determined by the metal alloy being used. Metallic piments have no inherent colour, they are achromatic. They differ from black and white pigments by their metallic lustre produced by light reflection at the pigment particles.
Light reflection and light scattering are strongly affected by particle size. Coarse pigments produce high reflection, fine pigments -high scattering.
Every parameter, like brightness, chromaticity and flop effect, primarily depend on particle size distribution and the orientation of the metallic particles to a high degree.

Interference pigments produce their colours by light interference and not by light absorption. In the case of interference pigments, each particle is a microscopically small platelet with defined layer thickness. Consequently each particle behaves as a minute interfence film or filter which divides light into a reflected and a transmitted portion of complementary colour.
Thus, the ocurrence of lustre and colour phenomena in thin flakes is a combination of geometrical and wave-optical processess. Nacreous lustre is produced when transparent glossy surfaces transmit a greater or lesser portion of the incident light.
Even for the formation of an interference colour the parallel orientation of the pigment particles is of a geat importance.
Whereas the colorimetric analysis of absorption colours depends only insignificantly on the measuring geometry, colourimetric assessment of interference colours is extremely demanding on measurement technique.

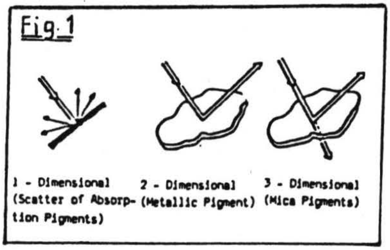
Internationally, several geometries have been standardised for measuring the properties of absorption colours (DIN 5033). For example, additional configurations with a measurement geometry of "$45^o/0^o$ with tilt" have been developed. The concept for measuring the directional spectral beam density factor is based on the average observation situation of $45^o/0^o$. Further measurement geometries are obtained by rotating the specimen about an axis perpendicular to the plane of the directions of illumination and observation thus providing additional information.

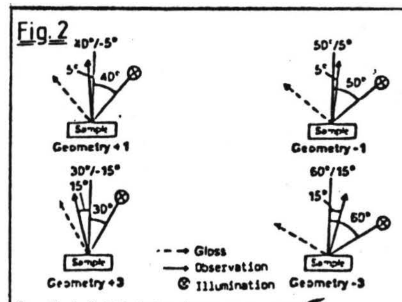
It has been proven, that a measurement at four different tilt angles will be sufficient for an unambigous characterization in most cases (figure 2). Based on this measurement, ist is possible to determine the so called "flop", i.e. the difference between the various symetrical tilt angles.

Today a lot of designers make effect coatings their goal. Metallic coatings with automobiles are the best known ones, but even in other fields these coatings become more and more popular, e.g., with furniture to coatings and in the field of printing inks.
For the manufacture of these effect coatings aluminium, as well as copper bronces and pearl lustre pigments (interference pigments) are used. These pigments can be used alone or in mixtures, as well as in mixtures with absorption colourants. Pearl lustre pigments are able to overcome the greyishing limit of metallic pigments which exclude e.g. bright red metallic colours.
As pearl lustre pigments are transparent, they have less hiding power. By adding optimal concentrations of aluminium bronces the hiding- and reflection-power can be increased. Thus even a better light-dark flop will be achieved.
The variety of mixing metallic, interference and absorption colour pigments is very wide. The characteristic features of these mixtures are to be shown with some examples.
For colour representation we chose the CIE L*a*b* system. The coatings were applied as draw-downs and provided with top coating. A black background was chosen as the interference appearance of pearl lustre pigments can be seen best with it.
If one compares the brightness values (L* values) of a metallic pigment with those of the interference pigment Pearl Silver, considering their dependence on concentration and measuring angles, so the metallic pigment shows an considerably higher reflection at the viewing angles; a reflection, which however, being measured at specular angle and with a concentration of more than 0.5 percent cannot be increased. With a concentration of two percent and at a measuring angle of $30^{o}/-15^{o}$ the brightness values of both pigments are almost the same (figure 3).
By increasing the concentration of Pearl Silver of mixtures with Aluminium pigment the colour cast of the mixtures changes, and the colour locations in the CIE L*a*b* system are reversed by changing the measuring geometry.
In figure 4 different concentrations of a metallic pigment and a Pearl Blue pigment mixed with a blue absorption colour pigment are shown; mixtures which are measured at an angle of $30^{o}/-15^{o}$. In this case the reverse course of chromaticity depending on concentration can be seen. The colour intensity (colour saturation) of Pearl Blue compared with an undyed pigment considerably increases.
When metallic pigments and pearl lustre pigments are mixed with black paste (black reduction), so other interesting colour effects may be obtained. The brightness values (L* values) of metallic pigments are considerably higher.

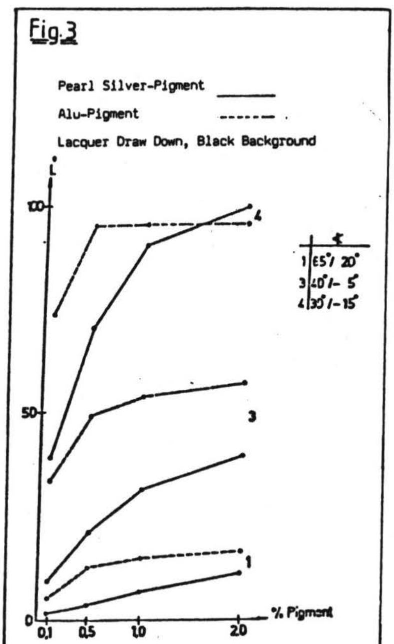
Interference pigments mix additively.

Figure 5 is showing the colour locations of mixtures of the interference colours yellow/red/blue/green in the ratio one to one according to the CIE L*a*b* system.
The effect of background is important with tranparent pearl lustre pigments. A pigment, e.g., pearl green on a black background shows only the green colour reflected by the pigment. The transmitted complementary red colour will be absorbed. Thus a clear colour flop between the measuring geometries $45^{o}/0^{o}$ and $30^{o}/-15^{o}$ is achieved.
By measurement with a specular angle ($30^{o}/-15^{o}$) on a white background one obtains a green reflectance colour. The measurement with a nonspecular angle ($45^{o}/0^{o}$) on a white background show the complementary red colour (figure 6).





Four Typical Tilt Angles (Based on the 45°/0° Geometry for the Characterization of Effect Surfaces



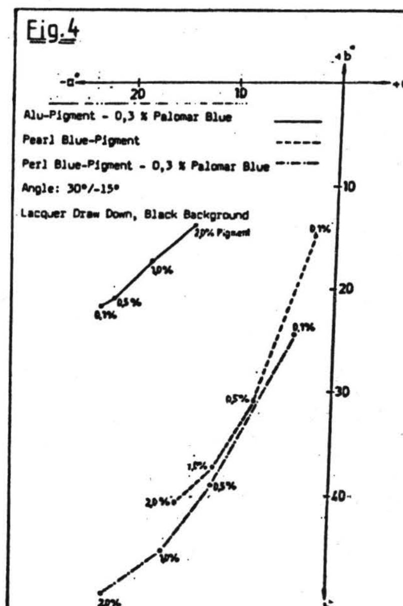


Fig. 5 L*a*b*-Messung zur additiven Farbmessung an Interferenzpigmenten
Mischungsverhältnis 1:1

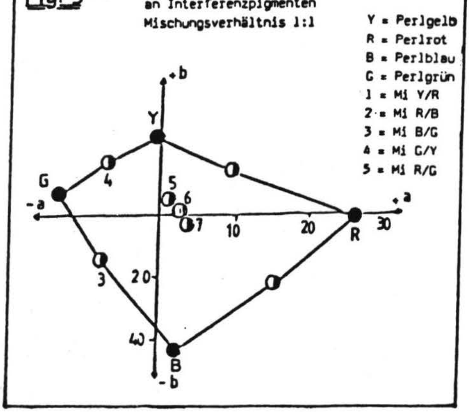
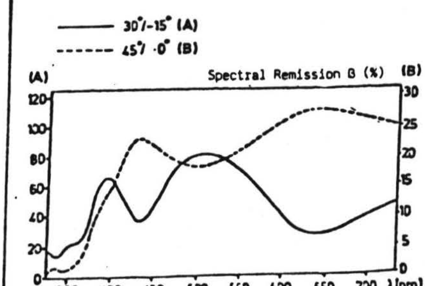


Fig. 6

Pearl Green-Pigment
5 % Lacquer Draw Down, White Background



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COLOUR IN FOLKLORE, SUPERSTITION, TRADITION AND LEGEND.

Colour has long been an important ingredient of many aspects of folklore, superstition, tradition and legend. Red ochre was scattered over graves in the palaeolithic period and this pigment is still used by Australian aborigines, who regard it as the blood of their ancestors. Neanderthal man used brightly coloured flowers in his burial ceremonies. Anthropologists have identified a basic colour triad of black, red and white, and this is found in many forms of body decoration used by "primitive" peoples. It has been suggested that this triad is among the earliest symbols used by man and that the three colours are a symbolic representation of the products of the body.

In "modern" life also, superstitions are associated with various lucky or unlucky colours, colours are also peculiar to certain traditional activities, beliefs and practices. These associations vary from country to country: black for mourning, white for brides in Europe; white for mourning, red for brides in Hindu India; saffron for Buddhist monks, black or grey for western clergy. Throughout the United Kingdom green is regarded as unlucky by many people. White or black animals are often regarded with veneration, bringing either good or bad luck according to the believer's background. Colour can form an important part of legend also. A white dove flying over the Snowdonian Lake Dulwyn in Wales is said to be the spirit of a beautiful woman on her way to Hell.

Tradition can be very regional, probably developing at a time when transport and communication were more difficult than today. For example, in one small area of Scotland custom dictates that at certain weddings the bridesmaid must wear a green garter.

Colour in folklore is a subject which has received little attention; it is a subject about which we all know something. In an attempt to learn more about this fascinating aspect of life a survey has been launched by the Folklore Society, which is based at University College London, and supported by the Colour Group (Great Britain). The poster will display some of the preliminary results. HOWEVER, THE MAIN PURPOSE WILL BE TO ADVERTISE THE SURVEY AND ASK FOR HELP FROM THOSE ATTENDING COLOR89. DELEGATES OF ALL NATIONALITIES WILL BE ENCOURAGED TO CONTRIBUTE EXAMPLES OF COLOUR IN FOLKLORE FROM THEIR OWN REGIONS.

** WILL YOU PLEASE HELP? **

Colorimétrie de la Pâte ,Rendement en pâte ,Aptitude au Blanchiment ,Longueur des Fibres de la Pâte à Papier de ·SIX ESPECES arbustives du MAQUIS MEDITERRANEEN :JUNIPERUS PHOENICEA ,RHAMNUS ALATERNUS ,PHILLIREA LATIFOLIA ,FRAXINUS ORNUS,ERICA ARBOREA, ARBUTUS UNEDO .

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1 - INTRODUCTION

L'étude de la valeur papetière de six espèces méditerranéennes fait suite aux travaux de P.LAVISCI (Thèse 1988 - Université de FLORENCE) sur la valorisation de ces espèces,par la détermination des propriétés de résistances mécaniques et de l'aptitude au tournage et de la couleur du bois.

En effet,la valorisation de cette matière première constituant le maquis méditerranéen, qui a pour seul débouché actuel le bois de feu ou de production de charbon de bois , ou encore occasionnellement la petite ébénisterie artisanale, peut être envisagée comme du bois pour la fabrication de pâte à papier.A cet effet,nous avons déterminé le rendement en pâte et la longueur moyenne des fibres, leur répartition. et leur aptitude au blanchiment .

En outre,au cours de l'appreciation des qualités de ces pâtes à papier,non encore décrites à ce jour,nous avons appliqué à ces pâtes les méthodes de mesures colorimètriques du système CIELAB 1976 :

- Luminance L* ,
- Saturation C* ,
- Angle de teinte H*

et mis les résultats en corrélation avec l'aptitude au Blanchiment :

- indice de ou permanganate (KMNO4)
- le Rendement en pâte à papier,
- le rapport:Rendement en pâte à papier / Indice de permanganate (KMNO4)

2 - RESULTATS

L'étude de ces Bois a été entreprise pour tenter de montrer que leurs qualités pouvaient les faire prendre en considération comme appoint dans la fabrication des pâtes à papier.

Cette ressource en Bois cesserait alors d'être vouée à la fabrication du charbon de Bois ou de bois de feu.

L'ensemble de ces mesures sera comparé à celles correspondant à des espèces méditerranéennes de référence comme les Eucalyptus .

2.1 - Rendement en pâte à papier

Les essais concernant la variation (la diminution) du rendement en fonction du % d'Alcali Actif (AA %) croissant montre que à 18 % et 20 % ,les valeurs sont comparables et varient (figure n° 1), (tableau 1).

. à 18 % : de 48 % à 43 %

. à 20 % : de 45,5 % à 40,5 %

Le classement des pâtes est à titre d'exemple :

18 %	. Juniperus phoenicea	: GE FE
	. Rhamnus alaternus	: ALA
	. Erica arborea	: ERI
	. Fraxinus ornus	: ORNI
	. Arbutus unedo	: COR
	. Phillirea latifolia	: FILLI

à 20 % , on retrouve le même classement sauf pour le Genévrier,mais rappelons-le , avec des valeurs plus faibles dans l'ensemble dûes à l'utilisation d'un A.A plus élevé.

Il convient donc de traiter ces espèces,si le cas se présente dans des conditions de cuisson Kraft à 18 %.

2.2 -Indice de permanganate et le rapport : $\frac{\text{Rdt}}{\text{Ind}}$

Cet indice de permanganate est le corollaire du rendement et renseigne sur l'aptitude au blanchiment.

S'il est compris entre 10 et 20 on se trouve avec une pâte facile à blanchir,puis de 20 à 25 la pâte devient plus difficile,et au dessus de 25 jusque vers 50 et plus , la pâte n'est pas destinée à être blanchie sauf pour des usages particuliers.

On voit donc que le tracé de la courbe des rendements en fonction de l'indice de permanganate (figure No 2) ,pour l'ensemble des espèces - sauf le Genevrier de Phénicie (GE FE) - se trouve dans le domaine des valeurs des indices de permanganate acceptables et même TRES INTERESSANTS pour FRAXINUS ORNUS(13,1) et PHILLIREA LATIFOLIA (FILLI 18,9.)

Les comparaisons les plus intéressantes et les plus démonstratives se retrouvent dans la figure n° 3 , où l 'on a tracé l 'évolution du rapport Rendement / Indice $KMnO_4$ en fonction de A.A % .

On peut retrouver les mêmes écarts et de façon plus significative :

- la position excellente de Fraxinus Ornus (ORN)
- la situation moyenne mais satisfaisante du groupe (COR) ,(ALA) , (FILLI) , (ER) , et l'exclusion de l 'espèce GENEVRIER de Phenicie (GE FE) qui présente le plus mauvais rapport entre le rendement et la valeur de l'indice de permanganate ou de blanchiment.

- APPLICATIONS à LA CARACTERISATION de ces SIX ESPECES MEDITERRANEENNES

-CORRELATIONS avec les INDICES PAPETIERS USUELS

POUR LA PREMIERE FOIS , les caractéristiques physiques d'ASPECT des pates écrues concernant leur "COULEUR" ont été mesurées en fonction des traitements d'ALCALI-ACTIFS % variables auxquels elles ont ete soumises.

Ces mesures ont pour but de montrer que la quantification de l'ASPECT et la COULEUR des pates à papiers peuvent être corrélées avec les caractéristiques technologiques trés importantes des pâtes :

- le rendement en pâte (en fibres)
- l'indice de $KMNO_4$ ou indice de blanchiment
- le rapport : rendement/indice de $KMNO_4$ qui traduit le meilleur compromis entre un rendement en pâte suffisamment élevé et une bonne aptitude au blanchiment(indice de $KMNO_4$ faible) .

Nous rappelons que dans le tableau n° 1 nous donnons pour les six Espèces les valeurs calculées à partir du système CIELAB 1976 qui fournit les coordonnées : L* a*, b* , les caractères suivants :

- L* ou luminance de la pâte

- C* la saturation de la teinte ($C^* = \sqrt{a2 + b2}$)

- H* l'angle de teinte (H* = Arctang b/a)

2.4 - Les MESURES de LONGUEUR des FIBRES

la Méthode de MESURE AUTOMATIQUE de la LONGUEUR des FIBRES réalisée à l' aide de notre appareil " HISTOFIBRE " sur un nombre de 10.000 à 17.000 FIBRES par échantillon a permis de classer les espèces entre elles et aussi de pouvoir les comparées à celles couramment utilisées en papeterie .

Ainsi le groupe des epèces feuillues s'ordonne de la façon suivante :

-FRAXINUS ORNUS (ORNI)	1,21 mm
-PHILLIREA LATIFOLIA (FILLI)	0,97 mm
-RHAMNUS ALATERNUS (ALA)	0,96 mm
-ERICA ARBOREA (ERI)	0,81 mm
-ARBUTUS UNEDO (COR)	0,71 mm

pour la longueur moyenne pondérée des fibres , ce qui les situent dans les espèces à FIBRES COURTES . L' emploi de ces fibres en Indutrie, sous forme de pâte blanchie, concerne les papiers d' Impression - Ecriture .

La seule espèce résineuse étudiée:

-JUNIPERUS PHOENICEA (GE.FE) 1,46 mm

avec cette longueur moyenne pondérée se classe dans les longueurs peu élevées pour un résineux .De ce fait et en

3 - CONCLUSION

Cet exposé d' une tentative de valorisation des espèces du MAQUIS MEDITERRANEEN par la production de pâte à papier est présentée comme une ALTERNATIVE POSSIBLE aux usages actuellement en vigueur : emploi comme BOIS de feu , fabrication de charbonnette (charbon de Bois) ,tout en conservant les usages locaux et occasionnels en petite menuiserie et tournage de petits objets

La possibilité de transformer ces espèces en pâte à papier , en les considérant comme une MATIERE PREMIERE d' APPOINT , n' avait jamais été envisagée jusqu'à ce jour à notre connaissance , et elle intéresse tous les PAYS du POURTOUR MEDITERRANEEN qui ont une végétation identique ou bien dont les espèces n' ont pas encore été testées et qui mériteraient de l'être .

Rappelons que certaines d'entre elles devront êtretraitées séparément ou écartées , comme le GENEVRIER , pour ne pas nuire à l'homogénéité de la pâte résultante ,et cela implique de pratiquer des essais préliminaires sur le plus grand nombre d'espèces pour en évaluer les utilisations papetières possibles pour chaque PAYS soucieux de sa production en pâte à papier .

La valeur des rendements en pâte est pour l' ALCALI-ACTIF de 18 % très voisin des espèces feuillues croissant au bord de la Méditerranée.

Les méthodes utilisées sont celles des MICROTESTS PAPETIERS , dans les quelles les méthodes de MICROCUISSONS présentent l'avantage d' une facilité de mise en oeuvre au laboratoire , à la fois sur des très petits échantillons et , ce qui est à souligner dans un espace de TEMPS TRES COURT .

La Méthode de Mesure des LONGUEURS de FIBRES a montré que ces espèces semblables aux autres espèces feuillues ne devaient pas être rejetées pour cette raison , sauf peut être pour le JUNIPERUS qui n' apporte pas de très longues fibres et qui de plus sont très difficiles à blanchir .

A ce descriptif des propriétés papetières conventionnelles il manque EVIDEMMENT les caractéristiques Mécaniques des papiers que l' on pourrait obtenir après les divers traitements technologiques appliquées à toutes les pâtes , mais notre but était de montrer la faisabilité de la production de pâte à PAPIER avec ces espèces MEDITERRANENNES.

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USE OF SOME EMPIRICAL FORMULAS FOR THE COURSE OF THE K/S FUNCTION

The computer color matching is a modern, on the Kubelka Munk theory based method of working out recipes for textile dyeing. In order to obtain high quality and optimum recipes, the Kubelka Munk values K/S must precisely be determined, depending on the concentration of individual dyestuff on the selected substrate:

$$(K/S)_{\lambda_j} = (K/S)_{\lambda_j}\ (c)$$

For this purpose throughly performed primary dyeings with 6-10 different concentrations are necessary. After conversion of the measured reflectances $R_{\lambda_j}\ (c_i)$ into $(K/S)_{\lambda_j}\ (c_i)$ values and subtraction of $(K/S)_{\lambda_j\ SUB}$ we get 16 sets (one for each wavelenght $\lambda_j, j = 1,2,\ldots, 16$) of the form

$$(c_1,(K/S)_{\lambda_j}\ (c_1)),\ (c_2,(K/S)_{\lambda_j}\ (c_2)),\ldots,\ (c_n,\ (K/S)_{\lambda_j}\ (c_n)).$$

In these data, the random errors of different origins are included.

To reduce the influence of these errors, instead of piece-wise linear interpolation we use some appropriate curves to "smooth" the measured data. For each single wavelenght we try to fit our data with the following simple two-parameter formulas:

$$y(x) = x/(ax+b) \qquad \text{(model 1)}$$
$$y(x) = axe^{bx} \qquad \text{(model 2)}$$
$$y(x) = ax + bx^2 \qquad \text{(model 3)}$$
$$y(x) = a\ln(x+1) + bx \qquad \text{(model 4)}$$
$$y(x) = ax + b \qquad \text{(model 5)}$$

and than we use that one with the best fit (the meaning of variables: $x = c$, $y = K/S$).

Parameters a and b in these formulas or their transforms in linearized equations can be determined by the standard least squares method.

In following diagrams an example of the principle of determination of $(K/S)_{\lambda_j}$ (c) is shown:

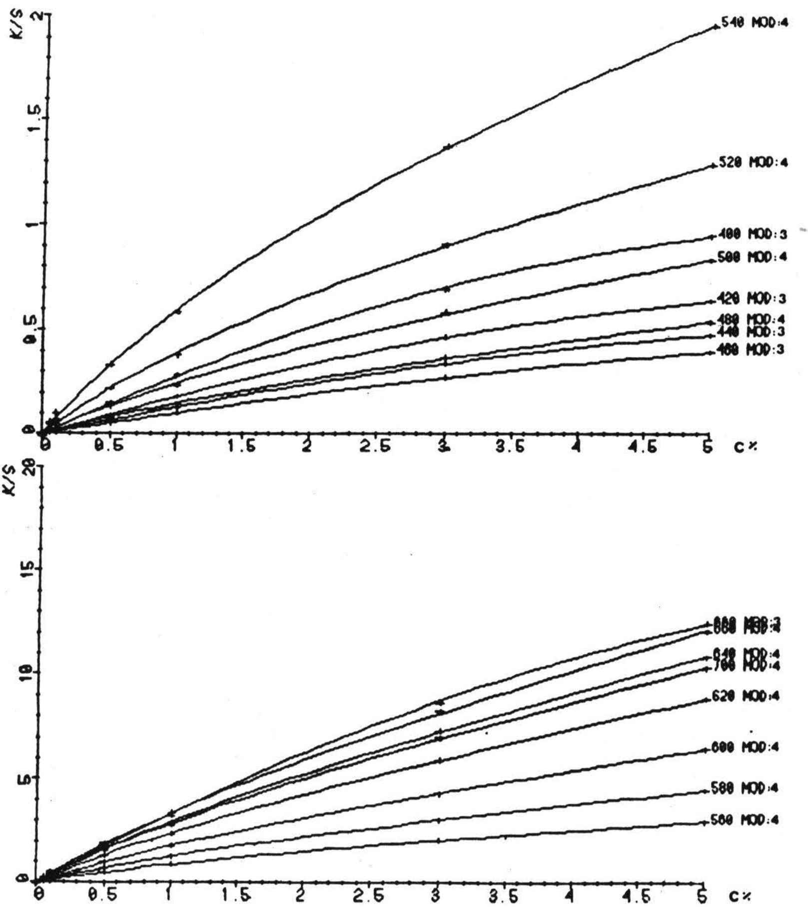

Fig 1.: Determination of $(K/S)_{\lambda_j}(c)$ values for the dyestuff C.I. Disperse Blue 87 on PES yarn

The $(K/S)_{\lambda_j}$ (c) values determined in this way have been used in the process of computer based reciping. The optained recipes have given good results.

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THE SUBSTRAT INFLUENCE ON COLOR OF VARIOUS PAC-FIBRES

The textile substrate with its chemical and physical structure does not influence only the dyeing resp. color of synthetic polymers but also the technological and technical parameters of the dyeing process.
The role resp. variability of substrate as a function of color can be determined under constant work conditions, if due to the precise knowledge of substrates the dyeing of different substrates is performed in the same dyeing bath at the same performance of process.
In the research work, the difference resp. similarity of six various PAC-fibres, large-scale dyed in Eurocolor-signed colors, has been investigated. The colors of the dyed substrate from the total chromatic circle have been numerically evaluated and the color differences depending only on substrate variation, determined.
The color differences were determined by CIELAB, Hunter LAB, FMC II, AnLAB 40, CMC (2:1) methods, using program and apparatus equipment ACS 1800.
Due to investigations, the correlation between physical fibre texture and substrate affinity towards the dyestuff resp. dyeing of PAC fibres has been defined, and the correlation factor which enables simplification of recipe preparation and dyeing performance, determined.
The obtained results represent a valuable contribution in solving problems of dyeing PAC fibres which are one of the important raw materials for the production of different textile products.

STUDY ON COLOUR TEMPERATURE OF LIGHT FROM SKY AND ITS DISTRIBUTION IN JAPAN

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1. INTRODUCTION

The characteristics of spectral distribution of light from sky seems to be essential for the visual environmental design. Perception of colour of visual objects illuminated by natural light relates with its spectral distribution. Both appearance of colour of objects under natural light in outdoors and those in interiors illuminated by natural light through windows, for instance, are considerably effected by spectral distribution of the light. Also selecting suitable colour of artificial light for natural light is very important for the lighting design in daytime.

Colour of light is one of phases of spectral distribution of light which effects appearance of colours of visual objects as well as spectral distribution. Colour of light from sky was measured in x-y chromaticity in order to collect as much data as possible, as measurements of spectral distribution of light of the whole sky are much more difficult than those of colour of light, and it has been discussed in this paper.

2. MEASUREMENTS

The measurements were carried out in 1976, 1977, 1985 and 1988 at Nagoya in Japan as shown in Table 1[1],[2]. The total number of measurements was 71.

Measured points were scattered almost evenly over a half of the sky, because the two hemispheres devided by an azimuth through the sun and the zenith were considered to be approximately same characteristics of colour. The number of measured points on the half sky were 129 in maximum to 55 in minimum as shown in Table 1. Colour of light from sky was measured by point by point method using one of two types of the colour luminance photometer (BM-2 and BM-5) with apertures of 1°, 0.5°, 0.2° or 0.1° as also shown in Table 1.

Luminance distribution of the sky was measured simultaneously by the photometric photometry or the colour luminance photometer (BM-2 or BM-5) by point by point method too.

3. ARRANGEMENT OF THE DATA

All the measured data were converted into correlated colour temperature in Kelvin[3] in order to examine them simply.

The examples of the distribution of measured sky colour temperature of clear sky, overcast sky and one of the other skies are shown in orthographic projection with the luminance distribution on the whole sky in Fig.2.

The average of sky colour temperature in each measurement is calculated from converted colour temperature at each sky element considering its solid angle at the sky element.

The total average of the averages of sky

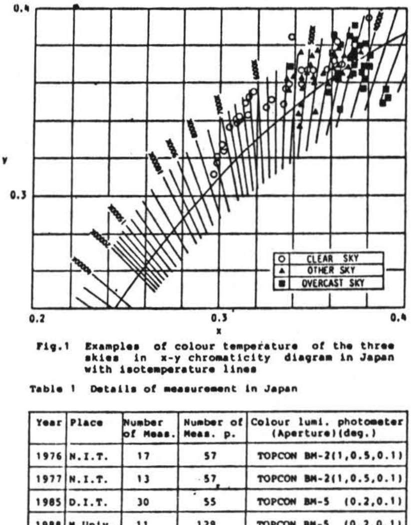

Fig.1 Examples of colour temperature of the three skies in x-y chromaticity diagram in Japan with isotemperature lines

Table 1 Details of measurement in Japan

Year	Place	Number of Meas.	Number of Meas. p.	Colour lumi. photometer (Aperture)(deg.)
1976	N.I.T.	17	57	TOPCON BM-2(1,0.5,0.1)
1977	N.I.T.	13	57	TOPCON BM-2(1,0.5,0.1)
1985	D.I.T.	30	55	TOPCON BM-5 (0.2,0.1)
1988	M.Univ.	11	129	TOPCON BM-5 (0.2,0.1)

N.I.T. : Nagoya Institute of Technology
D.I.T. : Daido Institute of Technology
M.Univ.: Meijo University

Table 2 The total average of the averages and the maximum and the minimum of the average of colour temperature in Japan

	Clear sky	Overcast sky	Other sky	Total
Number of data	28	26	17	71
Maximum and Minimum(K)	8,000 -16,000	5,500 -6,500	6,500 -8,000	5,500 -16,000
Total average(K)	10,200	6,120	7,250	8,380

colour temperature of measured data and the maximum and the minimum of them are shown in Table 2.

4. RESULTS

The results of this research are as follows;

(I)Clear sky

- (a)The nearer to the sun, the lower colour temperature is.
- (b)The nearer to the point about 90 degrees away in angular distance from the sun through the zenith, the higher colour temperature is.
- (c)At a sky element of which colour temperature is high, luminance at the element has a tendency to be low.
- (d)The average of colour temperature of the whole sky is considered to be higher than those of the other sky.
- (e)The difference of average colour temperature among the clear skies is larger than those of the other sky.

(II)Overcast sky

- (a)In geneal, the higher the altitude of a sky element is, the higher colour temperature is.
- (b)The average of colour temperature of the whole sky is considered to be lower than those of the other sky.
- (c)The difference of average colour temperature among the overcast skies is less than those of the other sky.

(III)Other Skies
(not clear sky and not overcast sky)

- (a)The averages of colour temperature seems to be effected by amounts and types of clouds or mists and to be intermediate between the Clear Skies and the Overcast Skies.
- (b)The characteristics of colour temperature distribution are complicated and their tendency can not be explained in this stage.

5. CONCLUSIONS

As the result of the consideration, colour temperature of sky element and its distribution are considered to be related to sky luminance and its distribution.

The outline of sky colour temperature and its distribution has been investigated and discussed.

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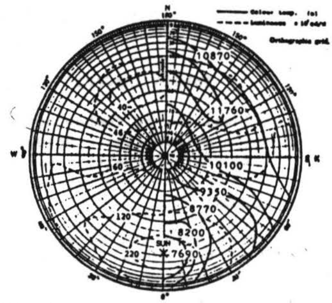
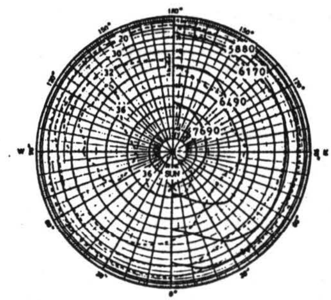
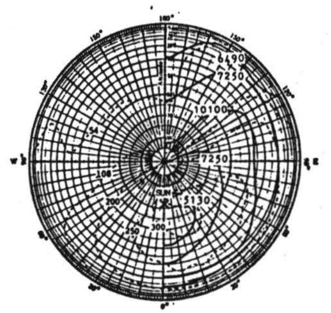


(a) Clear Sky
Date 22 October 1976
Japan time 11h 17m
Solar altitude 43 49'
Solar azimuth 06 43'
Zenith liminance 5.4 x 10^3 (cd/m^2)



(b) Oovercast Sky
Date 06 July 1976
Japan time 11h 26m
Solar altitude 75 19'
Solar azimuth 27 34'
Zenith luminance 11.3 x 10^3 (cd/m^2)



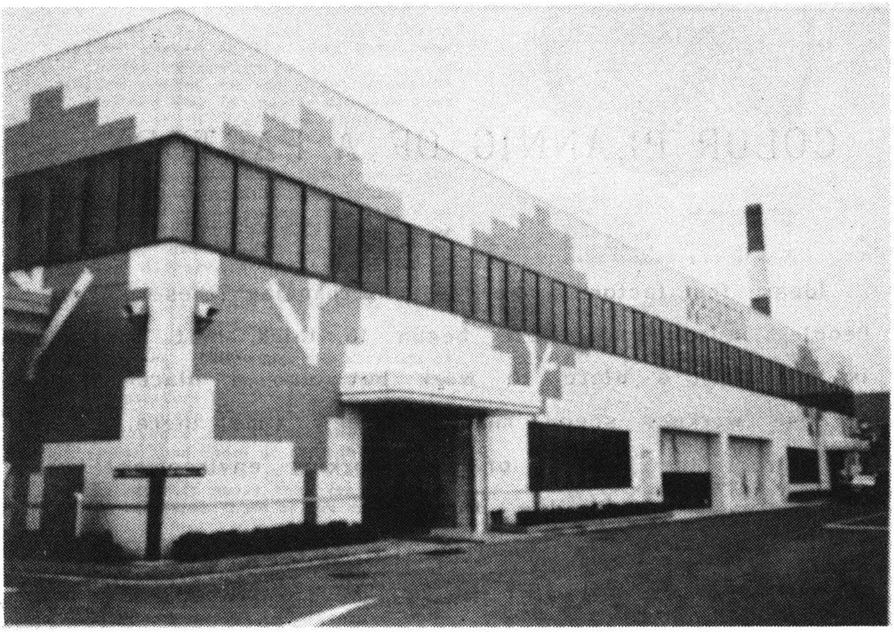
(c) Other Sky
Date 09 July 1976
Japan time 11h 14m
Solar altitude 73 56'
Solar azimuth 37 56'
Zenith luminance 18.7 x 10^3 (cd/m^2)

Fig.2 Colour temperature and luminance distribution of the three skies as shown in Fig.1

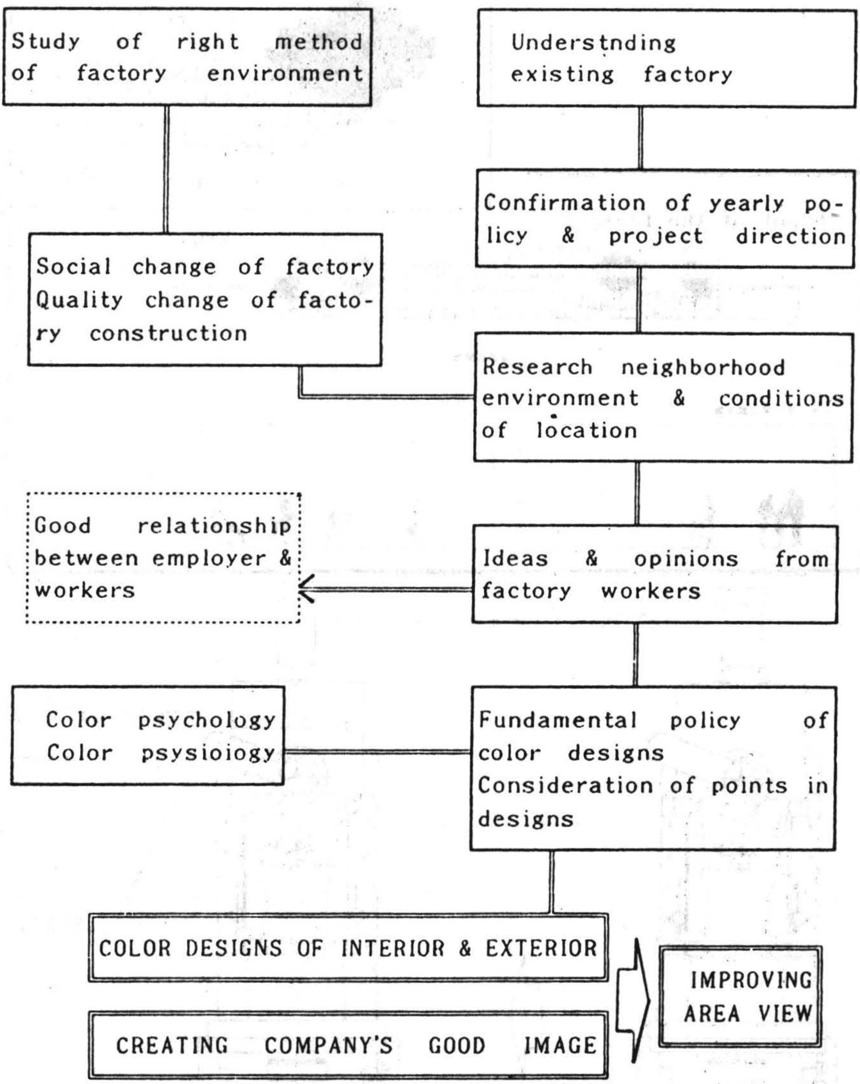
TOMIE INAMINE & HARMAN CORPORATION
1-18-31 HGASIYODOGAWAKU HIGASINAKASIMA OSAKA JAPAN
JAPAN COLOR TECHNOLOGY INSTITUTE(seiwa bldg #810)

COLOR PLANNIG OF A FACTORY

Ideas for factories have been changing these days. People , in general , have begun to think that a factory is not only a place to work but also a place to live because workers spend most of their time there.
Therefore , the quality of the working environment must be improved inside the factory.
Outside , the factory should give favorable impressions. It should blend in with its neighbourhood and surroundings as well as co-operate and have good communication with the residents. That is not the image factories used to have. In reflecting such demands of the times we have designed coloration of interior and exterior for HARMAN CORPORATION in order to create a comfortable working environment and to encourage sales promotion by enhancing the corporate identity.

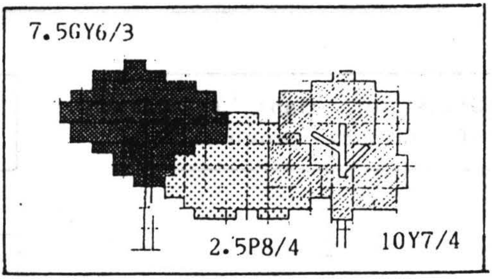


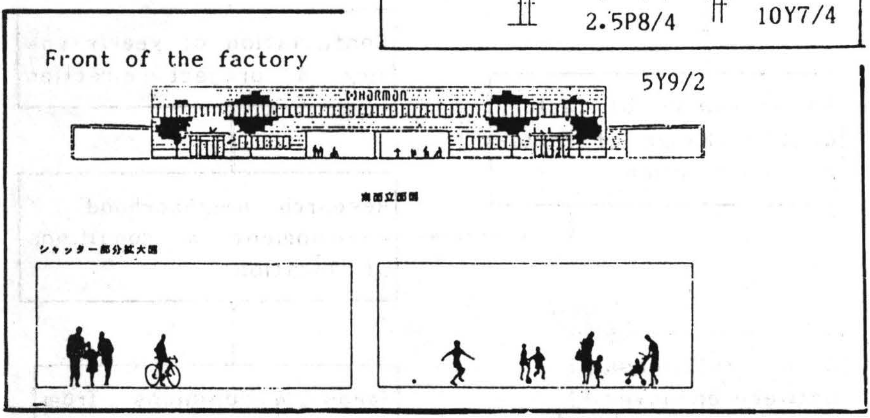
FLOW CHART OF COLOR DESIGN OF HARMAN'S NEW FACTORY



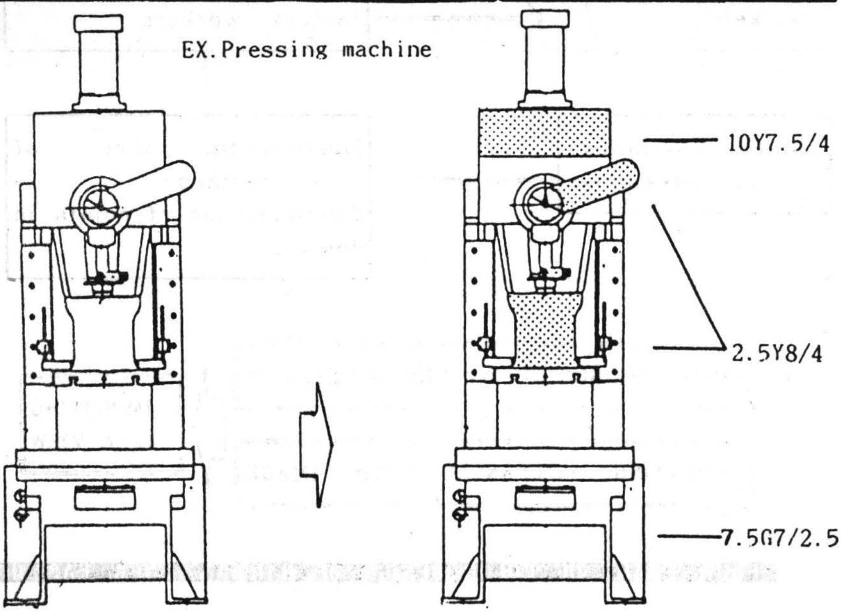
FLOW CHART OF COLOR DESIGN OF HARMAN'S NEW FACTORY

Magnifying front design





EX.Pressing machine



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JAPANESE COLOR PREFERENCES
- Pattern Classification Based on a Database Image Survey -

1. Aim

The need to gain a knowledge of the preferences and tastes of Japanese people is becoming increasingly evident among persons overseas who export merchandise to Japan. We thus conducted a survey in Japan's two major cities, Tokyo and Osaka, of the preferences of 400 persons in each city. Each sample of 400 persons consisted of an equal number of men and women and was classified into four groups consisting of 50 persons each: students, and persons in their twenties, thirties, and forties. Differences in preferences between the groups were expressed in the form of color image patterns.

A detailed study was also carried out to identify products whose selection was determined by these preferences.

2. Method

(1) Survey sheet: A database image survey sheet (Table 1) containing 180 image terms was used.

(2) Color combination software: 1,800 color combinations consisting of 10 three-color combinations for each image were classified qualitatively and arranged in the image space to correspond to the survey sheet with its list of 180 image terms.

(3) Test subjects: The test subjects were asked to select 20 of their favorite image terms from the database image survey sheet. The selected image terms were then displayed for test subjects individually or in groups as image patterns on the screen of a personal computer. Such image patterns can also be output to a color printer after image processing. We would like here to show the results in the form of patterns indicating the preferences of the individual groups of 50 persons. Differences in patterns indicate differences in preferences (e.g. for "soft" colors).

3. Results

(1) The 20 image terms selected were divided into 16 image categories.

(2) Three-color combinations were displayed in color on the image panels for the warm/cool and soft/hard axes or the clear/greyish and soft/hard axes. (See examples in Figs. 1. - 6)

(3) The following 20 image terms were those most frequently chosen and thus indicate the sentiments common and most meaningful to Japanese people.

1. Natural (317)
2. Refreshing (302)
3. Restful (292)
4. Clean (282)
5. Pretty (263)
6. Tender (249)
7. Simple (249)
8. Healthy (244)
9. Familiar (242)
10. Fresh (222)
11. Placid (221)
12. Free (219)
13. Simple and appealing (216)
14. Pure and simple (213)
15. Refined (212)
16. Domestic (205)
17. Peaceful (198)
18. Intellectual (195)
19. Enjoyable (195)
20. Graceful ((186)

Note: Numbers in the brackets represent the number of subjects selecting that image term.

FIGURE:Examples of Japanese Color Preference

Fig.1 Group Women,Tokyo

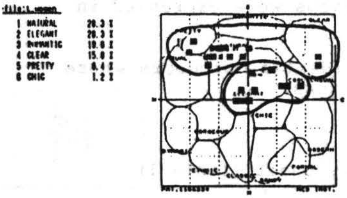

Fig.2 Group Men,Tokyo

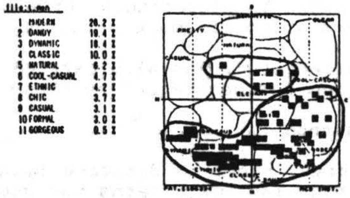

Fig.3 Group Students,Tokyo

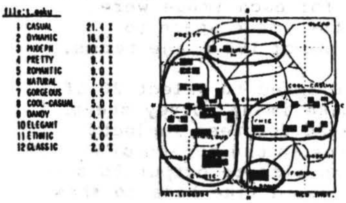

Fig.4 Group Persons twenties,Tokyo

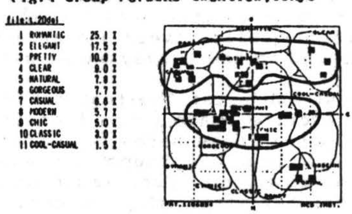

Fig.5 Group Persons thirties,Tokyo

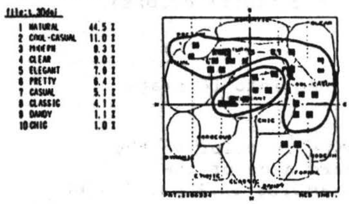

Fig.6 Group Persons forties,Tokyo

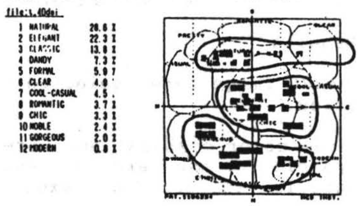

Table 1. 180 Image Terms

1	emotional	61	interesting	121	dynamic
2	sweet	62	sharp	122	polished
3	pretty	63	sublime	123	gentle and elegant
4	soft	64	precise	124	dry
5	crystalline	65	peaceful	125	tropical
6	refreshing	66	stout	126	noble and elegant
7	pure and simple	67	conservative	127	fascinating
8	natural	68	open	128	active
9	fresh	69	lofty	129	feminine
10	nimble	70	folksy	130	sound
11	youthful	71	domestic	131	decorative
12	refined	72	provocative	132	child like
13	quiet	73	innocent	133	assiduous
14	intellectual	74	sweet and dreamy	134	wild
15	solemn	75	dreamy	135	sedate
16	masculine	76	pure	136	gorgeous
17	subtle and mysterious	77	lighthearted	137	vivid
18	quiet and sophisticated	78	free	138	simple
19	heavy and deep	79	familiar	139	dauntless
20	placid	80	gentle	140	dewy
21	traditional	81	subtle	141	vivid and intense
22	untamed	82	simple and appealing	142	extravagant
23	bold	83	neat	143	amiable
24	luxurious	84	vigorous	144	noble
25	mellow	85	large-hearted	145	delicious
26	brilliant	86	mild	146	precious
27	stylish	87	fresh and young	147	clean and fresh
28	graceful	88	young	148	robust
29	pleasant	89	steady	149	Japanese
30	calm	90	fleet	150	hot
31	tender	91	sporty	151	mysterious
32	friendly	92	alluring	152	forceful
33	enjoyable	93	substantial	153	smooth
34	bright	94	modest	154	salty
35	lively	95	pastoral	155	grand
36	colorful	96	dignified	156	earnest
37	plain	97	exact	157	sweet-sour
38	progressive	98	rational	158	proper
39	clear	99	composed	159	sunshiny
40	charming	100	fiery	160	clean
41	supple	101	dynamic and active	161	bitter
42	delicate	102	tasteful	162	joyful
43	tranquil	103	rustic	163	Western
44	chic	104	classic	164	mirthful
45	elegant	105	majestic	165	aromatic
46	romantic	106	metallic	166	noble and dignified
47	healthy	107	serious	167	pristine
48	mature	108	authoritative	168	august
49	showy	109	festive	169	cheerful
50	sober	110	casual	170	genteel
51	urbane	111	flamboyant	171	cultured
52	modern	112	formal	172	merry
53	simple, quiet and elegant	113	dapper	173	complex
54	fashionable	114	sleek	174	citrus
55	rich	115	agreeable to the touch	175	nostalgic
56	elaborate	116	glossy	176	aqueous
57	intense	117	smart	177	fruitful
58	provincial	118	light	178	dazzling
59	sturdy	119	cute	179	pure and elegant
60	practical	120	old-fashioned	180	restful

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THE MYTH OF THE WHITE OFFICE

As a capitalistic nation, the USA is concerned with productivity. For example, American employers are continually trying to increase worker output. Several researchers claim that by improving worker satisfaction with the workspace and thus the job in general, one can also increase the employee's productivity (Brill, Margulis, & Konar, 1984; 1985; Wineman, 1982). It has been speculated that environmental color is a catalyst that may induce a series of behavioral reactions related to worker satisfaction, as well as mood, absenteeism, and tardiness (Becker, 1981). Oldham and Fried (1983) found that darkness of the workspace, along with other aspects of the environment, predicted worker satisfaction.

Neither overstimulation, which may induce stress, nor understimulation which may result in monotony for the worker, is appropriate for an office (Mahnke & Mahnke, 1987). Oldham and Rotchford (1983) found that individuals had difficulty focusing on their work when they were overstimulated by the environment. A designer has the responsibility to determine the balance between too much complexity and a lack of variety in the office environment. Color is a viable resource for designing an appropriate environment for a workspace.

The white office is ubiquitous to American businesses. A stark work environment is assumed conducive to productivity and may create the appearance of technological advancement. However, a white office may understimulate the worker. Mahnke and Mahnke (1987) state that the American population has been conditioned to a white office by its overabundant use, but suggest that there are better alternatives. Over forty years ago Louis Cheskin (1947) said, "White walls...are an optical strain and a psychological hazard." Mahnke and Mahnke (1987) are hopeful that color will be the vanguard for the office environment.

Experiments were conducted to test the notion that a white office is the best color for a work environment. Three realistic offices (8 ft wide, 11 ft 9 in long, and 8 ft 9 in high) were built and furnished with a desk, two chairs, books, a window, lamp, small plant, fan, phone, two framed prints and certificate (11" x 15"), small desk, file cabinet, stool, and other office amenities. Each office was lighted artificially by four Westinghouse recessed flourescent bulbs, each with forty watts of cool white light (F40CW) shining through four translucent fiber glass luminous panels. The desk lamp had a three-way 120V incandescent bulb set at 80 watts and radiated through a white, translucent lamp shade. The temperature of the offices was controlled between 72 and 78 degrees Fahrenheit.

In the first experiment subjects worked in either a red (Munsell color notation 6.05R 4.59/11.15), white (Munsell color notation 9.75YR 8.74/0.45), or green (Munsell color notation 1.51PB 4.95/8.05) office. An equal number of males and females were administered standardized number and name proofreading tests - common office tasks - in one of the monochromatic offices. The subjects also completed the Profile of Mood States Questionnaire (POMS; McNair et al., 1981) before and after they worked in one of the offices so any changes in mood could be assessed. The POMS gives scores on six scales: Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment. The subjects were administered a final questionnaire on which to indicate their color preferences, opinions on how the color might have affected their mood and performance, and assessment of whether they found the office spacious or confining. For the second phase of the experiment, the three offices were painted either orange (Munsell color notation 3.15YR 6.23/12.63), yellow (Munsell color notation 4.06Y 7.99/12.11), or blue (Munsell color notation 2.43PB 5.12/10.51), and subjects followed the same procedures as in the first experiment.

The main finding was that subjects who worked in the white office made a significantly greater number of errors, especially on the name comparison test (the second test) than the subjects who performed in the offices of the other colors. In terms of productivity, the findings suggest that a stark white office may not be the best choice for a work environment. However, the subjects selected white more than any other color as the most appropriate for a work environment. These results imply that Americans believe white is most appropriate for an office. This myth is now being challenged. Has not white been chosen for the office environment out of convenience and uniformity rather than based on human response?

The experimental results also suggest that color preference may be psychologically important for the worker. In the first experiment subjects who reported that they did not like the color of the office in which they worked or indicated that they would not like to work in that office environment experienced a significant increase in tension as reflected by their responses on the POMS. More subjects indicated that they would prefer blue over other colors for their office environment. Although white was a second choice for an office environment, it was at the bottom of the list of the subjects' favorite colors.

People design their homes and select colors for environments to make their surroundings more aesthetically pleasing and livable. Similarly, the office environment in which many Americans spend up to sixty hours per week should be comfortable, aesthetic, and pleasant along with being functional. Through judicious use of color in the office, the employee, along with the employer, could be more productive and satisfied.

During the next few months, experiments will be conducted in which subjects will work in offices painted either black, gray, or purple. The results from these three experiments will be combined, anaylsed, and presented in Argentina. Long-range plans include testing subjects in more realistic color schemes than just monochromatic offices.

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COLORIMETRIE DU BOIS DE SIX ESSENCES DU MAQUIS MEDITERRANEEN (ITALIE): DESCRIPTION, IDENTIFICATION ET POSSIBILITE DE TRI.

WOOD COLORIMETRY OF SIX SPECIES FROM THE "MEDITERRANEAN BUSH" (ITALY): DESCRIPTION, IDENTIFICATION AND POSSIBILITIES OF WOOD SORTING.

LAVISCI Paolo* - JANIN Gérard** - UZIELLI Luca***

RESUME

Le bois en tant que matiére premiére peut être caracterisé par son aspect et sa couleur.

L'exemple fourni par les six essences méditerranéennes traitées dans ce raport montre bien que la mesure de la couleur ou les coordonnées chromatiques constituent des critères nouveaux et utiles, qui contribuent à leur description technologique.

De plus nous avons montré que l'on peut obtenir un TRI ou séparation des deux essences, difficiles à distinguer, à l'aide des coordonnées chromatiques CIELAB: L*, a*, b* ou C* et H*, qui correspondent mieux au mecanisme de perception de l'oeil humain.

SUMMARY

Wood, as a raw material, can be characterized by its appearance: aspect and colour. The example given by the six mediterranean wood species described in this report shows that colour measurements and chromatic coordinates are new and useful criteria which contribute to their technological description.

Moreover we showed that a WOOD SORTING can be performed to separate two species, uneasily distinguishable by the naked eye, by means of their CIELAB chromatic coordinates: L*, a*, b* or C* and H* which correspond better to the human eye's perception mechanism.

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INTRODUCTION

L'aspect, et donc la couleur, est un facteur clé de qualité pour beaucoup de produits en bois (Beckwith, 1979 - Janin, 1986).

La colorimetrie est l'une des plus nouvelles et des plus interessantes methodologies qui permettent d'étudier certaines caractéristiques macroscopiques et physiques du bois (Hofmann, 1987 - Lavisci, 1988).

Au cours d'une recherche sur la qualité des bois de six essences du maquis méditerranéen (caractéristiques physico-mécaniques et essais de tournage), des mesures de la couleur du bois dans des conditions différentes, ont permis de:

- étudier la variabilité de la couleur pour chacune des six essences
- décrire et interpréter une anomalie (bois de coeur anormal) réperée dans le bois d'Arbousier (&Arbutus unedo&)
- définir des critéres de séparation fondés sur leurs coordonnées chromatiques pour les bois de deux essences: Bruyère (&Erica arborea&) et Arbousier (&Arbutus unedo&), difficiles à distinguer à l'oeil nu
- évaluer l'influence du type d'illuminant utilisé (type A et D65) sur le choix des caractéres chromatiques: L*, a*, b*, C*, H* les plus utiles lors de l'identification et du tri industriel des bois.

Les mesures ont été exécutées en se référant aux Normes ISO 7724-84 et UNI-ISO 8941 (publication à paraître) à l'aide d'un spectrophotométre, sur une surface tangentielle dont la finition de l'etat de surface est obtenue avec du papier abrasif à grain fin (degré 180) dans le sens du fil du bois.

Les éprouvettes ont été equilibrées en atmosphére 20/65, selon la Norme ISO 554 (T=20°C, Hr=65%).

RESULTATS

1 - Les six essences méditerraneénnes

Le Tableau 1 donne les valeurs moyennes des coordonnées chromatiques L*, a*, b*, C* et H* mesurées, pour chaque essence, dans les conditions d'illumination specifiées (legende tableau n°1). Toutes ces valeurs caractérisent la variable "couleur" des bois considerés.

2 - Le TRI

Le Tableau 2 montre que l'utilisation de l'illuminant A (par rapport à l'illuminant D65) augmente les possibilités d'identification des deux essences, parce que il exalte les differences des couleurs associées aux longueurs d'onde > 600 nm.
En effet, la seule utilisation de L* et H* pour l'illuminant D65, n'aurait pas été suffisante pour distinguer les deux bois, bien que l'oeil soit trés sensible à ces caractéres.

Les Figures 1 et 2 montrent que avec une forme simplifiée de "cluster analysis" il est plus aisé de distinguer le bois de Bruyère de celui d'Arbousier, par la combination de deux paramètres colorimetriques: H*/b* (Fig.1) et L*/b* (Fig.2).

CONCLUSION

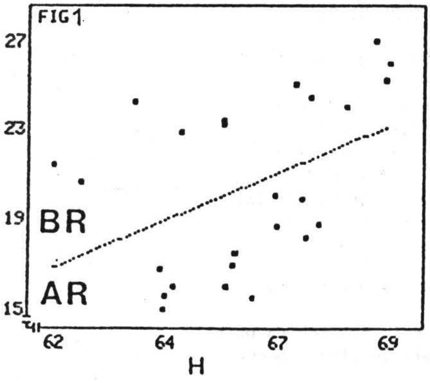
Les mesures de la couleur appliquées au bois donnent des bons resultats expérimentaux, et fourniront dans le futur le moyen de classer les bois en qualité, de les choisir et de pratiquer le TRI pour la realisation de divers produits en bois.

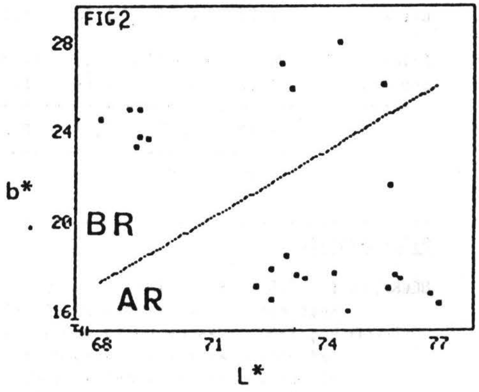
TABLEAU 1

COORDONNEES CHROMATIQUES CIELAB ET LCH DU BOIS DES SIX ESSENCES
CIELAB and LCH chromatic coordinates of the six wood species
SURFACE TANGENTIELLE - GEOMETRIE 8/d - ILL. D65 - CIE 10° ST. OBS.
Measures taken on tangential surfaces (see also French caption)

ESSENCE / Species		L*	a*	b*	C	H
	! AUB	80.55	3.66	19.88	20.22	79.07
Arbutus	! DUR	71.60	8.95	17.61	19.78	65.84
unedo	! DUR ANOR	58.18	14.73	16.91	22.50	50.52
Erica	! AUB	79.43	4.56	23.54	23.98	79.14
arborea	! DUR	70.19	10.37	24.13	26.35	66.09
Fraxinus ornus		79.91	3.10	18.02	18.30	81.73
Phyllirea latif.		79.91	4.33	19.58	20.06	77.09
Rhamnus	! AUB	71.46	6.43	30.39	31.10	78.57
alaternus	! DUR	47.68	9.66	17.72	20.20	64.33
Juniperus	! AUB	78.91	5.38	24.75	25.34	77.43
phoenicea	! DUR	62.34	14.33	34.76	37.64	67.80

AUB = AUBIER / sapwood DUR = BOIS DE COEUR / heartwood
DUR ANOR = BOIS DE COEUR ANORMAL / abnormally coloured heartwood





FIGURES 1 - 2
SEPARATION DES BOIS DE DEUX ESSENCES PAR COMBINATION
DE LEURS COORDONNEES CHROMATIQUES
Separation of wood from two species through the combination
of their chromatic coordinates
BR = Erica arborea ; AR = Arbutus unedo

TABLEAU 2

POSSIBILITES DE TRIER DEUX ESSENCES SELON LES
DIVERSES COORDONNEES CHROMATIQUES EN UTILISANT DEUX ILLUMINANTS
(A et D65) - 10 MESURES PAR SERIE
Separation of two species from their
chromatic coordinates measured with two illuminants (A and D65)
10 measurements each series

/////// Standard Illuminant D 65 ///////

ESSENCE / Species	L*	a*	b*	C	H	
Arbutus	71.60	8.95	17.61	19.78	65.84	Average
unedo	2.05	0.71	1.58	1.38	1.04	St Dev
Erica	70.19	10.37	24.13	26.35	66.09	Average
arborea	2.62	1.82	1.78	1.19	2.23	St Dev
	1.53	2.69	9.89	12.88	0.37	t calculé
	80	98	99	99	20	NIVEAU de CONFIANCE (%)

****

/////// Standard Illuminant A //////////

ESSENCE / Species	L*	a*	b*	C	H	
Arbutus	73.53	8.48	19.01	25.68	56.08	Average
unedo	2.16	0.93	1.33	1.23	1.08	St Dev
Erica	70.36	10.7	24.62	31.58	57.26	Average
arborea	1.08	0.47	1.84	1.71	0.79	St Dev
	4.15	6.73	7.81	8.85	2.78	t calculé
	99	99	99	99	98	NIVEAU de CONFIANCE (%)

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Coloris et couleur - figure comme types expressifs dans l'art des jardins en France et en Angleterre, 1830 - 1930.

Les études récentes sur l'art des jardins ont surtout porté sur la période qui s'étend de la Renaissance au XVIIIe siècle avec une optique paysagère privilégié Cette période correspond à la domination d'un type expressif : le coloris. Très peu de recherches portent sur l'art des jardins des XIXe et XXe siècle et encore moins (cela est possible) sur l'usage des couleurs qui les caractérise. Or cette période est fondamentale en ce qui concerne l'actualisation et la création de nouveaux types expressifs.

Types expressifs

Les types expressifspermettent de dépasser l'analyse ponctuelle des phénomènes couleurs en se situant dans le langage, sur le plan de l'expression. Les types expressifs se présentent comme des agglomérats culturels, ancrés dans l'histoire des modes d'expression, inscrits dans les images quotidiennes,mis en oeuvre autant en peinture, en architecture, que dans l'art des jardins.
Ils constituent des galaxies fécondes, des pôles d'attraction puissants pour les couleurs. Les couches géologiques qui les instituent par transformations et sédimentations successives (le coloris du XVIe siècle, du XVIIIe siècle...) imposent un travail d'archéologue de l'imaginaire.
Le type expressif, enfin, par son enracinement technique, fait partie de la boite à outil du créateur de jardins.
Comme pôles formels, ils s'orientent soit vers le coloris (qui s'est imposé au XVIe siècle) soit vers la couleur-figure (ré-inventée au XIXe siècle).

Le coloris

De 1830 à 1930, dans l'art des jardins européens, la mise en oeuvre du coloris dans l'art des jardins va se référer continuellement à la peinture. Les grands principes du coloris élaborés du XVIe au XVIIIe siècle vont être appliqués.

- L'imitation (de l'apparence, de la nature) qui, en peinture, donne l'effet bulle de la perspective aérienne, de la totalité reconstituée opère dans l'art des jardins une relation d'analogie sur le mode du plus semblable que.
Le jardin paysager est plus nature que la nature dans sa totalité. La perspective dei colori impose, par exemple, le feuillage bleu dans les lointains et, de là, un hommage métaphysique au bleu.

- La séparation du dessein et du coloris avec, aspect plastique, le modelé des massifs et, aspect rhétorique, la mise en ordre des jardins réguliers lors de la restauration des jardins de la Renaissance (Villandry entre 1906 et 1924) et de ceux des XVIIe et XVIIIe siècle.*

* Par exemple, les restaurations d'Achille Duchêne (1866-1947) à Vaux-le-Vicomte Champs sur Marne(France), Blenheim Palace (Angleterre)

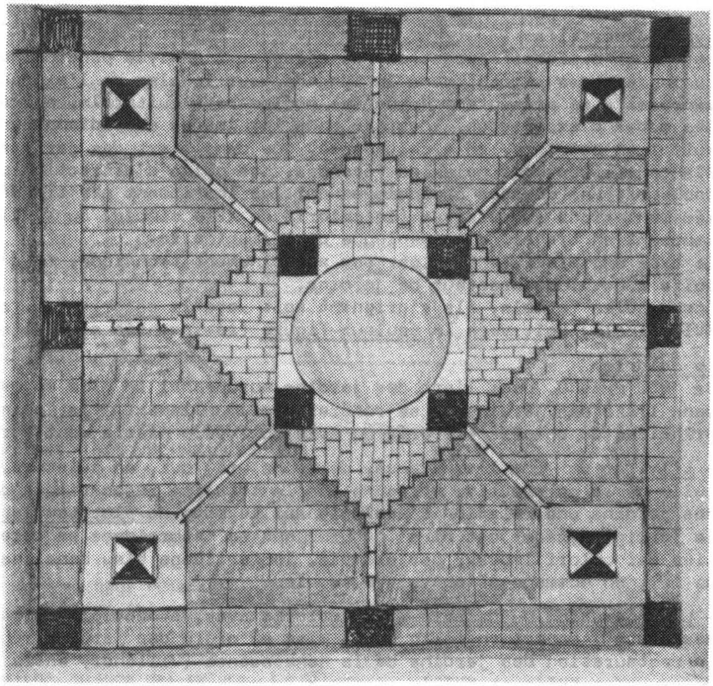
- La distinction entre couleur et coloris :

L'art des jardins, grâce aux progrés de l'horticulture possède une véritable palette de couleurs (rhododendrons, azalées, plantes naines à feuillage coloré...) Mélange des couleurs (dans les massifs) et, surtout couleurs locales (relation de distance) font les jardins du XIXe siècles - jardins victoriens en Angleterre et du Second Empire en France.

- le coloris à une logique qui suit les figures du discours tenu par les parcs et jardins de cette époque - au jeu du jour principal et des repoussoirs en peinture peuvent être mis en parallèle dans l'art des jardins, avec les combinatoires de percées, de clairières et d'ombrages.

La couleur-figure

Ce n'est que plus récemment que d'autres usages de la couleur ont été explicités et théoricisés dans l'art des jardins.
La couleur-figure, autre polarité des types expressifs, alliance chimérique et indissociable de la couleur et de la figure ne prétend pas tant à représenter un / plus semblable que / qu'à produire un/ plus réel que /, à réaliser l'invisible. La couleur-figure dans l'art des jardins suit les différentes modalités de la figure selon qu'elle est figurée (couleur cernée,fixée, marquée du blason), qu'elle est figurante (modulation, color-scheme) ou, enfin, qu'elle se déploie en extension (color-field).



Ferdinand BAC. Projet pour la cour pavée de la villa CROISSET, Grasse France.

A la couleur-figurée correspondent les jardins qui se réfèrent à la Renaissance (Sissinghurst, Hidcote Manor) et à l'art mauresque (Villandry). Les créateurs de jardins modernes tels que Ferdinand Bac (1859-1952), André Vera et Jean-Claude Nicolas Forestier * (1861-1930) utilisent des variantes de ce type expressif.

La couleur-figurante dans laquelle le facteur temporel, le mouvement interviennent, se manifeste dans les Wall garden de Corenvon ainsi que dans les réalisations de Gertrude Jekyll (1843-1932).
La couleur-champ (color-field) apparaît dans les jardins dédiés à une couleur : jardins blancs de Lawrence Johnston (1871-1958) et de Vita Sackville West (1892-1962) dans le Thym lawn de Sissinghurst (1950).
Les types expressifs, macro-systèmes d'analyses comparatives et différencielles des différents usages de la couleur, reposent sur des micro-systèmes, des paquets de relations (transparent/opacité, clair/sombre, mélange/non mélangé , scandé/non scandé)qui relèvent plus du mythème (unité de mythe) que d'un aspect purement formel ou phénoménal.

* Jean-Claude Nicolas Forestier, avant de superviser les parcs et jardins de l'Exposition Internationale des Arts Décoratifs a, en 1923-4, participer à l'urbanisation de Buenos Aires.

Peter Marx

1. Transimpedanzverstärker zur Messung von Photoströmen und Beleuchtungsstärken

Die meisten Probleme der konventionellen Operationsverstärker entstehen aus dem Einfluß, den die Verstärkungseinstellung auf den Frequenzgang hat. Eine Steigerung der Verstärkung von 1 auf 10 bedeutet eine Reduzierung der Bandbreite auf 1/10. Gleichzeitig verschlechtert sich auch das Impulsverhalten, d.h. die Messung schnell veränderlicher Beleuchtungsstärken (bzw. Photoströme) geringer Intensität kann problematisch werden infolge großer Einschwingzeiten. Bei rechnergeführten Lichtmeßanlagen kann dieser Effekt zu großen unerwünschten Meßzeiten führen.

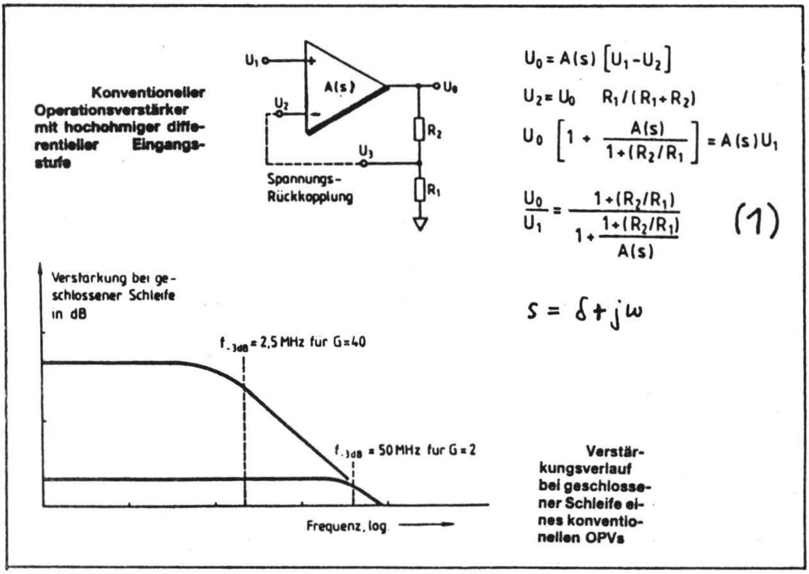


Abb.1: Übertragungsfunktion konventioneller Operationsverstärker

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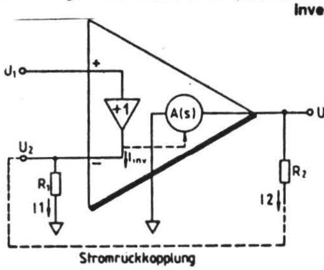
Ein neuartiges OPV-Design, der sog. Transimpedanz-Verstärker, löst die vorher geschilderten Probleme. Als Eingangsstufe dient ein Impedanzwandler mit dem Verstärkungsfaktor 1. Dieser verbindet die beiden Eingänge des Operationsverstärkers miteinander. Im Betrieb wird durch diese Schaltung erzwungen, daß die Spannungen U_2 und U_1 gleich sind, und zwar unabhängig von der externen Rückkopplung durch R_2. Dadurch erhält der invertierende Eingang eine sehr niedrige Eingangsimpedanz, die sich bei geschlossener Schleife weiter reduziert. Diese niedrige Impedanz führt dazu, daß ungehindert Strom in den invertierenden Eingang hinein oder aus ihm heraus fließen kann. Aufgabe des Transimpedanz-Verstärkers ist es, den Strom, der in den invertierenden Eingang hinein oder aus ihm heraus fließt, zu erkennen und in die Ausgangsspannung umzuwandeln.

Wichtigstes Merkmal eines Transimpedanz-Verstärkers ist der hochohmige nichtinvertierende Anschluß und der niederohmige invertierende Anschluß



Das eher ungewöhnliche OPV-Design. Die eigentliche Verstärkung übernimmt ein Transimpedanz-Verstärker

Die Übertragungsfunktion des Transimpedanz-Verstärkers ist $A(s) = U_0/I_{inv}$, gemessen in Ω.

Die Gegenkopplung ist durch den Strom gegeben, der durch R_2 in den invertierenden Eingang fließt. Es gelten folgende mathematische Zusammenhänge:

$$I_{inv} = I_1 - I_2$$

$$I_{inv} = U_2/R_1 - (U_0 - U_2)/R_2$$

Da $U_0 = I_{inv} \cdot A(s)$ und $U_2 = U_1$ (durch den Eingangsverstärker) sind, ergibt sich:

$$\frac{U_0}{A(s)} = U_1\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{U_0}{R_2}$$

$$\frac{U_0}{U_1} = \frac{\frac{R_1 + R_2}{R_1 R_2}}{\frac{1}{R_2} + \frac{1}{A(s)}} = \frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_2}{A(s)}} \qquad (2)$$

Ein Transimpedanz-Verstärker zeigt große Verstärkung über einen weiten Bandbreitenbereich

Abb.2: Übertragungsfunktion eines Transimpedanzverstärkers

Der Vergleich der beiden Übertragungsfunktionen (1) und (2) erlaubt folgende Aussagen.

a) Die Gleichspannungsverstärkung ist mit $1 + R_2/R_1$ für beide OPV-Typen völlig gleich.

b) Im Frequenzgangverhalten sind die beiden Verstärkertypen völlig unterschiedlich. Bei Transimpedanz-Verstärkern verschwindet der verstärkungsabhängige Pol im Nenner, da mit R_2 das Frequenzverhalten festgelegt ist. Unabhängig davon ist mit R_1 die Verstärkung einzustellen.

<u>Ergebnis:</u> Bei richtiger Wahl des Widerstandes R_2 (optimale Werte sind im Datenblatt spezifiziert) erhält man ein Verstärkersystem, das bei Verstärkungen von 1 völlig stabil arbeitet und bei größeren Verstärkungen kaum an Bandbreite verliert. Dabei erfolgt die Berechnung der Verstärkung nach den gleichen Formeln, wie sie für konventionelle OPV's eingeführt sind.

2. Spiralphotometer zur Messung des Lichtstroms von Kompakt-Leuchtstofflampen (KLL)

Das mechanische Abtastsystem gestattet die Messung von KLL in ruhender Brennlage (nach DBP 1928815).

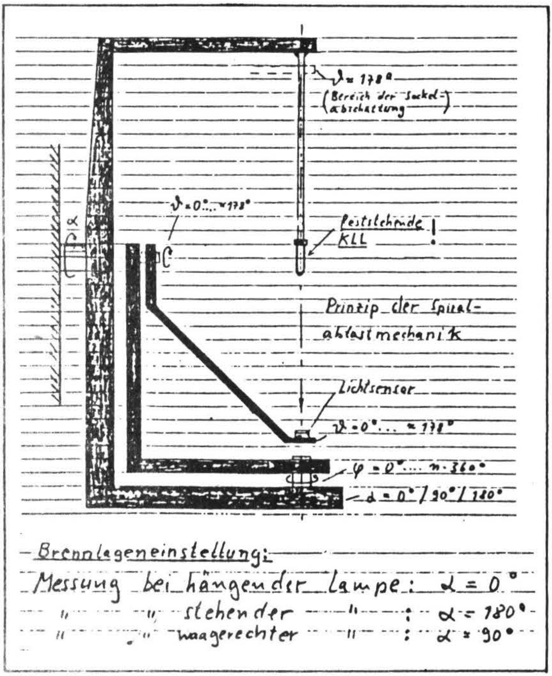


Abb.3: Spiralphotometer zur Messung von Kompakt-Leuchtstofflampen

Mikrocomputergeführte Integrationselektronik

Für die Fläche einer von den Elevationswinkeln ϑ_1 und ϑ_2 begrenzten Kugelzone gilt:

$$A_{Zone} = r^2 \cdot 2\pi \cdot (\cos\vartheta_1 - \cos\vartheta_2) = r^2 \cdot 4\pi \cdot \sin\vartheta_I \cdot \sin\frac{\Delta\vartheta}{2}$$

mit $\vartheta_I = \frac{\vartheta_1 + \vartheta_2}{2}$ und $\Delta\vartheta = \vartheta_2 - \vartheta_1$

Ein zwischen zwei Meridianen liegendes Flächenelement der Kugelzone ist dann

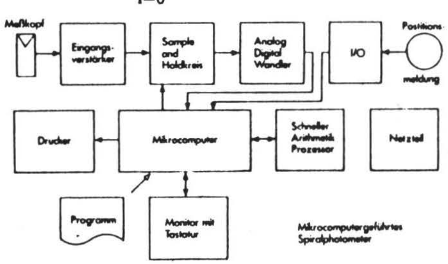
$$\Delta A_{Zone} = 2 \cdot r^2 \cdot \Delta\varphi \cdot \sin\vartheta_I \cdot \sin\frac{\Delta\vartheta}{2}$$

und der hierauf entfallende Teillichtstrom

$$\Delta\Phi = 2 \cdot r^2 \cdot \Delta\varphi \cdot \sin\frac{\Delta\vartheta}{2} \cdot E_I \cdot \sin\vartheta_I$$

Der Gesamtlichtstrom wird nun durch fortlaufende Summation der Teillichtströme längs der Spiralbahn gebildet

$$\Phi = 2 \cdot r^2 \cdot \Delta\varphi \cdot \sin\frac{\Delta\vartheta}{2} \sum_{I=0}^{M} E_I \cdot \sin\vartheta_I \qquad \text{mit} \quad M = \frac{360°}{\Delta\varphi} \cdot \frac{180°}{\Delta\vartheta}$$



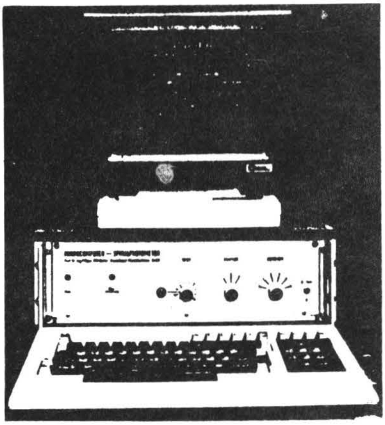
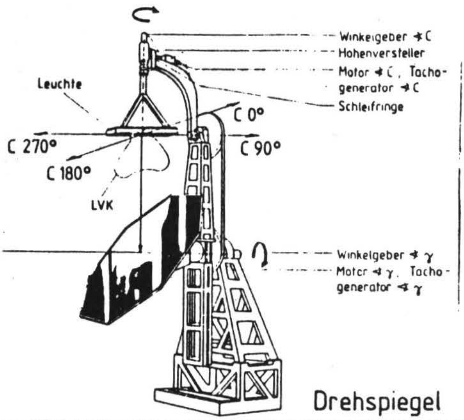


Abb.4: Erläuterung des Spiralphotometers zur Lichtstrommessung von Kompakt-Leuchtstofflampen. Das Photo zeigt das fertige Gerät mit dem integrierten Mikroprozessorsystem Motorola 6809, 4 kByte EPROM, 2 kByte RAM, Arithmetikprozessor AMD 9511, PIA 6821, ACIA 6551 und TIMER 6840. Meßraster: 2 Grad, max. 16200 Meßpunkte pro Gesamtlichtstromintegration werden ausgewertet. Verarbeitungsgeschwindigkeit: 200 Meßwerte pro Sekunde

3. Neuartige raumsparende Drehspiegelsysteme zur Messung von Lichtstärkeverteilungen und Lichtströmen

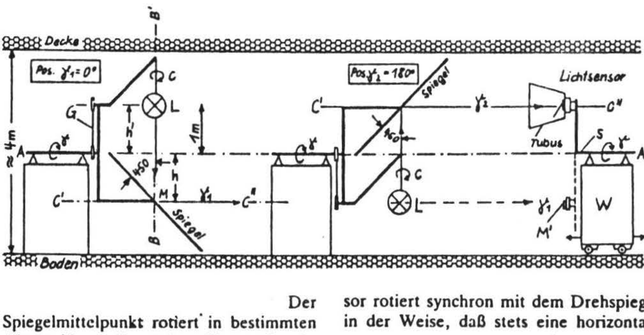
Abb.5 zeigt die vom Autor 1972 konzipierte Drehspiegelkonstruktion, die sich inzwischen bei etwa 25 Anwendern im In- und Ausland bewährt hat. Der entscheidende Nachteil dieser Konstruktion besteht jedoch darin, daß die Bauhöhe rd. 6 Meter beträgt und somit die Baukosten für einen entsprechend hohen Laborraum erheblich sind. Es wurden daher vom Verfasser in diesem Jahr zwei neue Drehspiegelvarianten konzipiert (vgl. Patentanmeldung P 3802115.3 vom 26.1.88), die mit einer Bauhöhe von rd. 4 Metern auskommen und dennoch die Messung von Langfeldleuchten erlauben (vgl. Abb. 6 u. 7).



Drehspiegelsystem: Rotation des Spiegels um horizontale Achse, gleichzeitige Drehung der Lichtquelle um horizontale und vertikale Achse. Raumfester Lichtsensor. Diese Mechanik ist sehr gut geeignet für große Leuchtenhersteller, der technische Aufwand ist erheblich, ein hoher Raum (> 6 Meter) ist erforderlich.

Abb. 5: Konventioneller Drehspiegel mit großer Bauhöhe

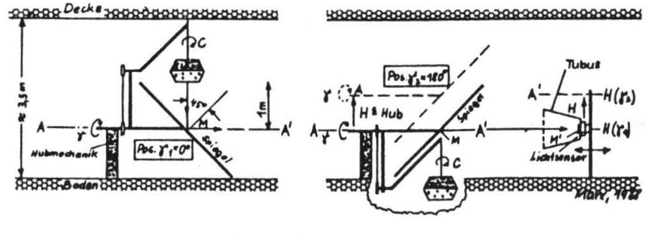
Drehspiegelsystem mit synchron rotierendem Lichtsensor



Der Spiegelmittelpunkt rotiert in bestimmten Abstand h um die ortsfeste Hauptachse A-A'. Diesem gegenüber rotiert die Lichtquelle L im Abstand h' um die Hauptachse und gleichzeitig um die vertikale Achse B-B'. Die stets vertikale Lage der Lichtquellenachse wird durch ein mechanisches 1:1-Getriebe G erzwungen. Der Lichtsensor rotiert synchron mit dem Drehspiegel in der Weise, daß stets eine horizontale Achse gleichzeitig durch die Mittelpunkte des Spiegels und des Lichtsensors verläuft. Der Synchronlauf kann in einfacher Weise durch eine elektrische Welle zwischen der Drehspiegel-Hauptwelle (Achse A-A') und der Welle des Schwenkarms S, an dem der Lichtsensor montiert ist, erreicht werden.

Abb.6: Neues raumsparendes Drehspiegelkonzept 1

Prinzip des Hubdrehspiegels



Hier kann in Abhängigkeit vom Drehwinkel γ die Hauptachse des Drehspiegels A-A' vertikal kontinuierlich oder diskontinuierlich bis zur Hubhöhe H angehoben werden. Synchron wird auch der Lichtsensor kontinuierlich oder diskontinuierlich so in der Höhe verändert, daß die Achse A-A' stets durch den Mittelpunkt des Lichtsensors verläuft.

Abb.7: Neues raumsparendes Drehspiegelkonzept 2

Lichtstärken und Lichtströme werden über die folgenden Beziehungen bestimmt:

$$I = E \cdot r^2 \cdot \frac{1}{\Omega_0}$$

$$\Phi = r^2 \cdot \int_{\vartheta=0}^{\pi} \int_{\varphi=0}^{2\pi} E(\varphi, \vartheta) \cdot \sin\vartheta \cdot d\varphi \cdot d\vartheta \qquad \Phi \approx 4\pi r^2 \cdot \sin\frac{\Delta\vartheta}{2} \sum_{m=1}^{k} \sin\vartheta_m \cdot \frac{1}{n} \cdot \sum_{i=1}^{n} E(\varphi_i, \vartheta_m)$$

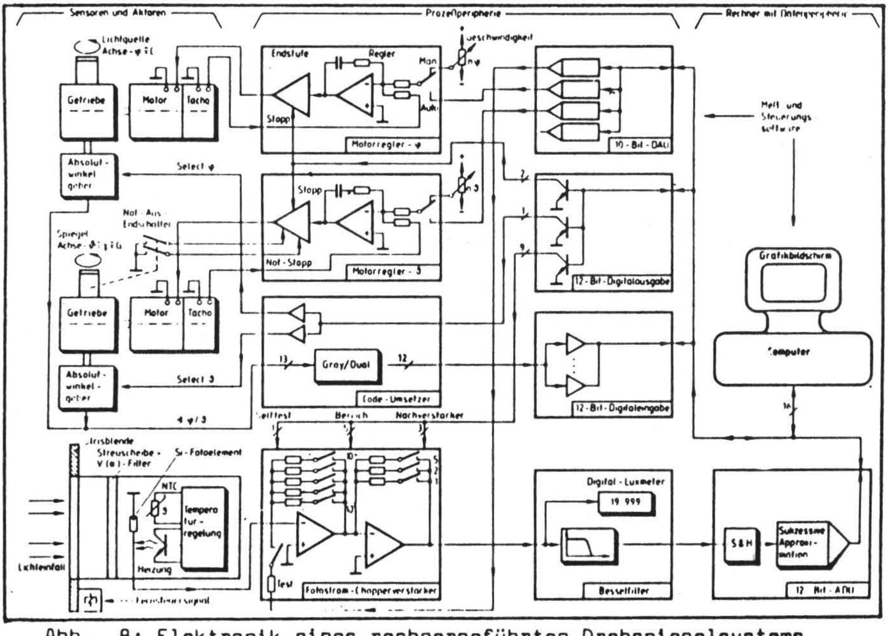


Abb. 8: Elektronik eines rechnergeführten Drehspiegelsystems

Durch eine neuartige Zwangsführung der elektrischen Kabel können Drehspiegelsysteme o h n e Schleifringe um die horizontale Hauptachse beliebig oft in beiden Drehrichtungen umlaufen, d.h. der aufwendige und umständliche Reversierbetrieb mit Notausschaltern bei den Endwinkeln kann entfallen (vgl. Abb. 9).

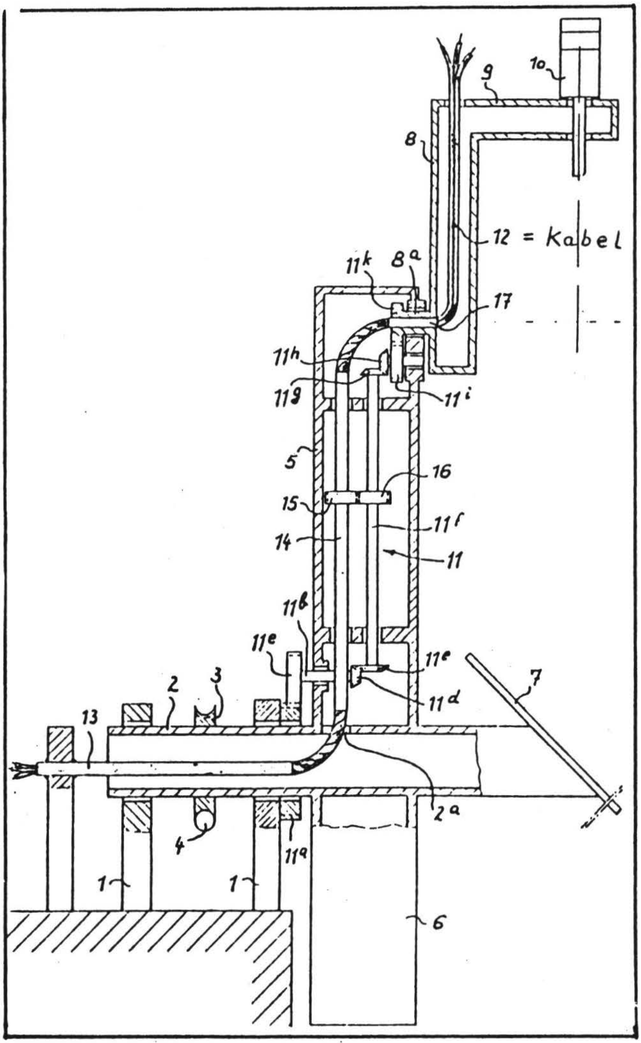


Abb.9: Patentierte Drehspiegelkonstruktion mit Zwangsführung der Kabel, beliebig oft um die horizontale Achse durchdrehbar ohne Schleifringe

4. Moderne rechnergeführte Labormeßtechnik mit IEC-Bus-Meßgeräten und Personalcomputern

Der IEC-Bus - nach DIN IEC 625 - hat sich als Standard-Schnittstelle zwischen Meßgeräten und Steuerrechnern (z.B. Personalcomputern) durchgesetzt und in der Laborpraxis beim Betrieb automatischer Meßplätze mit busfähigen intelligenten Meßgeräten bewährt. Als Programmiersprache wird i.a. BASIC verwendet.

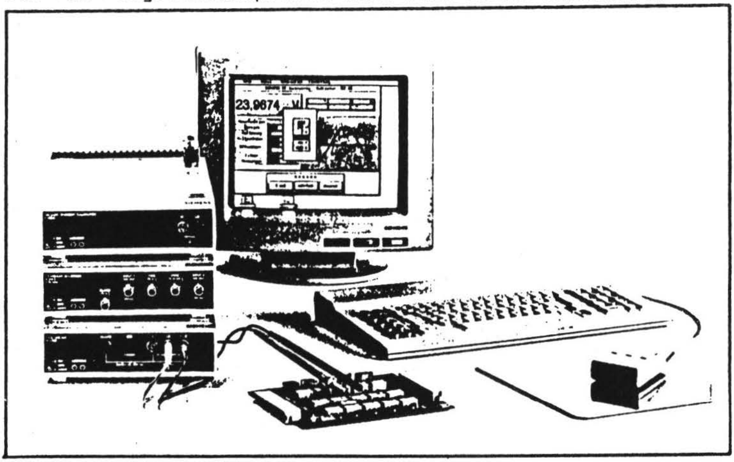


Abb.10: PC-Meßplatz mit IEC-Bus-Geräten. Mittels Windowtechnik werden alle Meßgeräteparameter auf dem Farbbildschirm dargestellt. Die Bedienung erfolgt nur über den PC-Monitor und die Maus.

Auch in der lichttechnischen Industrie wird diese neue Technik zunehmend in Verbindung mit CAD-Systemen für die Leuchtenkonstruktion eingesetzt. Lokale Rechnernetze können realisiert werden. Betriebsmittel wie Drucker, Plotter, Plattenspeicher , Programme und Dateien können gemeinsam mit anderen Netzwerk-Teilnehmern genutzt werden. Die Kopplung kann z.B. über eine koaxiale Busleitung (ETHERNET) erfolgen.Übertragungsrate: 10 Mbit/s.

Literatur:

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Marx, P.;Strung,K.: Ein modernes computergesteuertes Drehspiegelsystem. LICHT 1981, H. 11, S.586...595

DIN 5033 : Farbmessung

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**CITEFA, División Electrónica, Zufriategui y Varela. Villa Martelli (1603). San Martin. Prov. de Buenos Aires, Argentina.

LIGHT COHERENCE AND THE CHROMATIC CONTRAST FUNCTION

It is a well known fact that one of the distinctive characteristics of the coherent (CTF) and incoherent (ITF) transfer functions is the cutoff frequency value.
This value is duplicated in the incoherent transfer function at the expense of the contrast sensitiveness.
This paper analyzes the sensitiveness to contrast of different frequencies at threshold and supra threshold levels, using coherent and incoherent stimulation.
To that effect, a dye laser permitting a spectral 500 to 630nm variation was used. A Ronchi network with spatial frequencies between 3 and 20 cycles per degree, a photometric wedge and a diffuser disk, making incoherent the light coming from the source when rotating, were mounted on the the laser's collimated beam (1).
For all the wave lengths and frequencies analyzed, a loss of luminosity and greater border definition was observed in the ITF case as compared to the CTF. This effect decreased at high and low freceuncy.
It was also observed that when the coherent light was used, the maximum sensitivity point was displaced towards the low frequency.
The influence of color and the determiantion of achromatic threshold were finally examined.
The resulting data - schematically represented in the figure - are analyzed with other previously obtained where the contrast functions linearity was also studied (2).

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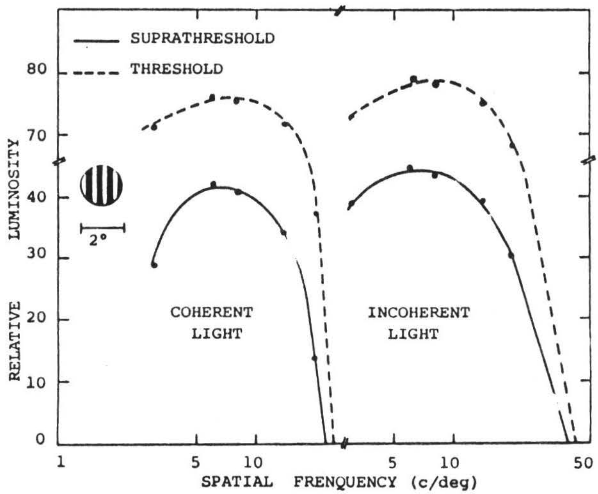

Light coherence and the chromatic contrast function

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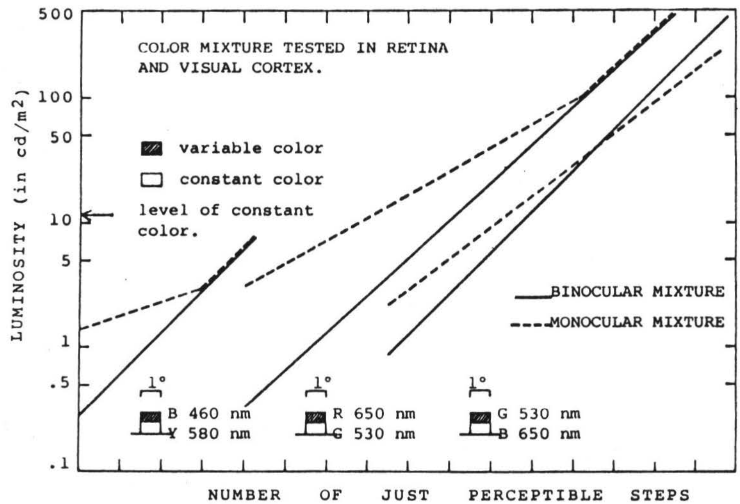
DETERMINATION OF THE RETINA AND VISUAL CORTEX SENSITIVENESS TO ADDITIVE COLOR MIXTURE

The well-known methods of additive color mixture allow the production of spectral color mixtures.
These mixtures may be produced monocularly and binocularly, situations that mainly imply treatment of the information at retinal and visual cortex levels respectively (1,2).

This paper mainly compares the sensitiveness of these two areas by means of a Wright colorimeter (3) to which a second channel furnished with filters has been added. This channel could be finely regulated at the observers'interpupilar distance, in order to obtain an accurate superposition of the stimulus.
The stimulus produced through the additional channel were matched to those from the colorimeter, and thus specified.
The stimulus covered a visual angle of 1°and produced an image entirely within the pupil of the eye. Four observers who participated in the experiment, had normal vision and ages ranging from 20 to 25 years.
The mixtures, considered in independent experimental sections were: red-green; blue-yellow and green-red.
The luminosity remained constant (12 cd/m^2) for the second color of each pair. Consequently, only the first color had variable luminosity.
When the experiment was performed monocularly, the mixture was produced in the classical manner (3), the second channel being switched off.
When working binocularly, the variable color was produced by the colorimeter and the constant color by the additional channel.
The experiment consisted in : a)recognising the just perceptible steps of red, blue and green increments in the mixtures, and b)matching the monocularly and binocularly obtained mixtures.

The result showed that for a monocularly produced mixture, the tested color required greater energy to reproduce an identical binocularly produced sensation. In other words, the monocular mixtures showed less saturation than the binocular ones, especially at low range of luminosity A slight hue change was also observed.

These data appraising the inhibition degree,for the adopted experimental situation, implicit in the monocular mixtures, are schematically represented in the figure.
The relation of the results to the inhibitory phenomena described in the bibliography is discussed, with special emphasis on the part played by the retina and the cortex within the visual system.



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THREE PARADOXES OF WAVELENGTH DISCRIMINATION

In the short-wave part of the spectrum, near 460 nm, there is a region of poor wavelength discrimination (König and Dieterici, 1884; Wright and Pitt, 1935), the 'short-wave pessimum'. We have examined three experimental operations that paradoxically improve discrimination at the pessimum.

Measurements were made by a two-alternative temporal forced-choice method, using monochromators (Bentham Instruments M300E) that have integral stepping motors. The bandwidth of the stimuli was typically 0.9 nm and the centre wavelength of the band could be varied in steps of 0.05 nm. On each trial there were two presentations of a horizontally divided bipartite circular field. On one of the two presentations, the upper and lower halves of the field were of the same wavelength; and on the other presentation, the wavelength of the lower half was greater by an amount $\Delta\lambda$ The subject was required to indicate by pushbuttons on which of the two presentations the two half-fields were different. $\Delta\lambda$ was adaptively adjusted according to the subject's accuracy, so as to track the value that gave 71% correct responses (Mollon and Cavonius, 1987).

Three remarkable results are found at 460 nm:

1. Wavelength discrimination improves as luminance is reduced in the range 100 to 1 troland; near the latter value, thresholds may be as low as 0.5 nm. This result is foreshadowed, between 440 and 460 nm, in the curves of König and Dieterici, who used the method of average error. Their effect was rediscovered by McCree (1960). Figure 1 shows new measurements obtained by two-alternative temporal forced choice.

2. Discrimination improves if the duration of a 50-troland target is reduced in the range 50 to 3 msec. The result is the contrary to that found in other parts of the spectrum; and has not previously been reported.

3. Discrimination improves if a congruent long-wave field is added to both halves of the short-wave stimulus. Phenomenologically, the added field desaturates the discriminanda. The improvement in performance is

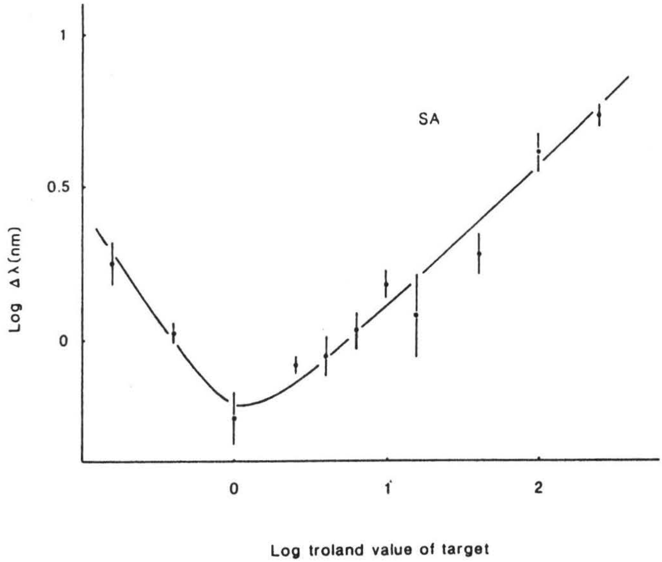

Figure 1. Wavelength discrimination at 460 nm as a function of the troland value of the target. The thresholds shown are the means of four independent runs; within each run the order of troland values was randomized.

paradoxical because, when the long-wave field is added, the sets of quantum catches from the two half-fields must be more similar than they are for the same Δλ in the absence of the long-wave field.

To explain these findings, we consider separately the two main post-receptoral channels of human colour vision. The channel that compares the absorptions in the long- and middle-wave cones cannot sustain good discrimination at 460 nm under any conditions; for near this wavelength, the ratio of quantum catches in the middle- and long-wave cones passes through a shallow maximum and its rate of change with wavelength (on which discrimination must ultimately depend) slows down. The same cannot apply to the phylogenetically older pathway that compares the quantum catch in the short-wave cones with that in the middle-/long-wave cones. In this case, the ratio of absorptions is changing rapidly near 460 nm. Rather we suppose that this post-receptoral channel is driven into a saturating region of its response function by long-duration 100-td lights of 460 nm. Any operation that removes the channel from the saturating region (e.g. a reduction of stimulus energy by shortening the duration or lowering the troland value; or the addition of a long-wave field) will improve performance.

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SPECTRAL REFLECTANCE AND COLOUR OF NAMIB BEETLES

Of the many beetle species living in the Namib desert, some develop a wax layer (wax bloom) on their bodies which reflects a high proportion of the solar irradiance. Measurements were performed at the CSIR to determine the spectral reflectance (0°/d) and the colour of those beetles with and without the waxbloom. The measuring equipment is described and the measurement results are discussed. The chromaticities under illuminant D_{65} are calculated and represented on a CIE chromaticity diagram.

It is shown how these species benefit from a gain in reflectivity over the whole visible spectrum and how well the colour of certain species matches that of the desert sand on which they live.

Unter den vielen Arten von Käfern in der Namib Wüste bilden einige eine Wachsschicht auf ihrem Körper, welche einen hohen Prozentsatz der Sonnenstrahlung reflekliert. Messungen wurden beim CSIR durchgeführt um den spektralen Reflexionsgrad (0/d) und die Farbe dieser Käfer mit und ohne Wachsschicht zu bestimmen. Die Meßapparatur wird beschrieben und die Meßresultate werden diskutiert. Die Farbkoordinaten für die lichtquelle D_{65} werden berechnet und im CIE Diagramm angegeben. Es wird gezeigt, wie diese Tierarten von der erhöhten Reflexion im gesamten sichtbaren Spektralbereich profitieren und wie gut die Farbe von einigen Arten an die des Wüsten sandes angepasst ist, in dem sie leben

Parmi les nombreuses espèces de scarabées peuplant le désert de Namibie, le corps de certaines d'entre elles secrète une cire qui réfléchit une proportion importante de l'éclairement énergétique solaire. Des mesures ayant pour but de déterminer le facteur de réflexion spectrale (0°/d) et la couleur de ces scarabées avec et sans leur sécrétion ont été faites au CSIR. La technique de mesure et les résultats sont analysés. Les chromaticités sous l'illuminant D65 sont calculées et représentées sur un diagramme de chromaticité CIE. Il sera établi combien ces espèces profitent d'une augmentation de leur réflectivité sur l'étendue du spectre visible et à quel point la couleur de certaines espèces se confond avec celle du sable sur lequel elles vivent.

INTRODUCTION

The Namib desert and its few life forms are being studied extensively by biologists and physiologists. They discovered beetle species uniquely adapted to the extreme desert conditions. These species are active during the day and are hereby exposed to high solar irradiance levels, high temperatures and low humidities. They only survive because nature has provided them with a unique protection in the form of a shielding layer, named the wax bloom.

The wax bloom is a secretion on the cuticle which production is triggered by hot and dry conditions. One of the functions of the wax bloom is to increase the reflectivity, hereby reducing the absorption of radiation. In order to determine the gain in reflectivity it was necessary to measure the spectral reflectance of those beetles with and without the wax bloom. This was done at the CSIR in Pretoria.

MEASUREMENT PROCEDURE

The following measurements and calculations were made for each sample

1. Measurement of spectral reflectance (380-750 nm)
2. Calculation of the reflected spectral power distribution: by multiplying the spectral reflectance with the spectral distribution of daylight (illuminant D_{65})
3. Calculation of the CIE (x,y,z) chromaticity coordinates
4. Calculation/determination of the dominant wavelength
5. Calculation/determination of the colour purity

1. Measuring Equipment

Figure 1 shows the schematic diagram of the measuring instrumentation. A quartz halogen lamp with compact filament was used as the stable light source and placed inside a cylindrical housing in order to reduce unwanted straylight. Lens No.1 focuses the image of the filament at the centre of an iris diaphragm while lens No.2 focuses the image of the diaphragm aperture at the position B which is at the centre of an 8 mm aperture in the 100 mm diameter integrating sphere. Aperture A has a diameter of 25 mm.

The integrating sphere, with a $BaSO_4$ coating at the inside, collects the reflected light from the sample in B. If there is no sample in B the focused light beam passes through the sphere into the darkened room and the sphere only collects small amounts of straylight. Integrated light from the sphere passes through a third aperture E into the 100 mm focal length double monochromator which has a photomultiplier tube with S-20 response at the exit and which is powered by a stabilised high-voltage supply. The signal from the phototube is amplified by an operational amplifier, measured by a digital voltmeter and recorded by a desktop computer. This computer also controls the steppingmotor which selects the appropriate wavelength at the exit of the monochromator.

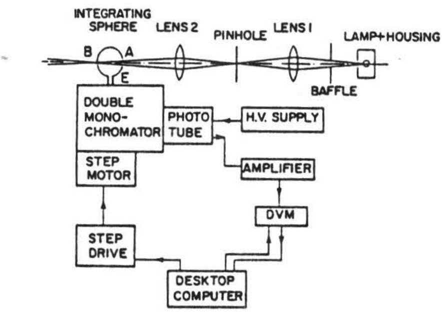

Fig.1. Schematic diagram of the measuring equipment

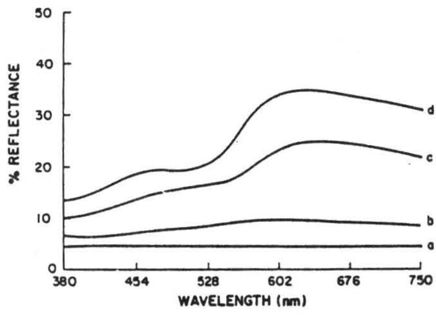

Fig.2. Spectral reflectance of zophosis testudinaria

2. Measurement of spectral reflectance

The spectroradiometric measurements on the beetles were made in the visible portion of the spectrum from 380-750 nm in steps of 10 nm. At each wavelength several signal readings were taken and averaged by the computer. The slitsetting corresponded to a bandpass of 8 nm.

The following detector readings were taken.

- Spectral distribution of 0% reflectance $B(\lambda)$; no sample at position B
- Spectral distribution of 100% reflectance $W(\lambda)$; a $BaSO_4$ tablet in B
- Spectral distribution of the sample reflectance $S(\lambda)$; the sample (a beetle) was placed in position B

The spectral reflectance of the sample is then given as

$$\rho(\lambda) = \frac{S(\lambda) - B(\lambda)}{W(\lambda) - B(\lambda)}$$

3. Results

In the unbloomed state the reflectivity for most species is approximately 4% and nearly constant over the measured spectrum. The colour is neutral and dark i.e. black. With the waxbloom the colour becomes lighter and more specific. The diagram in Fig.2 shows the reflectance curves of a specy for different stages of blooming. As the waxbloom increases the colour becomes more pronounced (pinkish/orange). However, as is the case for all species measured, the colour saturation remains fairly low as the reflectivity increases over the whole wavelength range.

Multiplying the spectral reflectances with the D_{65} distribution allows to calculate the x,y,z chromaticities for each measured sample and its representation on the CIE chromaticity diagram for the standard observer foveal vision for 2^{o}. The colour purity and the in this case vaguely defined, dominant wavelength can be determined on the chromaticity diagram.

4. Conclusion

The measurement results show a definite gain in reflectivity due to the waxbloom for all species measured. The reflecting wax layer certainly protects these species against the intense solar radiation and thus plays a role in their thermoregulation. As the colour of the waxbloom of certain species is very similar to that of the surrounding sand further conclusions could be derived. More specific conclusion as to the nature of the wax have to be made by biochemists and physiologists.

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COLORIMETRY OF WINES

Our previous works[1] in color of red wines have induced us to consider that the absorbance spectra of red wines are related (fig. 1) and they can be subjected to characteristic vector analysis, as it was made for spectral distribution of typical daylight[2].

We employed 229 samples of red wines in this work, and a mathematical statement of the method, adapted from Simonds[3], might be given as follows:

Response data A_λ (spectral absorbance) are avalaible for r (40) levels of the variable λ (wavelength). For each experimental condition, then, the r values of A_λ constitute a one-row r-column vector of response data. For n (200) sample set of data, the response vectors can be arrayed to form a data matrix of n rows and r columns.

It is possible to find a set of characteristic vectors, which, when added in the proper

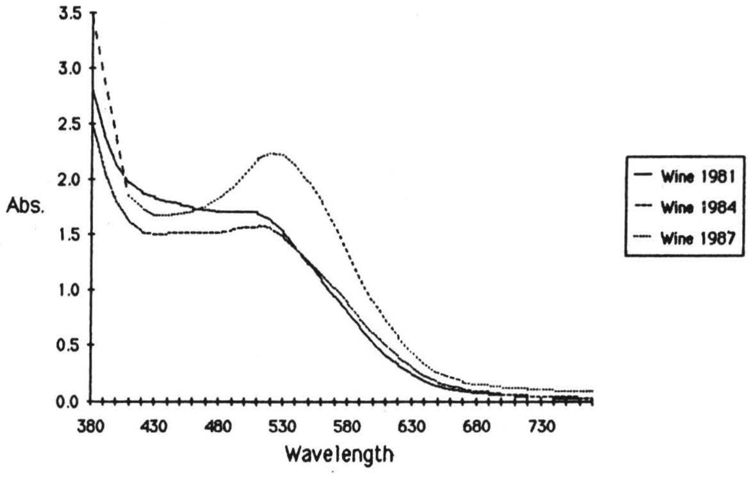

Fig. 1

amounts to the mean response vector, will adequately approximate any of the original family of n response vector. Mathematically stated, the sample responses at each value of wavelength are given by

$$A_1 = \bar{A}_1 + M_1V_{1,1} + M_2 V_{2,1} + \dots + M_pV_{p,1}$$

$$A_2 = \bar{A}_2 + M_1V_{1,2} + M_2 V_{2,2} + \dots + M_pV_{p,2} \qquad p \leq r$$

....

$$A_r = \bar{A}_r + M_1V_{1,r} + M_2 V_{2,r} + \dots + M_pV_{p,r}$$

The M's are the amounts of the characteristic vectors which must be added to the mean response vector in order to produce the sample response vector. The same characteristic vectors apply to all response vectors belonging to the original family from which the vectors are derived. Only the values of $M_1, M_2, \dots, M_p$ vary from one response curve to another. The M's therefore, are a complete specification of the response vector to which they apply. Together with the uniquely determined characteristic vectors and the mean response vector the M's are sufficient information with which to reconstruct the entire response vector from which they were derived.

The power of the tool comes from the fact that a large percentage of the variability among the family of homologous response vectors may be explained by using only a few characteristic vectors.

Figure 2 is a plot of the mean response vector, first, second and third characteristic vectors derived from the data. The first vector accounts for the 96.9% of the total response variability; the second vector accounts for the 2.4% of the variability, and the third vector accounts for the 0.5% of the variability. The total percentage accounted by the three first characteristic vectors is the 99.8% of total response variability.

When we apply the reconstituted spectral absorbance curve to determinate the respective color, in CIELAB space, color difference, between this color and the color determinated from experimental data, is under 6 CIELAB units for 216 samples (94%).

Figure 3 show a histogram of color differences for the whole group.

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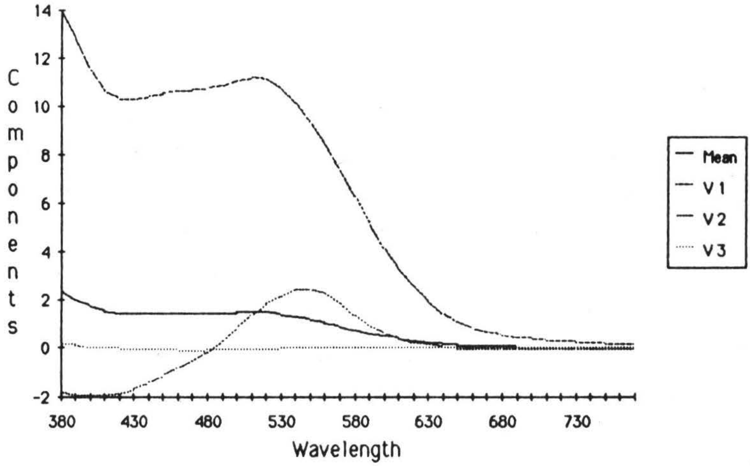

Fig. 2

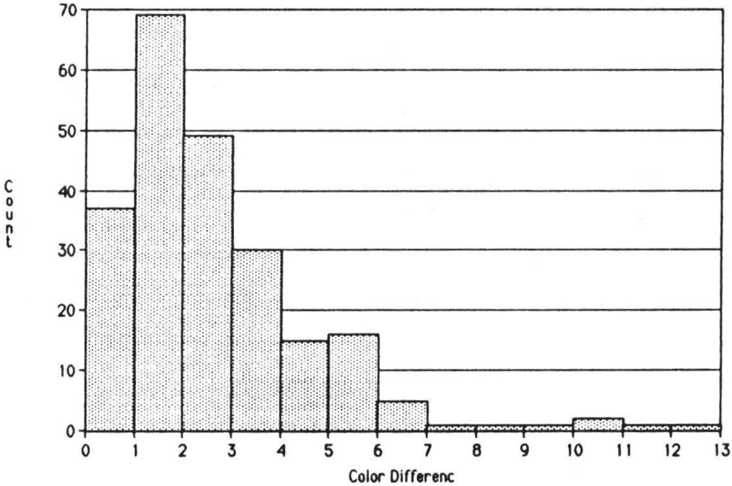

Fig. 3

COMPARISON BETWEEN COLOROID MUNSELL DIN NCS COLOUR SPACES

Antal Nemcsics[x]

Abstract

The generalization of environment colour design cannot dispense with the propagation of colour atlases in design practice. Their usefulness in colour design much depends on the set of samples. Quality of the set of colour samples depends on the colour space of the colour system underlying the atlas. Since in different regions of the world, colour sets of Coloroid, Munsell, DIN and NCS colour systems are increasingly utilized, let me make a comparative test of colour spaces of these four colour systems, comparing primarily their little-known low-saturation ranges. Differences between these low saturation ranges mainly reside in saturation and hue scales. Since among these four colour systems, only the Coloroid scales are simple to describe in relation to the measurable colour stimuli, for the sake of comparison, colour spaces of the other three colour systems have been converted to the Coloroid colour space. Conversion was made in several stages. For the sake of comparison, plane spreadings of colour space sections by coaxial cylinders could be applied. Conclusions drawn from these sections will be lectured on.

Captions: 1. Coaxial section of the Coloroid colour space

2. Coaxial section of Munsell colour space in the Coloroid colour space

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3. Coaxial section of DIN colour space in the Coloroid colour space

4. Coaxial section of NCS colour space in the Coloroid colour space

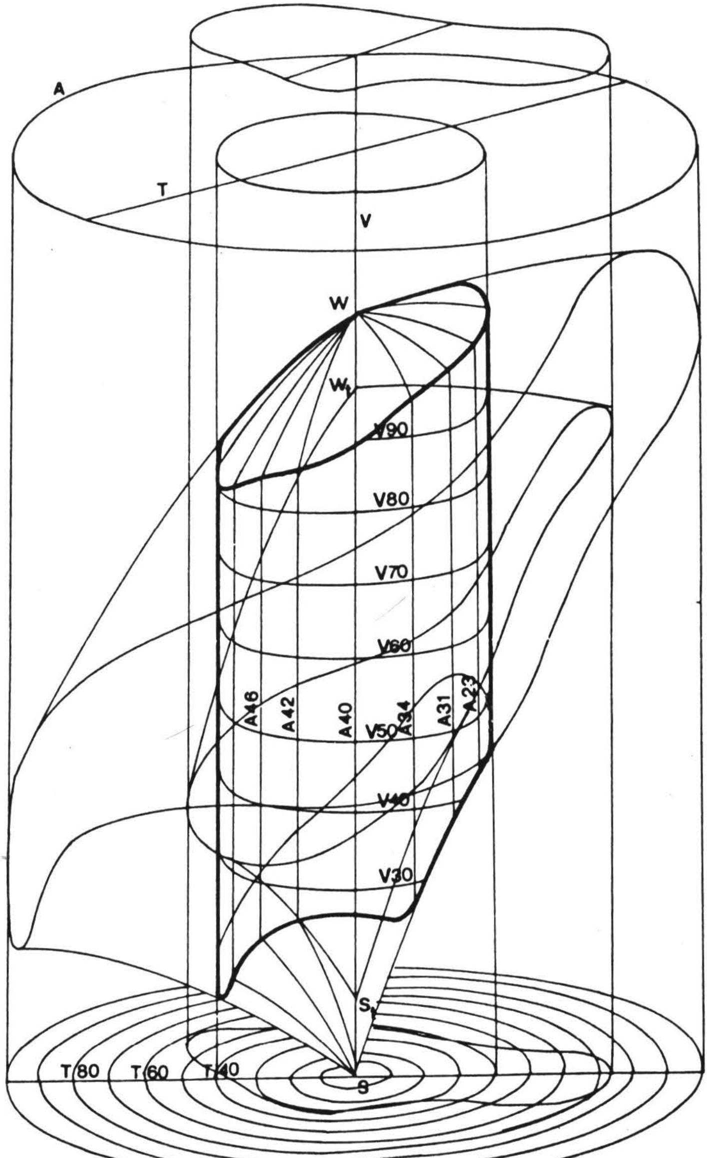

Fig. 1.

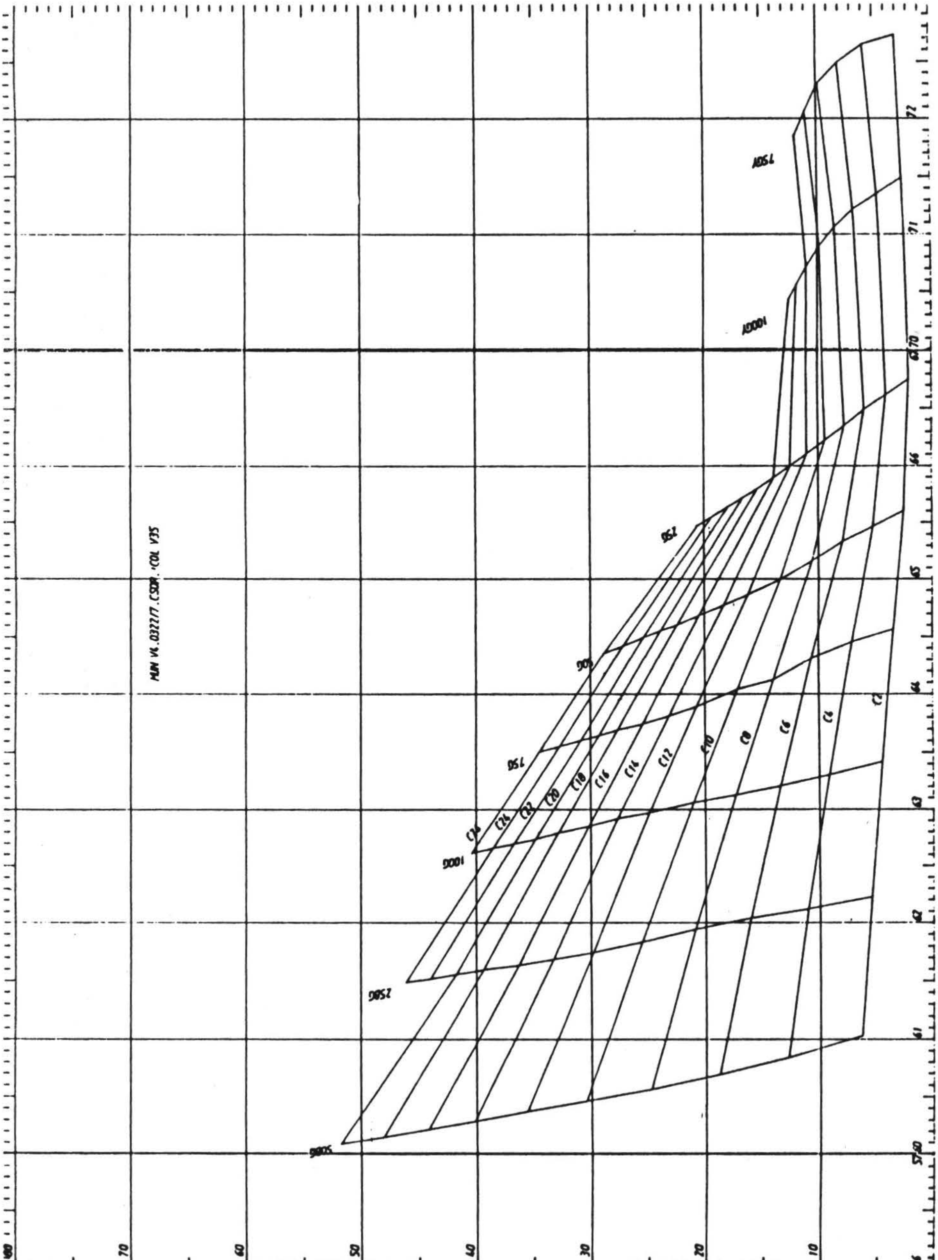

Fig. 2.

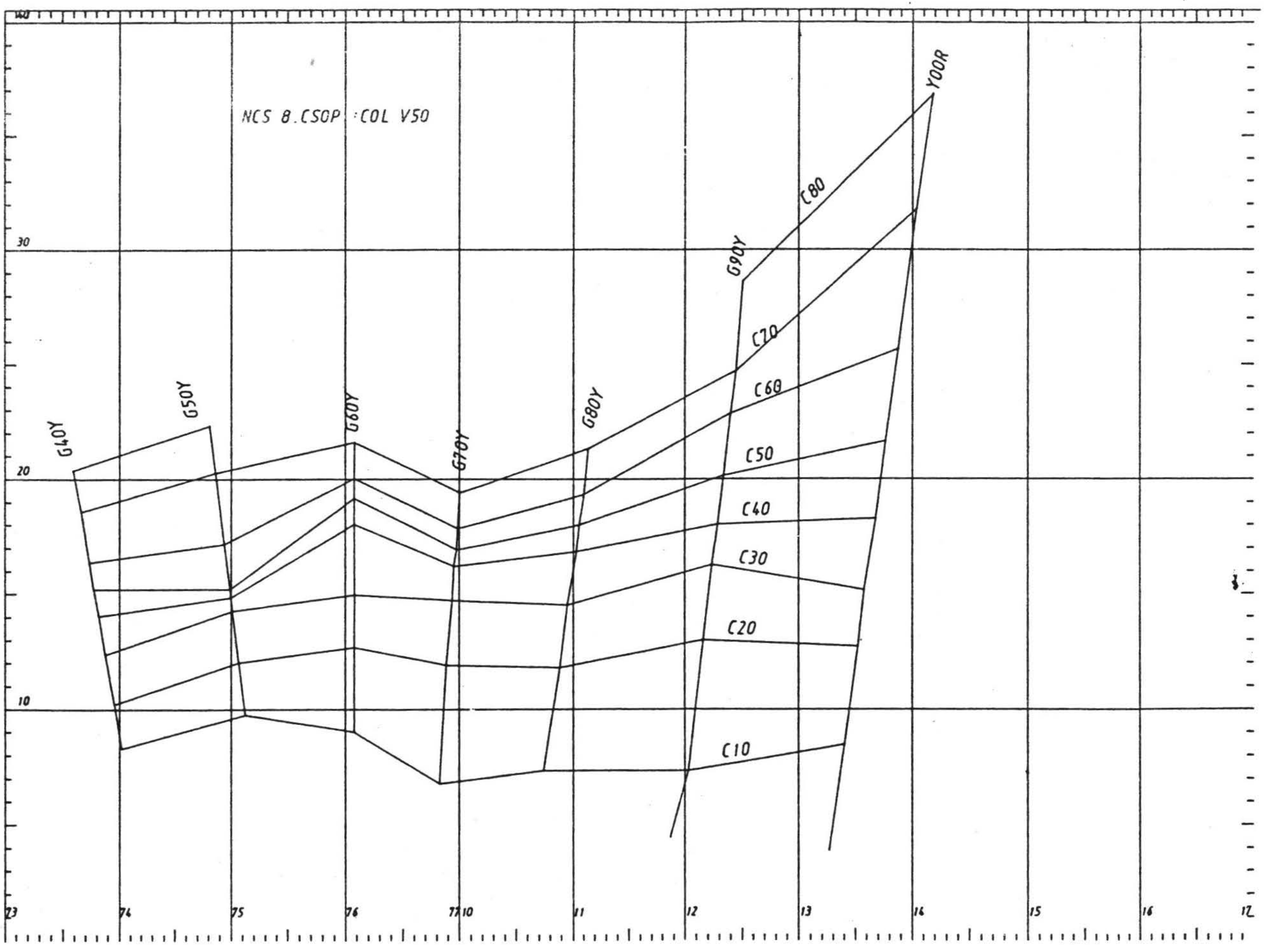
NCS 8.CSOP :COL Y50
Y00R
C80
G90Y
C70
C60
C50
C40
C30
C20
C10
G80Y
G70Y
G60Y
G50Y
G40Y

Fig. 4.

COLOR EDUCATION AT THE CENTRE FRANCAIS DE LA COULEUR

C. PELISSIER & R. SEVE
for a collective work made at the
Centre Français de la Couleur
(Paris, France)

The needs in color education are more and more diversified and important. CFC is mainly interested by three sectors :

. Personal expression with color : young childrens, graphical and artistic expression at school , creation of a colored environment at school...

. General knowledge about color, terminology, color schemes, color classification, choice of colors in advertising and in conditionning, fundamentals of color vision and color reproduction...

. Scientific and technical teaching related to the use of color in industry : color measurement, color systems, color reproduction...

Some examples of CFC' action in these sectors, will be given.

The greatest effort has been done for scientific teaching in industry. A pedagogy has been developed for taking in account scientific requirements as strong as possible.

First we underline relationships between :

. Psychological aspects : what we are perceiving and interpreting,

. physical aspects : the color cause we are measuring,

. biological aspects : how visual system answers in a complex manner.

Starting from this basis we were improving traditional teaching of colorimetry by the development of a rigorous mathematical structure, using separate, though bounded, sets : radiations set, metameric stimuli set, physiological responses set, perceived colors set, luminous values set. These sets are bringing some specific properties to the whole structure : vector structure, tridimensionality, orthogonality (Hering), linear application (brightness) thresholds. By this way it is also easier to underline limitations of classical colorimetry.

It is appearing how teaching aids for "playing" and "touching" colors are important. Development work should be made.

It would be interesting to discuss this matter with groups having a similar approach.

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FLICKER SENSITIVITY, COLOUR AND BINOCULAR INTERACTIONS

INTRODUCTION

While the response of the visual system to temporally modulated light made monocularly is well known (De Lange[1]; Kelly[2]; Pérez-Carpinell and Climent[3]), our knowledge of that response when both eyes are functioning is incomplete, being very little the studies of flicker realized in the binocular field and always using white light (Sherrington[4]; Perrin[5]; Cavonius[6]).

Our purpose in the present experiment is to determine the influence that the stimulation of contralateral eye with disturbing effects, flickering or steady lights of different chromaticity, has on the sensitivity to flicker function of its partner and the comparison with the same function in the case of absence of contralateral adapting light (monocular case).

The interest of this experimental work is due to the interaction phenomenon to study, since is binocular it is carried out, in a greater degree, at the visual cortex level and this will allow to increase the knowledge about the chromatic induction process.

METHOD

A complete description of the flicker system to the observer's left eye can be found in previous works[7]. The light source was a Spectra Physics 2w polarized Argon laser that provided us a blue radiation of 488.0 nm and $\Delta\tau=4.3.10^{-3}$ nm bandwidth. Light from the source goes through optical system with two channels S_1 and S_2, which illuminates the same test by means of a beam splitter. The stimulus was seen as a 2.3º circular test superposed on a dark surround. The modulator produced a sinusoidally modulated light beam. Vision was foveal through 2.6 mm dia artificial pupil. The retinal illumination used was 265 trolands (50 cd/m^2 of luminance).

The other eye (right eye) viewed a field constituted by four bicolour light-emitting diodes (LED's siemens LD 100). The LD 100 LED had peaks of spectral emission at 635 nm and 565 nm respectively and a bandwidth of approximately 30 nm. Uniformity of the field was achieved by the use of a diffussing sheet in front of the LED'S and a lens, so as to gave the appearance of an uniform field 10º. A digital LED'S driver circuit specially designed gave precise control of the luminance, flickering frequency and waveform (practically square). Luminances used were 20, 30 and 50 cd/m^2.

Complete modulation sensitivity functions were measured for one observer which sat on an adjustable seat resting his chin on a chin support.

Every session was preceded by a 5 minutes period of preadaptation to experimentation room and a further 5 minutes period of adaptation to the luminance of the test. In each session we determined the sensitivity curve to flicker (left eye) when the second eye (right eye) was stimulated. For each point, three or six readings are taken, depending upon the dispersion of the trials, and they are averaged.

RESULTS AND DISCUSSION

Tables 1 and 2 present modulation sensitivities data, measured in the monocular case (left eye) and in the case of a binocular combination of a 2.3º flicker field and dark surround in one eye (left eye) and a variable (steady or flicker and red or green chromaticity) 10º field in the other (right eye).

Table 1: Modulation (%) as a function of frequency (Hz) for different stimulations in the contralateral (right eye) caused by lights of the same luminance: a) 20 cd/m^2; b) 30 cd/m^2; c) 50 cd/m^2. Left eye: 50 cd/m^2 and blue stimulus. Median standard deviation was <10%.

a) 20 cd/m^2

f(Hz)	DARK	RED STEADY STIMULUS	RED FLICKERING STIMULUS	RED-GREEN FLICKERING STIMULUS	GREEN FLICKERING STIMULUS	GREEN STEADY STIMULUS
2	10.0	9.0	9.9	9.2	7.6	10.3
5	6.1	6.8	7.7	6.5	4.3	7.6
7	5.6	6.3	6.3	4.1	3.4	8.1
10	5.7	7.0	6.4	5.1	4.6	7.6

b) 30 cd/m^2

f(Hz)	DARK	RED STEADY STIMULUS	RED FLICKERING STIMULUS	RED-GREEN FLICKERING STIMULUS
2	10.0	11.0	13.1	7.8
5	6.1	6.0	6.7	4.5
7	5.6	5.8	7.0	3.3
10	5.7	6.0	5.5	2.8

c) 50 cd/m^2

DARK	RED STEADY STIMULUS
10.0	12.4
6.1	7.0
5.6	6.2
5.7	6.2

We observe that:

A) Experiments with steady stimulus.

In the steady-flicker binocular combination, if we use as steady stimulus (right eye) red or green chromaticity, we can see that illumination of one eye with a steady stimulus reduces the flicker sensitivity of its partner in the low frequencies region. This lateral inhibitory effect in the visual system appears, independently of the luminance of steady stimulus used (20, 30 or 50 cd/m^2) at least when this stimulus is red; in this region, the reduction of flicker sensitivity when we illuminate one eye with a steady field is similar to that caused by Cavonius[6] using white light.

In the high frequency region; steady illumination of one eye produces an increase of flicker sensitivity in the other eye with the red stimulus and 20 cd/m^2 while that if we use the green stimulus or the red stimulus (30 cd/m^2) the sensitivity recorded is identical to that monocular case and this behaviour is analogous to obtained by Cavonius[6] with the white light.

With red stimulus we obtain similar behaviour in the low frequency region independently of the luminance of the colateral eye. At high frequencies our results according to Lipkin's[8] findings, the CFF decreases as adapting luminance increases.

Table 2: Frequency (Hz) as a function of modulation (%) for different stimulations in the contralateral (right eye) caused by lights of the same luminance: a) 20 cd/m^2; b) 30 cd/m^2; c) 50 cd/m^2. Left eye: 50 cd/m^2 and blue stimulus. Median standard deviation was <4%.

a) 20 cd/m^2

m(%)	DARK	RED STEADY STIMULUS	RED FLICKERING STIMULUS	RED-GREEN FLICKERING STIMULUS	GREEN FLICKERING STIMULUS	GREEN STEADY STIMULUS
10	20.5	20.0	20.5	22.0	23.0	16.5
30	27.5	33.0	32.5	34.0	28.0	27.0
50	33.0	37.0	44.0	40.0	37.0	32.5
100	37.0	46.0	49.5	48.0	46.5	37.0

b) 30 cd/m^2

m(%)	DARK	RED STEADY STIMULUS	RED FLICKERING STIMULUS	RED-GREEN FLICKERING STIMULUS
10	20.5	19.0	21.0	23.5
30	27.5	28.0	31.0	29.0
50	33.0	35.5	35.0	35.5
100	37.0	37.0	43.5	40.5

c) 50 cd/m^2

m(%)	DARK	RED STEADY STIMULUS
10	20.5	17.5
30	27.5	28.0
50	33.0	34.0
100	37.0	36.0

B) Experiments with flickering stimulus.

In the flicker-flicker binocular combination used the stimulation of right eye is at a constant frequency of 20 Hz, that is below the CFF, and we have, in accordance with Sherrington's term "asymmetrical flicker" (the two eyes present different frequencies).

In the low frequency region, red flickering illumination (20 or 30 cd/m^2) of the non-tested eye reduces or inhibits the sensitivity to flicker of its contralateral eye and this one increases when we use red-green stimulus (both of them have the same luminance) or green stimulus as flicker stimulation.

At high frequencies, independently of the stimulus colour and luminance level, the simultaneous illumination in the two eyes produces an elevation of flicker sensitivity in respect to monocular case.

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The effect of colour on comprehension in communication. (The 3 C Concept)

The concept of colour has many facets. It could be linked to not only philosophical, psychological and physical aspects, but also to psycho-physical, physiological and psychometric properties.

The 3 C Concept of colour devised by the authors was investigated using normal presentations in colour to determine communication and comprehension. A special computer program was developed to evaluate the same normal presentations, using C R T displays.

Results of this unique research combining the various facets of colour are presented.

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Opponent model of achromatic vision with related line elements for threshold and scaling data

In the fields of lighting technic and color reproduction, e. g. color photography and computer graphics, there is a need to have a model for color vision over a wide range of test and surround field luminance levels. The present CIE color spaces define color scales and differences only for one surround field luminance which is a limitation for these applications. The model presented here is designed for test and surround field luminances of more then 6 log units. It seems the first model based on t w o opponent mechanisms in black-white direction which have been measured recently in physiological experiments by Valberg in the visual system of monkeys.

In Fig. 1 to 5 scaling and threshold data are shown for different central field and surround field luminances. The data are taken from literature (Bodman, Lingelbach, Richter) where a wide agreement is found. Up to now there seems to be no model which can describe both scaling and threshold data within a unique model of vision.

Fig. 1 and 2 describe scaling data. In a typical experimental situation (see Fig. 1 or 2) the colors between black (N=Noir) and white (W) are scaled on an interval or magnitude scale. This psychophysical scaling leads to numbers for lightness L*, e.g. between 0 for black and 100 for white, which can be described by curves shown in Fig. 2. The slope for scaling lightness L* as function of luminance L is 1/3 in Fig. 2. The luminance differences dL for equal lightness steps are computed from the functions shown in Fig. 2 by mathematical derivation and lead to the slope 2/3 of Fig. 1.

Fig. 3 to 5 describe threshold data. The colors between black and white are presented in the same grey surround. The just noticeable luminance difference dL for different central field luminances L are measured and shown in Fig. 3 which has a slope of 1 instead of 2/3 compared to Fig. 1. The number of threshold steps T* between a black and a central field color of luminance L is shown in Fig. 4 which is very different compared to Fig. 2. T* is described by a more linear function compared to L* and therefore T* in addition is shown in a linear-log-plot in Fig. 5.

Helmholtz made the assumption that the number of threshold steps T* between two grey colors describe their phychopysical difference in lightness L*. The comparison of Fig. 1 to 4 shows that this assumption is not valid. Up to now basic research in color has not developed different metrics for threshold and scaling data. We define in this paper a combined metric for both data by related visual threshold and scaling processes shown in Fig. 6. The firing rate (Impulse/s) measured by Valberg in physiological experiments is described as function of central field luminance L at one constant surround field luminance Lu. There are t w o visual threshold processes active: one for colors darker and one for colors lighter compared to the surround field luminance. We call one the visual threshold process N (N=noir=black) and the other one the visual threshold process W (W=White) according to the opponent color theory. The summation of both firing rates give a new curve with approximately a constant slope (see Fig.6).

The change of the firing rates dF(x)/dx of the model curves are shown in Fig. 7. The slope of the two threshold processes N and W reach a maximum near the surround field luminance Lu and change by a factor up to 3 more rapid compared to the scaling process with approximately a constant slope over a wide range (4 log units) of central field luminances. This slope of the sum is here approximately 1/3 which we know from Fig. 2 (lightness scaling data) but the ordinate scale is not a log scale.

The model shows therefore three related curves which can represent data of two threshold processes and one scaling process with different slopes. The different slopes define the line elements for threshold and scaling data. Line elements have been developed by Helmholtz, Schroedinger, Stiles and others. All these kown line elements try to describe both threshold and scaling data by the same slope and therefore must fail either to describe scaling or threshold data because the slopes are very different.

Our solution for describing the "conflicting data" is shown in Fig. 8. The receptor system P,D,T (Protanop, Deuteranop, Tritanop) fits into two different visual processes N and W. In a first step two functions qN and qW describe these processes. The firing rates of the two threshold processes are given by the natural logarithm of these functions which define the functions QN and QW shown in Fig. 6 and their derivations known from Fig. 7.

The s u m of the two logarithmic functions QN and -QW define the slope necessary to describe scaling data. The sum is identical to the d i f f e r e n c e of two logarithmic functions QN and QW which is identical to the logarithm of the r a t i o of qN and qW. This leads to the property that the scaling data (lightness L*) may directly correspond to a function of the ratio qN/qW.

Our model therefore describes both scaling and threshold data shown in Fig. 1 to 5 with very different slopes within one unique opponent model of vision in black-white direction. A complete model defines an opponent color space (OCS) and is designed for achromatic a n d chromatic colors. One color space labeled OCSLAB 1988 describes scaling data and the other OCSJND 1988 describes threshold data (JND=just noticeable difference). The "scaling" color space CIELAB 1976 is a special case of OCSLAB 1988 and the earlier published "threshold" color space LABJND 1987 is a special case of the more general space OCSJND 1988.

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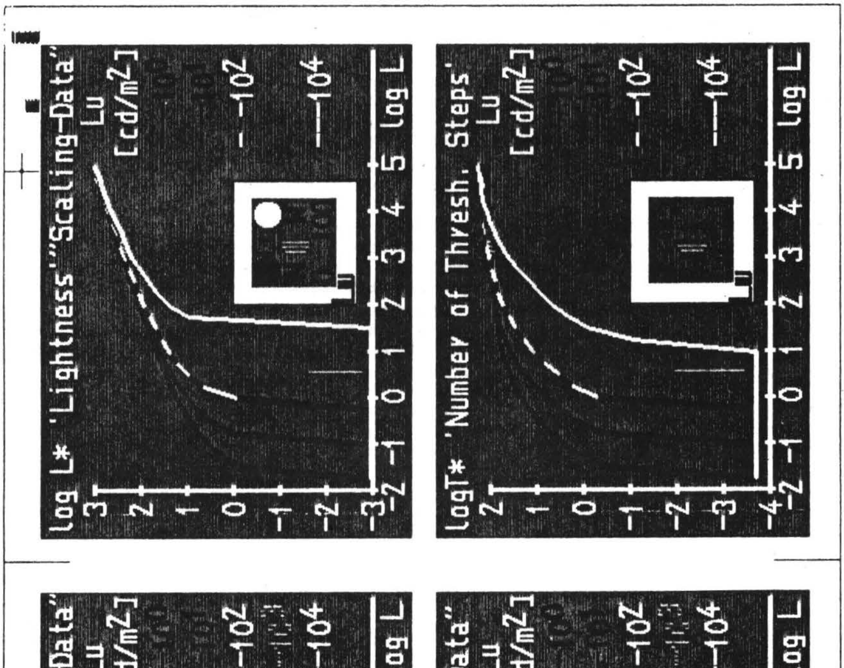
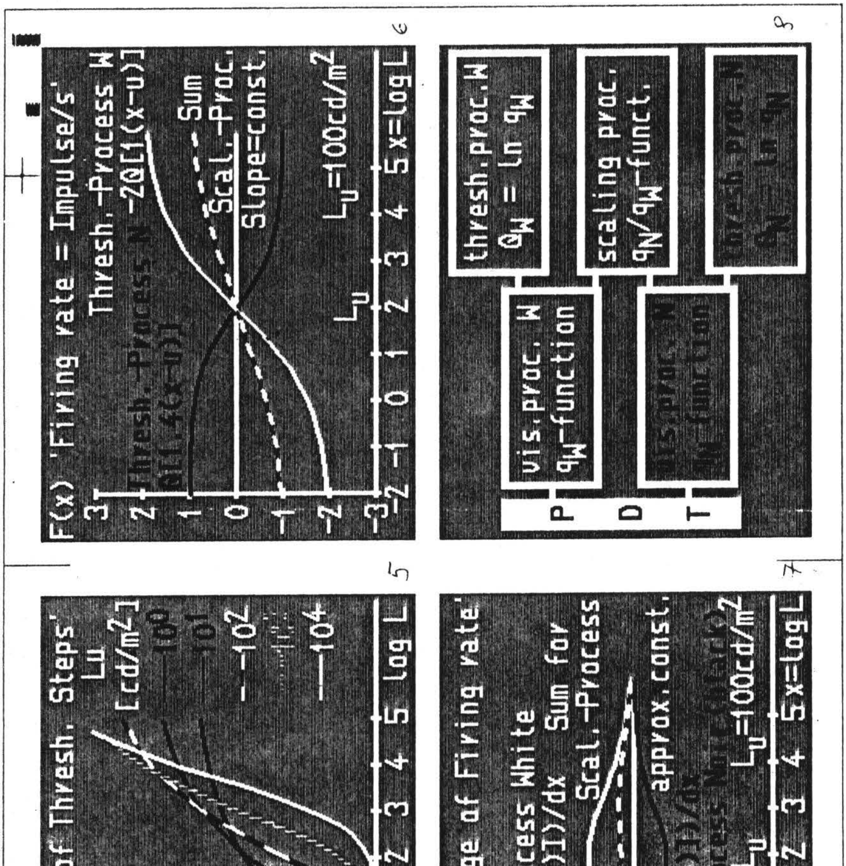

log dL 'L=Luminance' "Scal.-Data"
log L* 'Lightness' "Scaling-Data"
log dL 'L=Luminance' "Thr.-Data"
LogT* 'Number of Thresh. Steps'
Lu
[cd/m2]
10^2
10^4
log L



0,1T* 'Number of Thresh. Steps'
Lu [cd/m2]
dF(x)/dx 'Change of Firing rate'
Thresh.-Process White
Sum for Scal.-Process
approx. const.
Lu=100cd/m2
5 x=log L
F(x) 'Firing rate = Impulse/s'
Thresh.-Process W
Sum
Scal.-Proc.
Slope=const.
vis.proc. W
qW-function
thresh.proc. W
QW = ln qW
scaling proc.
qN/qW-funct.
P
D
T

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NEW COLOR-DISCRIMINATION ELLIPSES

In several occasions it has been pointed out the necessity of new color-difference data, obtained under a wide range of experimental observation conditions, that complete those available at the present. Thus, the CIE (Cfr. Robertson, 1978) has fixed some lines of research to be followed by a same research group, with the aim of avoiding the great dispersion among color-difference results. In a similar way, Prof. MacAdam, during the 1986 OSA Annual meeting and also in a personal letter sent to our group, has expressed the convenience of repeating his famous experiment on discrimination ellipses (MacAdam, 1942), but using a different experimental method to obtain them and working at two luminance levels with three observers. These last ideas joined with the trajectory of our research group during the last few years, have led us to plan a set of experiments to determine color-discrimination thresholds that in a first step constitute the results exposed in this communication.

That principally distinguishes our investigation to previous results in this field (MacAdam, 1942; Brown and MacAdam, 1949; Wyszecki and Fielder, 1971) is the experimental method employed to obtain the ellipsoids in the 1931 CIE (x,y,Y) color representation system. This is based on the constant stimuli method instead of making the observer color matchings by manipulating a colorimeter. We have also used visual colorimeters but during our experiments the observer has only to say if he sees equal or not two juxtaposed stimuli that are presented in a bipartite field. Then he is isolated from the control of the experiments, that joined with the great number of measurements need to determine a threshold give a great objectivity and reproducibility to the results.

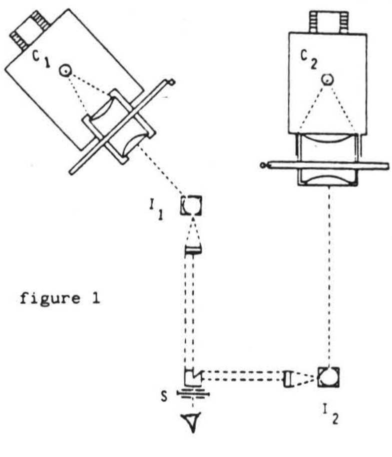

figure 1

We have planed our experiments to obtain the color-differential thresholds at 12 points of the 1931 CIE (x,y) chromaticity diagram, five of which are those recommended by the CIE (Robertson, 1978), working in a first step at a luminance level of 3 cd/m2. An schematic view of the device is schown in figure 1. C1 and C2 are Donaldson-type colorimeters and I1 and I2 integrating cavities. S represents an electromechanic shutter that is open during 1 sec at intervals of 8 sec. The field of vision subtends 2º, one of its halves always occupied with the color that we determine its threshold and the other with a different color in each pulse of the shutter. After each exposure the observer has to judge if he sees equal or not both stimuli. Each of these variable stimuli is presented 10 times in a random order. It was necessary several experimental sessions to obtain a threshold, always no more longer than 20 min with a 5 min previous period of dark adaptation. When the variable stimuli are represented in the 1931 CIE color representation system they form a cloud of points around the reference one. This cloud of points with their weights (number of times seen equal to the reference stimulus) is ajusted to an ellipsoid by the method of Wyszecki (1959). Nearly 1000 measurements are necessary in obtainig each threshold.

Figure 2 shows the principal-cross sections of the ellipsoids for two observers and figure 3 shows one of these ellipses in which the points of the cloud are represented by their weights.

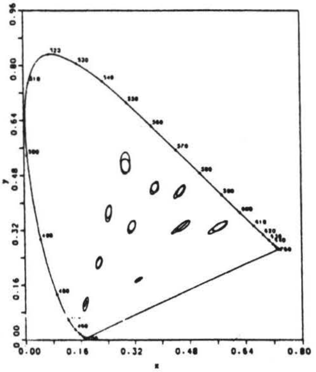

figure 2

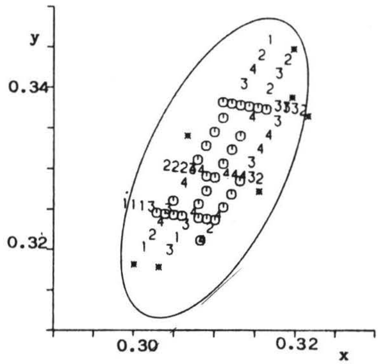

figure 3

Since our differential thresholds have been determined in points of the chromaticity diagram different than those studied by the other mentioned authors, it is difficult to make a comparison between them. Nevertheless, they can be compared with MacAdam's (1943) results because we can calculate a discrimination ellipse at any point of the chromaticity diagram from the graphics given by this author. Also we can make a comparison of our results with the ellipses of discrimination given by different color-difference formulae. Table 1 shows the whole comparison including the ellipses given by a new color formula proposed by us in a previous work (Romero et al., 1988; in press).

As it can observed, the formula cdf-G* approaches better to our experimental results than the rest. It can be pointed out that such formula was derived from MacAdam's (1943) results, thus the good agreement between these sets of results. Also, a certain good agreement between results of MacAdam (1943) and results of observer AH is found. However some discrepancies are shown between the two observers, specially in the blue and green zones. Nevertheless, the necessity of further investigations arises from the results, including more observers and working at a high luminance level. These lines of investigation constitute our tasks at the present, although a detailed description of our first experimental results will appear ir a next publication.

	Experimental	MacAdam (1943)	CIELAB	CIELUV	cdf-g*
(x=0,313 y=0,331)					
Orientation (deg)	65.0	59.5	37.8	51.3	58.0
Relation of semiaxes	0.44	0.43	0.56	0.65	0.35
Area ($x10^{-4}$)	5.86	0.06	0.17	0.08	0.09
(x=0,453 y=0,330)					
Orientation (deg)	39.0	34.1	19.6	44.5	38.3
Relation of semiaxes	0.14	0.44	0.60	0.50	0.48
Area ($x10^{-4}$)	4.18	0.11	0.15	0.07	0.10
(x=0,214 y=0,228)					
Orientation (deg)	72.3	76.0	38.4	35.4	74.5
Relation of semiaxes	0.39	0.36	0.46	0.77	0.34
Area ($x10^{-4}$)	3.78	0.06	0.09	0.04	0.05
(x=0,381 y=0,445)					
Orientation (deg)	64.2	68.3	35.2	58.0	68.6
Relation of semiaxes	0.41	0.39	0.86	0.56	0.39
Area ($x10^{-4}$)	5.49	0.14	0.19	0.13	0.14
(x=0,245 y=375)					
Orientation (deg)	76.8	88.2	53.8	63.3	86.9
Relation of semiaxes	0.37	0.46	0.55	0.72	0.46
Area ($x10^{-4}$)	4.41	0.17	0.18	0.10	0.19
(x=0,171 y=107)					
Orientation	68.9	78.3	22.0	14.5	74.8
Relation of semiaxes	0.38	0.36	0.32	0.64	0.45
Area ($x10^{-4}$)	1.34	0.02	0.03	0.02	0.02
(x=0,563 y=329)					
Orientation (deg)	33.C	23.1	176.0	40.5	24.1
Relation of semiaxes	0.21	0.36	0.67	0.40	0.40
Area ($x10^{-4}$)	7.40	0.11	0.11	0.06	0.11
(x=296 y=0,517)					
Orientation (deg)	86.9	79.5	70.5	70.1	79.4
Relation of semiaxes	0.44	0.32	0.78	0.60	0.34
Area ($x10^{-4}$)	14.06	0.32	0.22	0.19	0.27
(x=0,330 y=0,177)					
Orientation	31.3	49.9	19.5	31.4	50.8
Relation of semiaxes	0.22	0.29	0.32	0.57	0.30
Area ($x10^{-4}$)	0.85	0.06	0.07	0.03	0.06
(x=0.453 y=434)					
Orientation (deg)	51.6	61.6	162.5	52.7	62.5
Relation of semiaxes	0.27	0.49	0.84	0.50	0.50
Area ($x10^{-4}$)	5.17	0.11	0.15	0.12	0.11

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TRANSIENT PURKIJ[redacted]IE SHIFT ON PHOSPHOR COLOR DISPLAYS

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An experiment is described,where the observer is instructed to evaluate the ratio of the brightnesses of two colored stripes,and for various color combinations, generated on monitors of different kinds.
Responses are gathered at various times,after the onset of the test--field,for various pre-adaptation conditions.
The time changes in brightnesses ratio are interpreted in terms of a compromise between the Purkinje effect and the so-called "brightness luminance discrepancy". The pre-adaptation is considered under two different viewpoints:the luminance of a wide white field,to which the eye is exposed, prior to the trials (simulating the case, for instance, of a VDD operator looking at the "domument") and the influence of the lighting installation in the room, which both casts a veil of luminance on the screen,and desaturates the generated colors.

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ORIGINE DES COULEURS DE LUMINESCENCE DES MINERAUX. APPLICATIONS EN RECHERCHE ET DANS L'INDUSTRIE

I. INTRODUCTION

La plupart des cristaux transparents ou de couleur claire sont luminescents lorsqu'on les excite avec des photons UV ou X, ou encore avec des électrons ou des ions. Le fait que cette luminescence soit colorée suscite beaucoup d'intérêt dans de nombreux domaines tels que la physique des matériaux, la recherche minière et pétrolière, la géologie et même l'archéologie, où elle est de plus en plus utilisée à des fins de détection ou de caractérisation (1,2). Cette utilisation n'est pas aisée cependant, car à la différence de la diffraction des rayons X ou de la microscopie en polarisation, la correspondance couleur de luminescence -nature du cristal- n'est pas toujours univoque.

En effet et c'est ce que s'attache à montrer la présente étude, la couleur de la luminescence d'un minéral, perçue par l'oeil ou enregistrée par le cliché photographique est en général la résultante de contributions chromatiques ayant deux origines : l'une, propre aux défauts physiques du cristal et que l'on peut considérer comme caractéristique de celui-ci, l'autre, propre aux défauts chimiques, impuretés localisées ou uniformément distribuées, caractéristique des atomes correspondants. C'est cette seconde contribution qui rend complexe l'utilisation de la luminescence pour caractériser un cristal car elle est à la fois sensible à la composition et aux variations de composition du milieu de croissance cristalline et à l'histoire physico-chimique du cristal.

Autrement dit, dans la mesure où à une couleur spécifique d'un cristal, se "superpose" une ou plusieurs couleurs spécifiques d'impuretés différentes, auxquelles correspondent des longueurs d'onde et des intensités partiellement imprévisibles, on peut théoriquement s'attendre à ce que la couleur de la luminescence d'un cristal soit quelconque. En pratique, les choses sont heureusement plus simples et l'observation quasi-quotidienne du phénomène nous permet de repérer sans difficulté des cristaux usuels grâce à la couleur -presque- constante de leur luminescence : orange pour la calcite, pourpre pour les quartz, bleue pour les feldspaths potassiques, vert-jaune pour les feldspaths sodiques, par exemple (3, 1). Tout se passe, en définitive, comme si la luminescence spécifique du cristal était prépondérante ou si les impuretés piégées, fonctionnant comme centres luminogènes étaient toujours les mêmes, pour un cristal particulier. "Presque" avons-nous écrit : en effet, nous avons constaté l'existence de calcites donnant une luminescence... bleue et de quartz donnant une luminescence... rouge. Ces résultats très différents décourageront le chercheur dont le problème est seulement l'identification d'un cristal. Par contre ils intéresseront le chercheur dont la préoccupation est de mesurer l'homogénéité d'un ensemble de cristaux, de nature déterminée par ailleurs (diffraction X, polarisation) en tirant parti d'hétérogénéités (2) ; il accède alors, grâce à la luminescence à des informations expérimentales tout à fait fondamentales qui peuvent rendre compte du degré de pureté d'un matériau destiné à une application industrielle (quartz piézoélectrique (4), éléments d'optique, ...), d'une origine géologique (5) ou des paramètres physico-chimiques de la cristallogénèse (conditions oxydo-réductrices, composition de la solution mère, ... données déjà exploitées en recherche pétrolière, par exemple, afin d'accéder à la composition des solutions de précipitation des carbonates et à la diogénèse des remplissages et des dépôts sédimentaires) (6).

La présente étude rend compte de notre recherche pour déterminer l'origine de la luminescence colorée dans des feldspaths, des zircons, des quartz et des calcites. La forme de luminescence choisie est la cathodoluminescence que nous examinons sur différents types de montage dont l'un sous microscope électronique à balayage qui autorise des analyses spectrales ponctuelles.

Méthodologiquement, nous avons tenté, dans certains cas, de simuler grâce à des cristaux de synthèse convenablement dopés, les phénomènes observés sur des cristaux naturels. Dans d'autres cas, c'est le couplage de l'analyse spectrale en cathodoluminescence avec d'autres méthodes, parmi lesquelles l'absorption optique et/ou la résonance paramagnétique électronique qui permet de déterminer l'origine d'une composante chromatique de la luminescence.

Dans un but didactique, nous présentons la démarche expérimentale choisie sur un cristal de synthèse, l'alumine Al_2O_3, diversement dopé.

... la suite de l'article précise :

II. - La nature et l'origine des minéraux étudiés
III. - Les conditions expérimentales d'étude de la luminescence
IV. - La méthode d'étude de la couleur de la luminescence de Al_2O_3 dopée (Cr, Ti, Eu...)
V. - L'étude de la couleur de la luminescence de feldspaths, de zircons, de quartz et de calcites.
VI. - Synthèse des résultats. Application en recherche et dans l'industrie.

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QUANTITATIVE ASSESSMENT OF WHITENESS AND ITS CORRELATION WITH VISUAL ASSESSMENT

A new formula incorporating CIELAB colour coordinates for assessment of whiteness of textile substrates treated with FWA is proposed. The formula is applied to 134 polyester and nylon textile samples treated with ten different FWA commonly used in textile industries. The results are compared with those determined by Ganz whiteness formula. Ganz formula has adjustable weighing parameters and known to have good correlation with visual assessment results (1,2). The whiteness assessed by proposed formula agrees with Ganz whiteness with an error less than 10 percent. The comparison of whiteness assessed by both the formula on DATACOLOR colour measuring instrument for Opticol PC FWA on nylon is shown in Fig. 1. The performance of the proposed formula is also verified using four different sources having varied spectral power distribution in UV region. The constants of Ganz formula for these four sources were quite different. indicating substantially different characteristics of the sources. The whiteness determined by proposed formula under all the four sources agrees very well with Ganz whiteness. The comparison of whiteness assessed by two formulae under two sources are shown in figures 1 and 2. The maximum difference between the whiteness determined by two formulae remains below 10 percent.

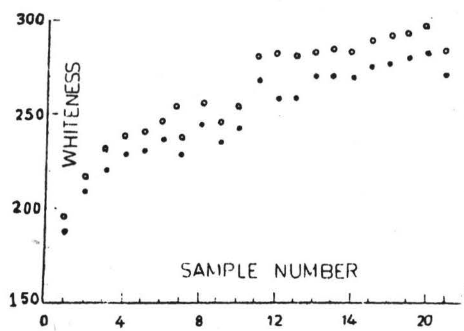

Fig.1 Comparison of whiteness assessed by proposed and Ganz formula for optical PC FWA under source S_1.

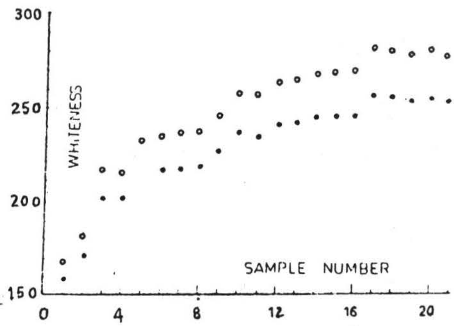

Fig.2 Comparison of whiteness assessed by proposed and Ganz formula for skywhite PC FWA under source S_3.

The potentialities of the proposed formula is also evaluated by comparing it with visual assessment results. The results of visual assessment experiments are considerably affected by the observer capability as well as preconceptions in various trades. Therefore ten observers having long standing experience and endorsed as experts in textiles and related industries were selected for visual assessment of whiteness. Three experiments were given for visual judgement. In the first experiment three sets of samples each containing textiles samples varying in Ganz whiteness by 5,10 and 20 units were given. The observers were asked to rank the samples with increasing order of whiteness. The frequency of correct judgement was 80 percent if we consider the samples varying in whiteness by 20 Ganz units. The frequency of correct judgement was below 40 percent if we consider all samples varying in whiteness in different steps. Second experiment was similar to first one but in slightly different format to confirm the results of first experiment. Observers were given group of samples each containing textile specimens varying in equal units of Ganz whiteness. In this experiment ranking of the samples were correct to 84 percent for group of samples varying in whiteness by 20 Ganz units. The frequency of judgement was correct to 40 percent for samples differing in whiteness by 10 Ganz units and much less for group of samples differing in whiteness by 5 Ganz units. Third experiment consists of pairing the samples of equal whiteness. In this experiment if we permit the error of 10 percent, the frequency of correct judgement was 87 percent. All these experiments were performed on clear sky days near a window receiving northern skylight. The visual test data were recorded about two hours before sunset and were completed in a week's time to confirm the uniform illumination.

The above experiments bring out the fact that the lowest perceivable whiteness difference is 20 Ganz units. As all the textile samples used in the present study had whiteness varying from 150 to 250 Ganz units, the error introduced in pairing the samples is between 15 and 25 Ganz units. This is of the same magnitude as that of difference in results of proposed and Ganz formula. Thus the proposed formula seems to give very good correlation with visual assessment results. The study reveals that the proposed whiteness formula; tested for two substrates, ten FWA, four sources alongwith visual assessment data; appears to function quite satisfactorily.

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A NEW METHOD TO DETERMINE EXCITATION AND EMISSION DOMAINS OF FLUORESCENT DYES FOR ITS COLOURIMETRIC ASSESSMENTS

The reflectance measurement of fluorescent material records total radiance factor (TRF), which includes truly reflected and fluorescent radiations. The TRF curve can be divided into three domains : the excitation region, the emission region and a small domain where excitation and emission region overlap. The development of rigorous method for the colourimetry of fluorescent colourants faces innumerable difficulties(1). The present trend for colour matching using fluorescent colourants, is to develop separate expressions to predict TRF in three different domains of the curve (2-4). This demands a precise and easy method to identify three domains of TRF curve of fluorescent material. These domains can be identified using instruments incorporating two monochromators or having provision for reversible optics. These are not conventional instruments and not available in most of laboratories. In our attempt to develop a method for colourimetric prediction using fluorescent dyes, we have been able to establish a criteria to identify three domains of TRF curve using commercially available colour measuring instruments.

Polyester substrates were dyed at eight different levels using Palanil Luminous Yellow-G and Red-G dyes. The TRF curves were recorded on three colour measuring instruments viz. the DATACOLOR system, the Applied Color System and the DIANO MATCHSCAN System. The first two equipments employ reverse optics and the third one had provision for reversible optics. The TRF curves recorded are shown in Figs. 1 and 2 for fluorescent dye Red-G. Similar curves were obtained for fluorescent Yellow-G

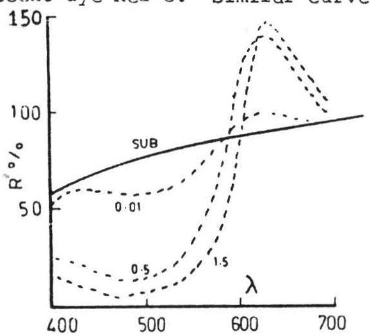

Fig.1 Schematic TRF curves recorded on DATACOLOR system for samples dyed with Red-G

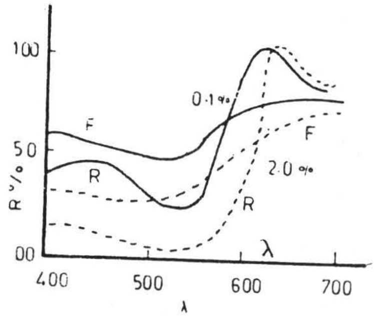

Fig.2 Schematic curves recorded using forward and reverse optics on DIANO system for samples dyed with Red-G

for non-fluorescent dyes, the curves for dyed samples in Fig.1 would have been below the substrate curve. Similarly the forward and reverse optics curves in Fig.2 would have coincided for non-fluorescent dyes. The crossover point between the curves observed in Figs.1 and 2 are due to fluorescent nature of colourants.

In Fig.1, the curve of sample with lowest concentration crosses the substrate curve at wavelength when the fluorescent emission just starts. With increase in concentration, the cross over points shifts towards longer wavelength side due to increase in absorption. At high concentration (e.g. 2 percent for yellow-G dye) the shift of cross over point ceases as fluorescence is very high compared to absorption. The excitation ceases from this wavelength onwards. In Fig.2 similar cross over points occur. The cross over point represent the separation of excitation and emission spectra with an overlapping region of both the spectra around this point (5). The cross over point shifts towards the longer wavelength side with increase in concentration of dye. The wavelengths corresponding to cross over points in both the sets of curves are given in Table 1 for yellow dye. Similar results are obtained for red dye. Cross-over points in both the cases starts almost at the same wavelength for sample at lowest concentration. The cross-over points shifts rather slowly in reversible optics experiments as the physics that determines the two curves is different compared to that for curves in Fig.1. Therefore saturation in shift of cross-over point will reach at very high

TABLE 1 : Wavelengths for cross-over points for polyester dyed with Palanil Luminous Yellow-G dye.

Concentration in percentage	Wavelength in nm of cross-over point with substrate curve			Wavelength of cross-over point of reverse and forward mode
	Datacolor	ACS	DIANO	
0.01	484	484	483	485
0.05	487	486	485	486
0.1	489	489	486	487
0.3	493	493	492	490
0.5	495	494	494	493
1.0	499	499	498	495
1.5	501	501	501	497
2.0	502	503	502	498

concentration. The study reveals that the wavelength range of shift of cross-over points in both the cases are identical and determines the overlapping region of excitation and emission spectra. Thus the comparison of results obtained with conventional instruments with reversible optics instrument clearly sets the criteria that overlapping region start at wavelength when substrate curve crosses the TRF curves of samples with lowest concentration and ends when the shift of cross-overs point ceases. Using this criteria, the three domains of the TRF curves can be easily determined by recording TRF curves of samples and substrates using commercially available colour instruments designed for reverse optics.

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A METHOD TO PREDICT TOTAL RADIANCE FACTOR CURVE OF FLUORESCENT DYES

A good deal of work is reported in the literature on colourimetry of fluorescent colourants. The attempts were directed towards the separation of fluorescent and reflected radiations and then predict both under CIE illuminant (1,2). This technique has not been accepted for use in industrial organisations because of its complexity in application. The present trend is to develop a method for colour matching of fluorescent colourants for a given instrument equipped with a light source which closely resembles to daylight (3,4). The method consists of developing separate empirical formula for excitation and emission region of total radiance curve of colourants. We are presenting here the results of our attempts to develop a method for colourimetry of fluorescent dyes.

For this study, polyester fabric was dyed at eight different levels, ranging from 0.05 percent to 2.0 percent using Palanil luminous yellow-G and Palanil luminous red-G fluorescent dyes. The total radiance factor (TRF) curves for all textile samples were recorded on DIANO MATCHSCAN colour measuring system equipped with integrating sphere and employing reverse optics mode. These curves for 0.5 percent concentration for both the dyes are shown in Figs. 1 and 2. The TRF curves for fluorescent dyes consist of three domains : excitation domain, emission domain and small part of curve where both the domains overlap. The location of these domains were determined using method proposed by the authors in another paper at this conference (6). It was observed that for yellow-G dye the excitation region is from 400 nm to 484 nm emission region from 502 to 700 nm and a small part of spectrum from 485 nm to 502 nm is identified as overlapping region. Similarly for red dye excitation, overlapping and emission regions are respectively identified for wavelengths 400 nm to 567 nm, 568 nm to 583 nm and 584 nm to 700 nm.

For colour calculations, it is required to predict TRF for wavelengths 400(20)700 nm. In emission region, the absorption is considered to be very small as compared to fluorescence. Therefore for this region

$$\beta_F = \beta_T - \beta_S \qquad \ldots(1)$$

here β_T is total radiance factor, β_F is fluorescence radiance factor and β_S is reflectance factor for substrate. We have found that the following equations is most suited to predict β_F for both the dyes at arbitrary concentrations :

$$\beta_F = \frac{MC_F}{K} \exp\left[-\frac{WC_F}{2K^2}\,(\ln\lambda - \ln\lambda m)^2\right] \qquad \ldots(2)$$

here C_F is the concentration of fluorescent dye. M and W are constants related to concentration of dye. K is the constant determined by the characteristics of dye. λm is the wavelength corresponding to maximum in emission region. λ takes the values of wavelengths in emission region required for colour calculations. In this study we have also determined β_T in overlapping region using eqn.(1) and (2), but we intend to develop separate equation for overlapping region after studying the behaviour of other fluorescent dyes and their mixtures with non-fluorescent dyes. The spectral reflectance curve for both the dyes in excitation region is determined using Kubelka-Munk equations.

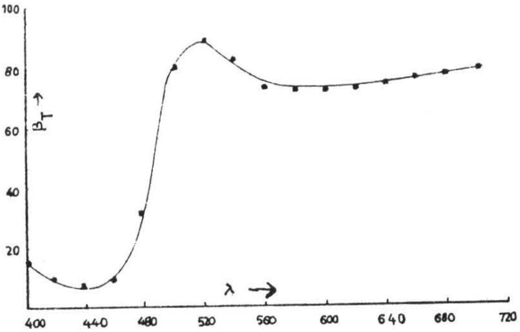

Fig.1 Comparison of experimental and predicted TRF curve for yellow-G fluorescent dyes.

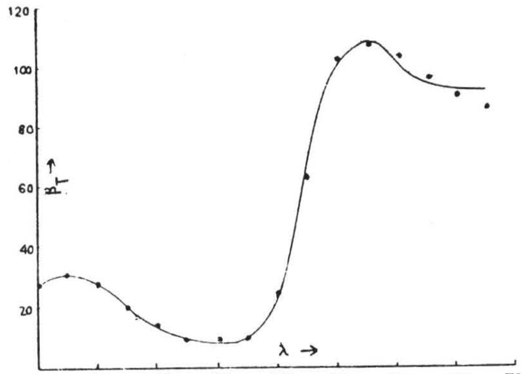

Fig.2 Comparison of experimental and predicted TRF curves for Red-G fluorescent dye.

The values of TRF predicted using eqns.(1) and (2) and K-M equations are shown by points for respective dye on Figs.1 and 2. Similar results are obtained for any arbitrary concentration between dyeing level 0.05 and

2.5 percent. The relation of M and W with concentration can be represented by a smooth curve. The figures show that the use of K.M. equations and eqns.(1) and (2) proposed in this paper can predict the TRF curve for a single fluorescent dye. The objective of work is to give a thrust to the concept that it is possible to work out equations for colourimetry of fluorescent colourants where the constants are related to concentration rather than wavelength. The calibration curve prepared using selected level of concentration can be stored in the computer to predict the TRF curve for any arbitrary concentration. This method will reduce the constants to be determined and stored in the computer memory. Our work to extend this equation to predict the TRF curves of mixture of dyes is in progress.

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RESEARCH ON THE MEANINGS OF COLOR COMBINATIONS

The question is often asked whether the colours around us have any meaning and, if so, what meaning and how great it is. The answer to the first question becomes evident if one takes into consideration that our ability to discern and determine colors and color differences constitutes the basis for our vision. We see forms and objects because we are able to distinguish figure from background, that is, color differences. But how important then is the choice between different colors in different contexts? In what way are we influenced if the "wrong" colors are used? Can people's behavior, emotions and thought be steered by manipulating the colors around them? Do all people react to colors in the same way? Many have speculated and had opinions about the psychological effects of color. Little of this would probably withstand any form of scientific inspection. On the other hand, I can say from my own experience that it is quite difficult to study the complex psychology of color. I shall here discuss briefly the multidimensionality of these problems.

Color systematics

A fundamental requirement in all research is of course that one knows what it is that one is studying. Within psychological color research a large number of studies are found in which the parameters of hue, value and chroma have been all too casually made use of without the researcher having any real understanding of the intricate problems that the interrelationships of colors imply. In Sweden during the past two decades we have had the privilege of being able to devote extensive attention to these questions which has among other things resulted in the development of the NCS-system, which is a description of colors as they appear. But it should be pointed out that even this is not enough. The world of color is so complicated that one not only needs a well devised color system but also a sophisticated theory development of the phenomenology of color. Such a necessary expansion of color systematics consists of, among other things, an analysis of

The relationships of color combinations

There is a scarcity of scientific studies concerned with the experience of color combinations and the reason for this is that the area is difficult and requires a long period of time to amass knowledge. The number of possible color combinations, for example, can be counted in billions, which of these are we to study? A meaningful selection requires a well thought out theory about how color combinations can be described. Such a theory naturally should not say anything per se about how different color combinations are evaluated as beautiful or ugly. But it should be able to be used as a frame of reference when one wishes to investigate all imaginable experiences that color compositions give rise to - including the aesthetic aspects. The descriptive model for color combinations which we have as our point of departure has been developed primarily by Anders Hård and has been previously described at color conferences like this one. It has the main dimensions COLOR CHORD, INTERVAL and TUNING, each of which having its own subdimensions. The model generates a large number of hypotheses about how different colors are experienced and evaluated in combination, hypotheses that, thanks to the fact that the model is based on a perceptual color system, are possible to test. Examples of such hypotheses and questions are: Are certain combinations more harmonious than others? Of what importance are the various types of contrast? What effect does complexity have and how multidimensional is this concept with relation to colors?

The structure of meaning

Already at the end of the 60's we in Sweden, using the NCS-system as a base, literally mapped the world of color with respect to how associations to various words systematically vary across different parts of the color world. These almost 20 year old studies were concerned with attitudes to isolated colors in the form of color samples. It may be mentioned that we also performed similar a experiment with colors on houses, as well as follow-up studies of color in real environments. This research is summarized in, among other places, a recent report from NASA on Human factors of color in environmental design (Wise & Wise , 1987).

In order to continue with the study of the meaning of color combinations it was first necessary to bring order to the manifold of words that describe complex color environments (one can easily come up with a few hundred words) and we therefore made an analysis of the semantic structure of color combinations. How do different words covary and can their interrelationships in meaning be structured in a meaningful way in a semantic space? In a study having 22 heterogeneously selected color combinations we studied 130 words using the so-called semantic differential scaling method. The subjects judged the pictures with color combinations as to how well the different words went with the color composition in question. A factor analytic solution with this data yielded four factors/dimensions: EVALUATION - ARTICULATION - LIGHTNESS - WARMTH, as well as a fifth, more difficult to interpret, containing words such as usual, traditional and popular. During the AIC conference I will illustrate these results and also show the color constellations which are most typical of the different areas in this semantic space. The picture below shows a two dimensional representation of this semantic space. The purpose of the above study was to obtain a small number of variables that would be reasonably representative of all color describing variables. With this as a handier instrument we now have the possibility to test the many hypotheses about color compositions that one can make.

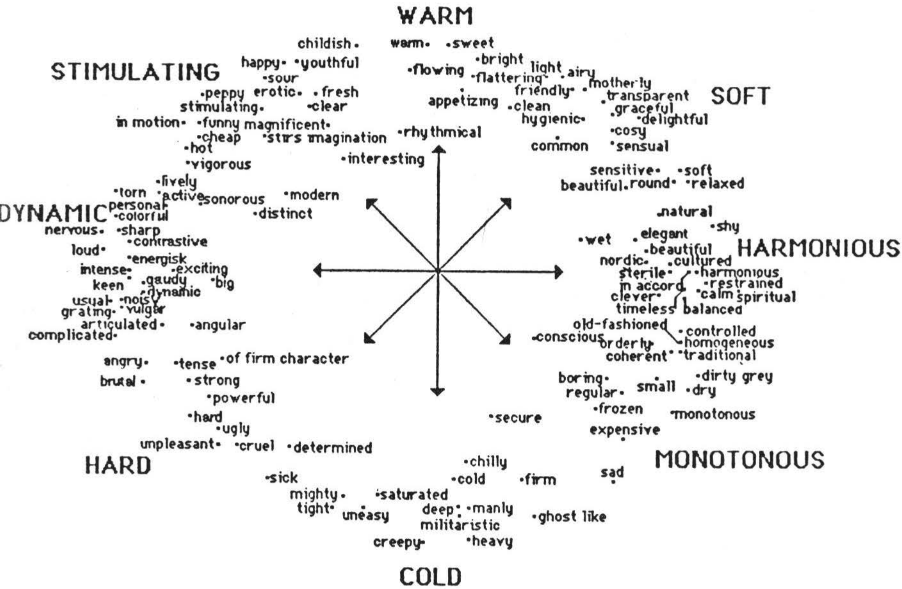

Figure. Two dimensional representation of a semantic space of color combinations.

Another central question, that we have devoted interest to, is that of generality. How concordant are people in their experiences and opinions of color? Our results have shown that people are remarkably similar for the most part, and it would be strange otherwise. But there are enough differences between individuals to arouse interest in such individual color perceptions and perhaps attempt to relate them to differential psychological parameters, we have also begun to investigate this.

One question is now how deep in the unconscious color associations and color emotions lie. It is easy for our consciousness to make light of the meaning of color. It seems that it is becoming more and more apparent that the activity in the archaic limbic system in the brain, where even color signals are transmitted, is not simply something superfluous and subordinate for modern man. Rather it is perhaps that our unconscious interferes with and effects most of what the more intelligent and logical cortex is up to.

Within advertising and marketing one has more or less consciously played on unconscious needs - what role does color play on the unconscious level? There are many questions that remain to be answered and that are left untouched in this difficult area. Brain research may soon approach both what Jung and what Freud said about the role of unconsciousness - just as neurophysiologists have come to admit that Erwald Hering was correct when he described what he and all others perceived with their senses. This self-evident method to study and analyze what one really experiences is called phenomenology.

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COLOUR IN ARCHITECTURE

Teresa Taboas Veleiro

THIS MOTION NAMED, " COLOUR IN ARCHITECTURE" DOESN'T PRETEND TO A REDUCED SUMMARY, MY INTEREST FOR THE CONTRARY IS TO PRESENT A "PROBLEMATIC RIGOROUS THEORY" FOR THOSE PEOPLE WHO POSSESS AN AESTHETICS SENSIBILITY AND AN ARTISTIC IMAGINATION, THROUGH WHICH ONE CAN ARRIVE AT ITS DEEPEST SENSATIONS; IMAGINATION AND UNDERSTANDING. I BELIVE IT NECESSARY TO MAKE AN EXTENSIVE DISSERTATION ABOUT ARCHITECTURAL POLICROMY: AESTHETIC, HISTORIC AND PARTICULARILY GRAPHIC. CLASSIFYING SPECIALLY THE DIFFERENTS STEPS EXISTS IN THE BIG ARCHITECTURAL POLICHROMATIC CONCERT.

I HOPE THIS MOTION WILL OFFERS THE POSSIBILITY TO PROVOKE A RELEVANT ANALYSIS ABOUT THE COLOUR IN ARCHITECTURE.

COLOUR REVEALS ITSELF AS AN INTERIOR REALITY OF THE CONSCIENCE EMERGING FROM THE DEEPEST PART OF THE BEING.

IN THE ARCHITECTURAL FACT COLOUR APPEARS AS A DIAPHANOUS SCREEN TRHOUGH WHICH A NEAR OSMOSIS HAPPENS THAT PROVOKESA CONTINUITY OF OUR DEEPEST SELF IN THE MATERIALIZED IDEA.

IN FINE ARTS, SPECEALLY IN ARCHITECTURE THERE ARE FOUR IMPORTANT ELEMENTS: DESIGN, COLOUR, PROPORTION AND TEXTURE. COLOUR ALLOWS US TROUGH THE OPTIC IMPRESSIONS, TOGETHER WITH OTHER SIMULTANEUS ELEMENTS IN THE ORIGEN OF THE PERCEPTION, TO VISUALIZE LIGHT AND

SHADE EFFECTS, OBJETCS AND SPACES DIFFERENTATION TROUGH CHARACTERIZATION, SINCE ALL VISUAL FORMS APPEAR FOR ITS GLOBAL VISUAL EFFECT. COLOUR PLAYS OPTICALLY WITH THE SURFACES AND SPACES GENERATING AND CHANGING OUR SENSATIONS.

COLOUR IN ARCHITECTURE

ARCHITECTURAL POLICROMY ISN'T EVERYTHING BUT IT DOES DETERMINE ARCHITECTURE'S VISUAL EFFECTS OF PROPORTIONS AND LINES, BECAUSE ARCHITECTURE IS THE STUDY OF FORM IN THE PRESENCE OF LIGHT.

MOREOVER THE COLOUR IN RELATION TO ITS ORIGEN, THAT IS TO SAY, AS LIGHT SUPPORTER, APPEARS ALSO AS ARCHITECTURE SUPPORTER, SINCE ARCHITECTURE EXISTS ONLY IN THE PRESENCE OF LIGHT AND SHADE, AND THEREFORE IN HARMONY WITH THE COLOUR VALUE.

COLOUR IS A STRONG FORCE, WHICH CAN RUIN OR EMBELLISH ANY SURFACE IT CAN MAKE IT RECEDE OR ADVANCE, THAT IS TO SAY, THAT IS TO SAY IT IS CAPABLE OF CREATING A NEW SPACE. THE DISTANCE, THE SENSIVITY THE TEMPERATURE, EVEN THE VOLUME OF ARCHITECTURE CAN BE REDUCED OR INCREASED BY THE COLOUR.

THIS MOTION PRETENDS TO SHOW CLEARLY THE ETERNAL PRESENCE OF COLOUR IN ARCHITECTURE, EVEN WHEN SOME PEOPLE PRETEND TO FORGET IT OR TO IGNORE IT. (WE CAN REMEMBER THE FAMOUS DEBATE DURING THE LAST CENTURY AMONG ACADEMICS WHO ADVOCATED A PURE ARCHITECTURE BASED ON THE CLASIC GREEK ARCHITECTURE -WITH WHICH THEY WEREN'T UNIFAMILIAR- AND HOW CONFRONTED WITH THE EVIDENCE THAT IT WAS PROFUSILY PAINTED, THEY CLOSED THEIR EYES TO THE FACT AND REJECTED IT).

FROM THE BEGINING COLOUR WAS PRESENT IN THE ARCHITECTURAL FORMS

AS EARLY AS PREHISTORICAL TIMES. THE USE OF COLOUR WAS NOT EXCLUSIVELY EMPLOYED TO HIGHLIGHT FORMS BUT BECAUSE A METHOD OF COMUNICATION TO IDENTIFY AN EXPLAIN A POWERFUL SIMBOLISM, WHICH WAS ESSENTIAL AND NOT IN ANY WAY ARTIFICIAL.

THE EVOLUTION OF THIS KNOWLEDGE AND USE OF COLOUR IN THE HABITAT OF PREHISTORICAL MAN DEVELOPED CENTURIES LATER INTO AN ARCHITECTURAL POLICHROME WHEN HE ABANDONS THE CAVE AND OCCUPAIS OTHER SPACES BUILT BY HIM. COLOUR WAS A RELIGOUS AND ASTROLOGICAL SYMBOL.

COLOUR IN ARCHITECTURE

IN MESOPOTAMIA LIGHT AND COLOUR WERE STUDIED AT THE SAME TIME AS ARCHITECTURE THE BIG BABILONIC PALACES WERE COMPLETELY PAINTED. AN INTERESTING EXAMPLE OF THE POLICROMY IS THE MARI TEMPLE, NEAR THE RIVER EUPHRATES. ANOTHER EXAMPLE THIS EARLY POLYCROMATIC ARCHITECTURE IS THE NEW BABILONIC CAPITAL, BUILT BY NABUDOCÓNOSOR. IN WHICH THERE WERE FIFTY TOWERS PAINTED WITH RED AN BLUE COLOURS. BUT THE BEST COMPLETE EXAMPLE IN THESE EARLY TIMES ARE THE INTERIOR WALLS OF THE AL' UQAIR TEMPLE NEAR BAGDAG.

THE RICH EGYPTIAN POLICROMY WAS EVIDENT IN EARLY ARTISTC FORMS. AND SO THE ARCHITECTURE OBTEINED ITS POWER BY MEANS OF COLOUR. AND LIKE ALL THE CULTURE CLOSELY REATED TO RELIGION, THESE ONE DOESN'T BE A SIMPLE USE OF COLOUR, BUT ITS ESSENCE. WHEN EGYTIAN ARCHITECT HAD TO REPRESENT THE WORLD IN A TEMPLE PROJECT. HE BUILT THE FLOOR WITH BLACK BASALT, HE PROVOKED PALM-TREES WITH RED GRANITE AND FOR

THE CEALING HE CHOOSED THE COLOUR OF THE SKY:BLUE. AS IS THE CASE IN THE SAHURE-ABUSIR TEMPLE.

THE SUBTLETY OF THE CONNECTION BETWEEN THE COLOUR AND THE EGYTIAN ARCHITECTURE, IS THE ESSENCE OF THE EGYTIAN ARCHITECTURE, WHICH HAD THE CLOSEST LINKS WITH THE BEGINNING OF THE USE OF COLOUR. THESE GOVERNED THE SPACES COMPOSITION, THE WALLS AND COLUMNS RAISED WORK, AND EACHONE OF THE ARCHITECTONIC PARTS.

BUT THE EGYPTIAN ABILITY IN THE USE OF COLOUR, WASN'T LIMITED EXCLUSIVELY AT THE VISUAL ROLE BUT IT TRASCENDED AT ITS SYMBOLISM, AT ITS MEANING AT ITS ESSENCE.

THE GREEK ARCHITECTURE UNDERSTOOD THE IMPORTANCE OF COLOUR IN THE ARCHITECTONIC SPACES, THEIR BUILDINGS EMBRACING AT THE SAME TIME: FORM, COLOUR AND SPACE. AMOUNG THEM IT WAS A QUESTION OF VITAL

COLOUR IN ARCHITECTURE

IMPORTANCE WHEN CREATING A WORK OF ART TO MAKE IT AS PLEASANT AS POSIBLE TO THE EYE AND THE SPIRIT IN AN ENDEVOUR TO GIVE IT AN INTRINSIC BEAUTY IN WHICH COLOUR WAS AN ESSENTIAL ELEMENT IN THE VISUAL EFFECT. IT WAS COLOUR IN GREEK ARCHITECTURE WHICH BROUGHT IN TO LIFE.

COLOUR SHOULD VARIEGATE THE MONOTONY OF A MASS OF MARBLE, IT SHOULD DEFINE WITH CLARITY THE ARCHITECTONIC ELEMENTS GIVING THEM VALUE AND PRESERVING THE PURITY OF FORM AND LINE RESPECTING CLEARLY LIGHT AND SHADE.

THE ESSENTIAL CHARACTER OF THE GREEK POLICROMY STOOD INMUTABLE IN AL THE AESTHETICS TRANSFORMATIONS, INCLOSED IN THE ROMAN ARCHITECTURAL POLICROMY, WITH THE DIFFERENCE THAT IN THIS ONE THE COLOUR WAS MORE SYMBOLIC THAN THE GREEK ONE, IN RELATION WITH THE SUBLIMATION AND SUPERATION CHARACTER OF THE ETRUSC POLICROMY. BUT NOW WITH A NEW EXPRESSION.

IN ANOTHER WAY IN THE ISLAMIC WORLD, ARCHITECTURE ALWAYS REFLETS THEIR RELIGOUS BELIVES, SOCIAL AND ECONOMICS STRUCTURES. THERE IS A DEEP AND UNITED TRADITION, AN INHERENT SYMBOLISM IN ITS CUPOLAS, ITS COURTS AND ITS SUBLIMES BLUE-TILES.

ONE OF THE MOST IMPORTANTS WAYS IN THE ARCHITECTURE IS TO CREATE AN ILUSION AT DIFFERENTS LEVELS TO OBTEIN AN OPTIC IMPACT.

ILUSION THAT GOES WITH CROMATIC AND TEXTURE VARIATIONS. THEREFORE THE IMPORTANCE OF COLOUR BECAUSE THE ISLAMIC ARCHITECTURE ALWAYS PRETENDED THAT THE WORK OF ART WAS A LUMINOUS VIBRATION.

THE COLOUR ARE IN THE ISLAM THE ETERNAL LIGHT DIVERSIFICATION.

THE COLOUR UTILIZATION IN ANOTHER CIVILIZATIONS LIKE: AZTECS, MAYAS OR TOLTECS, WAS A REQUIREMENT A NECESITY. SO AN ENSEMBLE OF PLAT-

COLOUR IN ARCHITECTURE

FORMS AT DIFFERENTS HEIGHTS, CONFIGURING DEEP SQUARES WITH A LITTLE PLATFORM IN THE CENTRE, ALL THAT IN CONTINOUS CROMATIC PLAY. MONTE ALBAN, TEOTIHUACAN, PALENQUE OR CHICHEN-ITZA SHOW VERY WELL THE ARCHITECTONIC FACT AND THE ARMONIC COMPOSITION OF MASS AND VOLUME.

GEOMETRIC PLAY OF MASS, VOLUMES, LINES AND COLOUR IN OPEN PROPORTION TO THE INFINITE.

FROM THE MIDDLE AGES A SIMILAR PROCESS TOOK PLACE CONSEQUENT ON THE NEED TO IDENTIFY AND DIFFERENCIATE BY COLOUR, PAINTING COLUMNS AND STRUCTURES AND LATER PALACES, CHURCHES, AND MONASTERY FACEDES (WHICH IN LATTER YEARS WERE WHITEWASHED AND REMAINED SO TO OUR DAYS DATING FROM THE RENASCENCE THIS RICH POLYCROMY BEGAN ITS DECADENCE. LATER WITH THE "TROMP L'OEIL" IN THE BARROQUE, THE COLOUR IMPORTANCE IN ARCHITECTURE SEEMS TO HAVE REVIVED. HOWEVER IT WAS WITH THE MODERN MOVEMENT (WITH THE BAUHAUS), WHEN THIS DIALOGUE BETWEEN ARCHITECTURE AND COLOUR FAKES ON A NEW IMPORTANCE.

AT THE PRESENT TIME, SOME CONTEMPORARY ARCHITECTS ARE TRYING TO USE AGAIN THOSE WONDERFUL ARCHITECTURAL PRINCIPLES IN WHICH LIGHT AND COLOUR PLAY AN IMPORTANT ROLE, LIKE LUIS BARRAGÁN OR ALDO ROSSI

USING A MODEL OF COLOUR VISION TO PREDICT THE APPEARANCE OF COLOURS IN PROJECTED SLIDES

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A model of colour vision has been used to provide predictions of the appearance of colours in projected images when a filter is used over a small part, or over the whole, of a slide. The predictions agree well the appearance of the colours found in practice.

Introduction

If a uniformly coloured filter is placed over the whole of a colour slide, then its appearance when projected can be similar to that of the slide when projected without the filter; this is because the observer adapts almost completely to the different overall colour of the projected image. But, if the filter is placed over the depiction on the slide of an object comprising only a small part of the area of the slide, then the apparent colour of that object in the projected image can change very dramatically. An example of these phenomena is a slide in which the picture contains a yellow cushion. If a cyan filter is placed over the whole slide, the projected image, although slightly 'colder', looks generally similar to its unfiltered projected appearance. But, if the cyan filter is placed over only the depiction on the slide of the cushion, then the apparent colour of the cushion in the projected image changes from yellow to green. In an earlier paper[1], the colorimetry of the stimuli involved in this example was measured and analysed. It is the purpose of this paper to apply a recent model of colour vision[2] in an attempt to predict the colour appearances.

Colorimetry

From the earlier paper[1], the following colorimetric results were used as a starting point:

	$100Y/Y_o$	x	y	$Y/Y_w\%$	$Y/Y_{wF}\%$
Open gate	100.0	0.418	0.404	158.5	-
White jersey	63.1	0.423	0.410	100.0	-
Yellow cushion	44.7	0.486	0.456	70.8	-
White jersey filtered	20.4	0.288	0.383	-	100.0
Yellow cushion filtered	13.6	0.378	0.511	21.6	66.7

The colorimetry originally used, as reference white, the light reflected by the screen when there was no slide in the gate (open gate condition), and the corresponding Y tristimulus value is designated Y_o. But the picture also contained a white jersey, and this was adopted as the reference white in this analysis, Y_w indicating the Y tristimulus value of the unfiltered jersey, and Y_{wF} that of the filtered jersey.

Application of the Model

In order to apply the model[2], it is necessary to assign absolute luminances to the stimuli, and to do this it was assumed that the open gate screen illuminance was 500 lux. The results would not have differed very much if a different figure had been adopted, provided it was within the range of typical projection conditions. The luminance of the white jersey was then calculated as $L_w = 500(Y/Y_o)/\pi$, and this yielded values of 100.4 cd/m^2 for the unfiltered slide, and 32.5 cd/m^2 for the filtered slide. It was also necessary to adopt values for N_c, the chromatic induction factor, and N_b, the brightness induction factor; in accordance with the recommendations in the paper[2], the values adopted were $N_c = 0.9$, and $N_b = 10$. Finally, factors, k_s, were required for converting photopic luminances to scotopic luminances (divided by 2.26 for convenience); the factors adopted were, for the unfiltered slide, 0.663 (typical of tungsten light), and, for the filtered slide, 1.000 (typical of illuminants similar to the equi-energy stimulus, S_E, to which the cyan-filtered light of the projector approximated). The input data for the model was then:

	L_w	Y	x	y	k_s
Illuminant	100.4	-	0.423	0.410	0.663
Reference white	-	100.0	0.423	0.410	-
Cushion	-	70.8	0.486	0.456	-
Cushion, filtered	-	21.6	0.378	0.511	-
Illuminant filtered	32.5	-	0.288	0.383	1.000
Reference white, filtered	-	100.0	0.288	0.383	-
Cushion, filtered	-	66.7	0.378	0.511	-

The results obtained were as follows:

	H_C	M_C	M_{CRG}	M_{CBY}	s	Q	J	C
Jersey	8R 92Y	11.9	1.1	-11.9	19.9	55.9	100	20
Cushion	98Y 2G	41.6	-0.8	-41.6	94.9	49.9	89	85
Cushion, filtered	9Y 91G	34.3	-31.8	-12.9	135.4	32.3	58	78
Jersey, filtered slide	91G 9B	14.9	-14.7	-2.7	30.3	46.0	100	30
Cushion, filtered slide	78Y 22G	36.2	-8.7	-35.2	107.5	40.4	88	94

where the perceptual correlates given by the model are as follows: H_C is the Hue Composition; M_C is the colourfulness; M_{CRG} and M_{CYB} are the colourfulness components in the red-green and yellow-blue directions, respectively; s is the saturation; Q is the brightness; J is the lightness; and C is the chroma.

It is clear from the above table of results that the model predicts that, for the unfiltered slide, the cushion appears predominantly yellow without the filter and predominantly green with it; whereas for the filtered slide, the filtered cushion appears predominantly yellow. This can also be seen from the figure, in which M_{CBY} is plotted against M_{CRG}, and in which the directions of the unique red, yellow, green, and blue hues are shown. The points representing the different stimuli are labelled as follows:

unfiltered, U; filter over the cushion only, FC; filter over the whole slide, FS. The figure shows that, for the unfiltered slide, the unfiltered cushion plots near the unique yellow line and the filtered cushion plots near the unique green line; whereas, for the filtered slide, the filtered cushion plots near the yellow line, but slightly on the green side, and this agrees with the fact that under these conditions the cushion does look a slighly greenish yellow. The figure also shows that the model predicts that the white jersey should look slightly yellowish in the unfiltered slide, and slightly greenish in the filtered slide; this agrees with the fact that the unfiltered projected picture has a slightly warm appearance resulting from the use of a tungsten lamp, and the filtered picture has a slightly cold appearance resulting from the use of the cyan filter.

Conclusions

The model has provided good predictions of the appearance of colours in projected images when a cyan filter is used over a small part, or over the whole of a slide.

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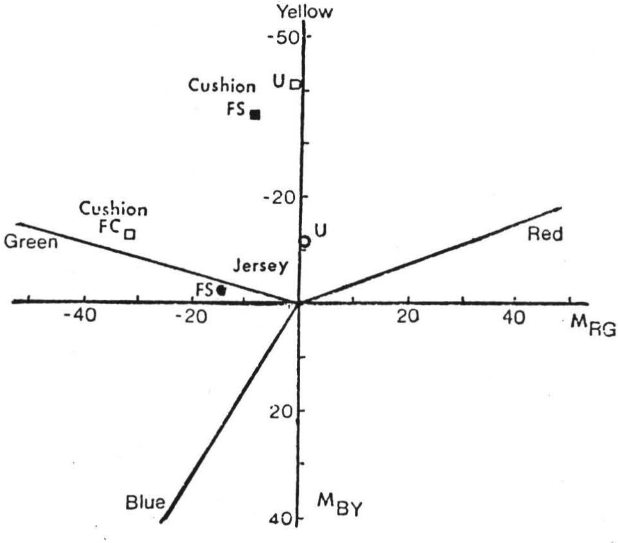

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SCALING COLOUR APPEARANCE UNDER THE D50 ILLUMINANT

1. Introduction

The work described here forms part of a research project, entitled Predictive Perceptual Colour Model. The major objective is to derive a colour appearance model that can predict changes of colour appearance under different viewing conditions. A specific application of this model in the present project is to the proofing simulation process used in the graphic art industry. The two collaborators involved are Crosfield Electronics Ltd. and the LUTCHI research centre.

Work in the project includes a series of experiments. The experiment, which is the subject of this paper, forms a part of the overall experimental programme. The experiment was divided into eleven phases corresponding to the parameters studied, ie.luminance levels, surround colours and dissimilar media (*luminous colours* were displayed on a high resolution colour monitor and *nonluminous colours* were presented in a viewing cabinet.) All the experiment sessions were conducted using a complex viewing field (Fig. 1) under a D50 light source conforming to BS. 950. (The actual chromaticity coordinates of the light source were 0.3465, 0.3569 for x and y respectively.) Table 1 summarises the differences for each phase.

Table 1 : Summary of experiment phases

Phase	Luminance Level	Surround Colour	Media	No. of Test Colours	No. of Estimations
1	H	White	Nonluminous	105	1890
2	H	Grey	Nonluminous	105	1890
3	H	Black	Nonluminous	105	1890
4	L	White	Nonluminous	105	1890
5	L	Grey	Nonluminous	105	1890
6	L	Black	Nonluminous	105	1890
7	L#	White	Luminous	94	1692
8	L	Grey	Luminous	100	1800
9	L	Black	Luminous	100	1800
10	L	Grey/White Border	Luminous	100	1800
11	L	Grey/Black Border	Luminous	100	1800
Total					20232

Note : For the luminance, H represents a high level having 267 cd/m^2, and L and L# represent low levels having 44.5 and 40 cd/m^2 respectively. For the surround colours, white, grey and black surrounds were given Y values of 89, 20.22 and 5.06 respectively.

The magnitude estimation method [1,2,3] was used to scale the lightness, colourfulness and hue for each test colour (see Fig. 1). The scaling task was undertaken by a panel of six observers who had normal colour vision and were each trained for at least 10 hours to use this scaling method. A Telespectroradiometer (TSR) was used to measure both luminous and nonluminous colours using the 1931 CIE standard observer. For nonluminous colours, 105 colours were selected from the OSA Uniform Colour Scale [4]. They were uniformly distributed in the CIE u'v' diagram (see Fig.2) and had Y values ranging from 6 to 59 (Munsell Values of 3 to 8). Each nonluminous colour was transformed to a luminous colour on a properly calibrated monitor in terms of CIE tristimulus values [5]. Some of the colours were outside of the colour gamut of the monitor (see triangle of Fig. 2) and hence were discarded.

A test procedure was carried out to check the repeatability of the TSR and colour monitor. This involved 62 luminous colours which were measured each day during the experimental period (10 weeks). For each colour, the CIE L*u*v* colour difference between the measurement from each day, and the overall mean was calculated, and these results were then averaged. The mean for all colours was 0.5 units, which indicates good TSR repeatability and monitor stability.

2. Data Analysis

For scaling of colourfulness, each observer was instructed to use an unconstrained scale. (The colourfulness scale is an open-ended scale since no top limit is set. Any colour perceived to exhibit no hue has a colourfulness of zero.) The geometric mean was used to determine the average results for the observers.

For scaling of lightness, each observer was instructed to scale the lightness in relation to the 'Reference white' (see Fig. 1), which had a lightness of 100, and their 'imaginary ideal black' having a lightness of zero. The arithmetic mean was taken to represent the mean results.

For scaling of hue, each observer determined the predominant hue, one of the four unitary hues, ie. red, yellow, green and blue, then the secondary unitary hue and finally, the percentage of the two. The results were transformed on to a 0 to 400 scale, ie. 0-100, R-Y; 100-200, Y-G; 200-300, G-B; 300-400, B-R. The arithmetic mean was taken to represent the mean results.

Data analysis was carried out to investigate the variation between each observer and the mean of the results. Two measures, correlation coefficient (r) and coefficient of variation (CV), which was calculated using the root mean square, divided by mean visual results and multiplied by 100, were used. For a perfect agreement between two sets of data, r should equal one, and CV should equal zero, or 0% error. The mean r values for all observer in 11 phases were 0.94, 0.91, 0.99, and mean CV values were 14, 22 and 8 for lightness, colourfulness and hue respectively. This indicates that the hue results were most consistent throughout the whole experiment, and that colourfulness scaling is most difficult to scale between 3 attributes. However even the worst colourfulness results, r of 0.91 and CV of 22, is still considered to be reasonably consistent in this kind of experiment [1,2,3].

3. Results

Several comparisons were made between different phases in order to understand the effects of the different parameters studied. For qualitative comparison of results obtained from two phases, the lightness results from each phase were plotted against each other. Similar plots were also made for colourfulness and hue. Any systematic discrepancy could thus be identified easily.

Quantitative comparison was made of results obtained from two selected phases. Using the least square method, intercept and gradient were calculated for lightness, and gradient only for colourfulness. (The relationship of lightness was not constrained to pass through the white point.) For the hue, the original results were used. The r and CV measures were then calculated to indicate the agreement between two phases for each attribute. In general, the correlation between all the comparisons is very high. The mean r values were 0.97, 0.91, 0.996 and mean CV values were 6, 17 and 5 for Lightness, Colourfulness and Hue respectively.

The hue results for every comparison were remarkably consistent throughout all phases. This indicates that hue appearance hardly changed with respect to the different parameters studied. For lightness and colourfulness, the results are summarised as follow :

Effect of luminous and nonluminous colours viewed at the same luminance level

For Lightness, dark colours appear lighter for luminous colours than those of nonluminous colours by about 10%. There is about 5% reduction of colourfulness for luminous colours.

Effect of high and low luminance levels for nonluminous colours

For Lightness, dark colours appear lighter in the high level of luminance than in the low level of luminance by about 5%. Colourfulness increases about 10% at high level.

Effect of white, grey and black surrounds

All colours tend to look lighter as the surround becomes darker. The largest effect is in the case of comparing black and white surrounds. (about 10 and 20% lighter on black surround for nonluminous and luminous colours respectively). There is about 7% colourfulness reduction with a white surround compared with a grey surround.

Effect of white, black borders around grey surround for the luminous colours

The white border made dark colours appear about 10% darker than grey surround without border. The black border had no effect; this is presumably because it merges with the dark surround of the monitor.

4. Constructing grids of lines of constant hue and colourfulness in the CIE u'v' diagram

For the five phases of the experiment using a grey surround, the mean results of hue and colourfulness were plotted in the CIE u'v' diagram. Lines of constant hue and contours of constant colourfulness were then drawn by hand. The lines of constant hue represent unique red, yellow, green and blue and also mixtures of each neighbouring hues.The contours of colourfulness were drawn using 10 unit intervals.

In general, all five grids plotted show great similarity in hue lines and slight variations in colourfulness contours. The grid of phase 2 (high illumination, nonluminous colours) is given in Fig. 2 and plotted using broken lines. The constant hue lines from the NCS [6] system were also plotted using solid lines (see Fig. 2). (The original NCS data was transformed from C to D50 illuminant using von Kries [7] chromatic adaptation formula.) The agreement between NCS and experimental constant hue lines is considered to be satisfactory.

5. Comparing colour models

The experimental results can be used to test the ability of various colour models to predict these results. The models selected were CIE L*u*v*[8], CIE L*a*b*[8], CMC [9] and Hunt [10]. The first three models are most commonly used by the colour industry to estimate colour difference. Their lightness and chroma scales were used to compare with lightness and colourfulness experimental results. (The hue scale from the colour difference models is designed from 0 to 360 degree to quantify the hue difference, not the appearance, so hue comparison is meaningless.) Hunt's model was designed to estimate the change of colour appearance under different viewing conditions, and is able to take into account all the parameters studied in this experiment. Three attributes from Hunt's model; lightness, colourfulness and hue, were used in comparisons with the experimental results.

Again, the mean results from the five phases which used a grey surround were used. (This is because the three colour difference models were designed to be used under grey surround condition.) For the hue results, only Hunt's model was used. The mean r and CV values for all phases were 0.996 and 6 respectively. This agreement is considered to be very good. For the lightness results, all models have high correlation (r equals to 0.97) with the experimental results. However, the mean CV values were 15, 19 and 28 for the CIE L*, Hunt and CMC respectively. By optimising Nb (brightness induction factor) in Hunt's model, the mean CV value reduced from 19 to 9.

In comparing the colourfulness scale, the results from each model were scaled so as to have a similar scale to those from the experiment. The r values were 0.91, 0.90, 0.91 and 0.91, and the CV values were 19, 23, 25 and 21 for CMC, L*a*b*, L*u*v* and Hunt respectively. The average CV value for the individual's results compared with the mean results was 22. This indicates that better predictions may not be possible.

In general, CIE L*u*v* and CIE L*a*b* gave a reasonable fit to both lightness and colourfulness results. This indicates that there is no significant difference for lightness and chroma between large colour difference data and colour appearance data. On the other hand, the CMC model gave the best fit to the colourfulness results, and the worst fit to the lightness results. This model was designed to fit small colour difference data, so this implies that the character of the chroma results from the small colour difference data is similar to the colourfulness results from the colour appearance data. However, the character of the lightness results from the two data are very different.

Hunt's model shows excellent agreement with the hue experimental results. Since the hue scale from Hunt's model was designed to fit that of the NCS system, this implies good agreement between the experimental results and the NCS system (see Fig. 2). Also, the colourfulness scale from Hunt's model fits the colourfulness results quite well (ie. CV value of 21). However, the non-optimised brightness induction factors as suggested by Hunt (100 and 30 for nonluminous and luminous colours respectively) are too low, since the optimised factors were found to be in the range 500 to 800 for the results obtained from the five phases.

The results from the other six phases were also used to test Hunt's model. Again, it was found that Hunt's model fitted very well to both hue and colourfulness results, but the Nb varied from 200 to 1100 which are very different values to those suggested by Hunt. This indicates that higher brightness induction factors should be used.

6. Conclusion

In total, about 20,000 estimations were carried out in this experiment. Changes of colour appearance under different viewing conditions were investigated. The effects of various viewing conditions are summarised in section three. The present results obtained using the magnitude estimation method is very consistent and the method is recommended for use in future studies.

In comparing the performance of four selected colour models using the present experimental data, CIE L*u*v* and CIE L*a*b* gave a reasonable fit to the lightness and colourfulness results. The CMC model performs best in colourfulness, but worst in lightness and Hunt's model is the most comprehensive model among all the selected models.

Hunt's model takes into account the variations of luminance levels, induction of different lightness of neutral surrounds, and dissimilar media. It performs very well for both hue and colourfulness, but not for lightness. Optimised brightness induction factors, based on the present results, are quite different from those originally suggested by Hunt. It seems that further investigations need to be carried out.

7. Acknowledgements

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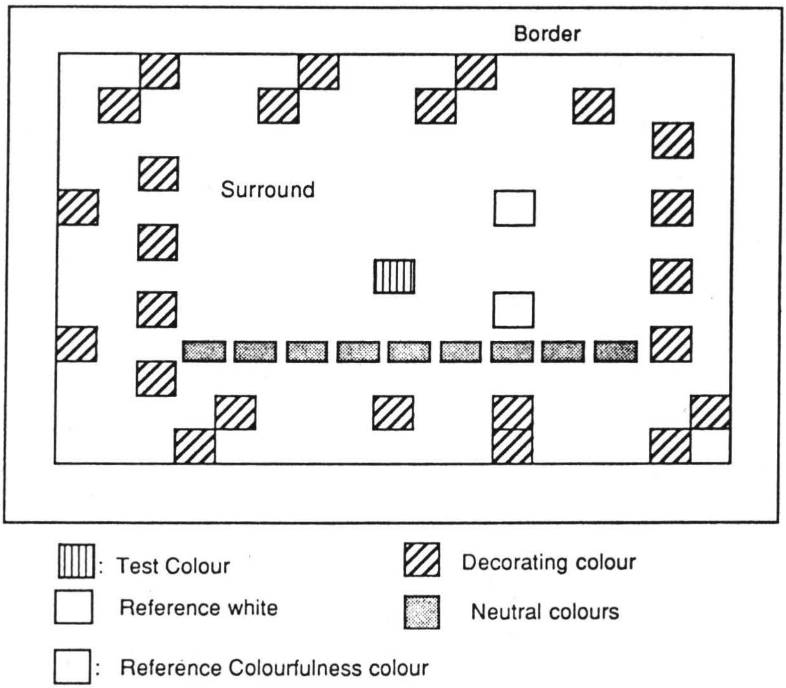
Fig. 1 The Complex Viewing Field



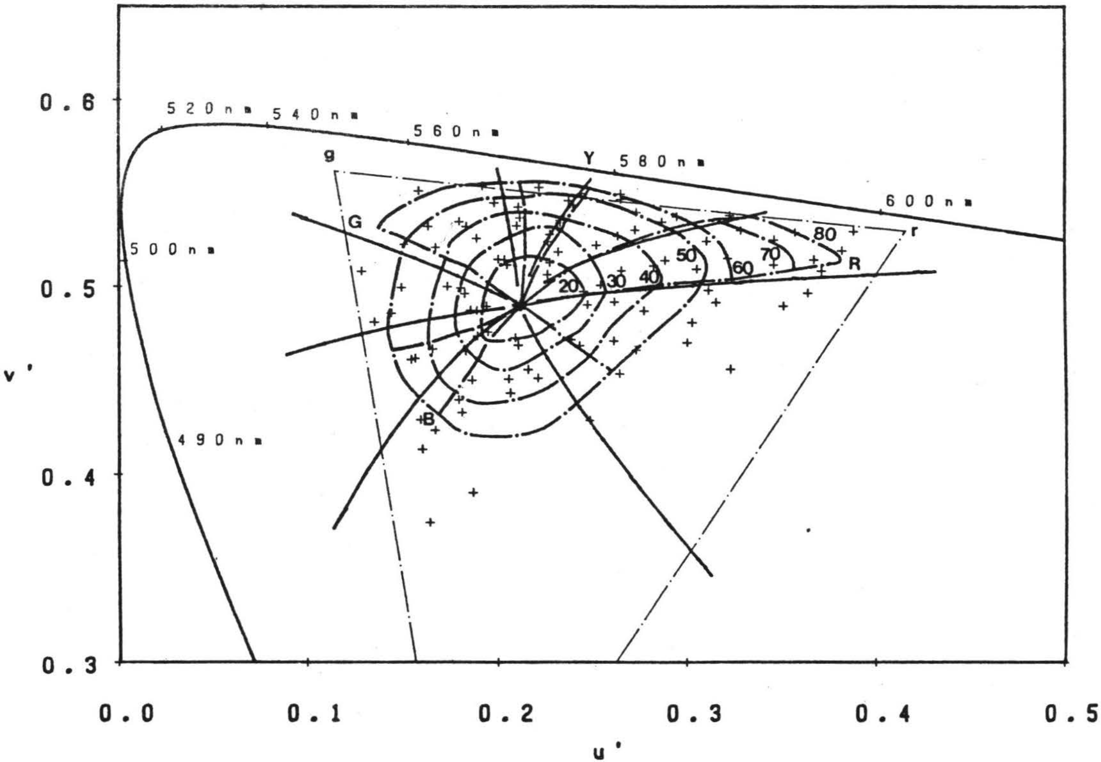


Fig. 2 Contours of constant hue and colourfulness for the phase 2 of the experiment plotted on a CIE u'v' diagram (using broken lines). Contours of constant NCS hue lines are also plotted using solid lines. The cross represents chromaticities of the test colours. The colour gamut of the monitor is also plotted (marked 'r' and 'g' corresponding to the chromaticities of the red and green phosphors of the monitor.).

A THEORETICAL AND EXPERIMENTAL STUDY OF CHROMATIC TRANSPARENCY

Osvaldo da POS - Padova

There are many different forms of perceptual (or apparent) transparency. In a very strict sense, we have perception of transparency when we see two colours at the same time and in the same point of observation: both colours, that opaque of the background and that transparent of the superimposed layer, are distinctly perceived one through and beyond the other. Our study of chromatic conditions of phenomenal transparency deals with this kind of transparency.

Metelli's (1972) mathematical model of phenomenal transparency is built according to the principle that the stimulation colour (seen through a reduction screen) splits in two apparent colours following the law of colour partitive mixture, read in the opposite direction:

<----- fusion

$$\begin{cases} p = \alpha * a + (1 - \alpha) * t \\ q = \alpha * a + (1 - \alpha) * t \end{cases}$$

scission ------->

where p,q are the measures of the fusion colours, a,b are the measures of the opaque colours of the background,t is the measure of the superimposed transparent colour, α is the transparency coefficient.

Da Pos (1976) extended Metelli's model to chromatic situations of transparency: his following systems reflect the achromatic filtering which is the characteristic of Metelli's model and should hold for chromatic transparency as they hold for achromatic transparency:

$$\begin{cases} Xp = \alpha X \cdot Xa + (1 - \alpha X) \cdot Xt \\ Xq = \alpha X \cdot Xb + (1 - \alpha X) \cdot Xt \end{cases}$$

$$\begin{cases} Yp = \alpha Y \cdot Ya + (1 - \alpha Y) \cdot Yt \\ Yq = \alpha Y \cdot Yb + (1 - \alpha Y) \cdot Yt \end{cases}$$

$$\begin{cases} Zp = \alpha Z \cdot Za + (1 - \alpha Z) \cdot Zt \\ Zq = \alpha Z \cdot Zb + (1 - \alpha Z) \cdot Zt \end{cases}$$

solved for αX αY αZ (physical degree of transparency) and for Xt Yt Zt (colour of the transparent layer); X, Y, Z are the tristimuli values for the different colours a, b, p, q, t.

The large number of positive cases produced by Da POS, and the fact that no contrasting example has been found till now, show that this extension effectively holds for chromatic partial transparency; unfortunately it holds quite seldom for chromatic balanced transparency.

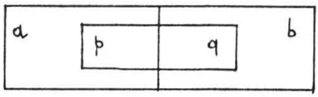
Hyptothesis. For this reason we put forward an alternative interpretation of Metelli's model, in the light of Hering's colour theory. Metelli's mathematical formulations are restricted to achromatic colours because of their semplicity (unidimensionality): we maintain the unidimensionality of the grey scale, but we recognize that two perceptual quantities, whiteness and blackness, are varying along it. Consequently the model can be used, without any modifications, in all kinds of colour scales, provided they are unidimensional.

Then we tried to test if Metelli's model, so interpreted, allows us to formulate verifiable predictions of transparency when chromatic colours vary along one of the following unidimensional scales (taken from N.C.S.): blackness/ chromaticness, whiteness/ chromaticness, yellowness/ reddness, and so on.

Method. The present research is divided into three parts. The first part (already finished) is further subdivided in 4 sections corresponding with the 4 examined hues: G70Y, Y10G, R10B, G10Y (from N.C.S.). For each hue 6 balanced transparency situations have been prepared together with 3 theoretically not transparent cases. In each situation the a, p, q, b, colours were varying along the whiteness/ chromaticness dimension while hue and blackness were constant. For each hue, a group of 22 subjects (88 in total) had to distinguish the situations which looked transparent from the opaque ones; afterwards they had to evaluate their degree of transparency following the pair comparison method (a total of 10 couples of situations for each group of subjects); finally the correspondent transparency scales were derived. The second part of the research (also finished) was identical with the first one, except that the a, p, q, b, colours were varying along the blackness/ chromaticness dimension for each situation; 4 more goups of 22 subjects each performed the same tasks as in the first part. The third part of this research is still in progress: situations of transparency are studied in which the a, p, q, b, colours are of the same nuance and their hues were varying inside one hue quadrant (4 situations), inside two hue quadrants (3 groups of 4 situations), and inside 3 hue quadrants (8 situations).

Results. 1) The theoretically transparent situations were ricognized as such and differentiated from the theoretically non transparent ones in all cases; 2) transparency scales are nearly the same inside every studied situation; 3) the resulting perceptual transparency scales were not those predicted using N.C.S. colour measures.

Discussion. The interpretation of Metelli's model according to Hering's point of view enables us to make simple predictions about transparency situations in which the 4 standard colours (a,p,q,b) vary along a unidimensional scale; such predictions have been nearly perfectly confirmed. However, the relative degrees of perceived transparency do not corrêspond to the predicted ones: this fact seems to depend on the metric characteristics of N.C.S. Therefore it seems that, at least for our special purpose, the problem of measuring colours has to be considered in a different way from that followed by Swedish Colour Insitute, even if the same structure, based on opponency and similarity, should be maintained.



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COLOUR CODIFICATION BY VISUAL INTERPOLATION IN COLOUR ORDER SYSTEMS: HOW EXACT IS IT?

Introduction:

Systematic collections of colour chips have been available since the beginning of this century. Normally, these collections cover the greater part of the colour space accessible with the paint system used. Architects, designers, and all those who select colours for any purpose, need extensive collections from which to choose. The colour in mind must be specified before it is lost from imagination. These practitioners need visually ordered colour sets which permit them to select not only specific colours found in the sets, but also to specify many intermediate colours by visual interpolation. A set of 1,000 colours may allow one to visualise and specify 100,000 colours [1].

On the other hand, it had been shown that the estimation of the codification of any given colour by visual interpolation is far from exact. The codification, obtained by 8 experienced people for 4 different colours in 3 different colour-atlases (DIN 6164, Munsell, NCS) showed a mean standard deviation between 2 and 4 CIELAB units [2] in each of the three dimensions of the system concerned [3]. These deviations are much greater than most colour tolerances in technical applications and, therefore, the ability of colour atlases to serve as reference specimen is limited.

Besides these limitations the use of systematic collections of colour chips from colour order systems is preferred to the definition of colours by colour measurement in some cases, e.g. in architecture and in design. The colour samples of such colour order systems are labelled by the three coordinates of the respective system and usually by the CIE tristimulus values. However, ordinarily these values are valid for the aim-points and not for the actual colour samples. The color coordinates of the actual colour samples deviate more or less from those of the aim-points, and these colour differences give rise to uncertainties during visual interpolation. With the experiments described in this paper the influence of these colour differences on the precision of colour codification by visual interpolation shall be shown.

Materials:

Three colour atlases with different colour differences for their colour samples have been used for the estimation of the colour coordinates of given colour samples by visual interpolation. The colour samples of the now expired glossy edition of the DIN colour chart [4] have very small colour differences: The 1,001 colour samples had a mean colour difference to their respective aim-points of 0.65 CIELAB units, the largest colour difference was 3.8 CIELAB units [5]. The 589 colour samples of the DIN colour chart with matt surface [6] had, according to the production techniques of the early sixties, larger colour differences: the mean colour difference to the respective aim-point was 2.0 CIELAB units. For the 1,412 colour samples of the NCS colour atlas [7] the colour difference depends on the region in the NCS colour solid. 377 colour samples from the border regions of the NCS colour solid (samples with blackness s = 0, with whiteness w = 0, and with high chromaticness c, resp.) have a mean colour difference of 5.3 CIELAB units to the aim-points. The mean colour difference for the other 1,035 colour samples was 1.1 CIELAB units. The largest colour difference was 16.2 CIELAB units [8].

Sets of 23 colour samples with high gloss, with semi gloss, and with matt finish, according to the finish of the samples in the colour atlases used, have been produced for the colour codification by visual interpolation. The positions of the colour samples in CIELAB colour space are shown in Fig.1. The codification of the high gloss samples in the glossy edition of the DIN colour chart, of the semi gloss samples in the NCS colour atlas, and the matt samples in the matt edition as well as in the glossy edition of the DIN colour chart had been done by 10 observers with normal colour vision. In total for each colour sample codification by visual interpolation was done between 23 and 35 times.

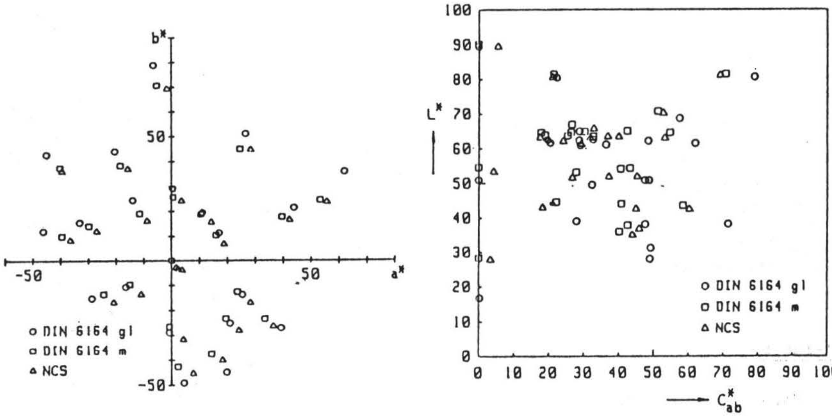

Fig.1: Position of the colour samples used for codification by visual interpolation in the (a*,b*)-diagram (left) and in the (C*,L*)-diagram of the CIELAB colour space. The samples marked as circles have high gloss finish (according to DIN 6164 glossy edition), the samples marked as squares have matt finish (according to DIN 6164 matt edition), and the samples marked as triangles have semi gloss finish (according to NCS).

Methods:

For colour codification by visual interpolation the samples and the resp. colour atlas were put in the horizontal plane and illuminated perpendicular by a xenon lamp of a Siemens colour-matching lamp with good daylight simulation. The observers had to view the samples and the color atlases under approximately 45°, so that disturbing reflections were excluded. Normally 8 samples from the respective colour atlas were used for the visual interpolation. The colour coordinates T (hue), S (saturation) and D (darkness degree) according to DIN 6164 had to be estimated for the glossy and the matt samples, Φ (hue), s (blackness), and c (chromaticness) according to NCS had to be estimated for the semi gloss samples.

Results:

A survey on the mean colour differences between the codifications obtained by visual interpolation and the codifications obtained by colour measurements is given in Table I. The accuracy of codification by visual interpolation is nearly equal

	glossy	semi glossy	matt	matt
		samples		
	in DIN 6164 glossy edition	in NCS colour atlas	in DIN 6164 matt edition	in DIN 6164 glossy edition
all 23 samples	2.0	4.0	1.9	2.1
low to medium chroma	1.7	1.2	1.7	1.7
higher chroma	2.3	6.6	2.2	2.5

Tab.1: Colour differences in CIELAB units between the codifications obtained by visual interpolation and the codifications obtained by colour measurement. The group "low to medium chroma" contains 11 colour samples, the group "higher chroma" contains 12 colour samples.

in the glossy and the matt editions of the DIN colour chart inspite of the fact that the colour differences of the color samples are markedly higher in the matt edition. For colour samples with higher chroma the mean color differences for the NCS colour atlas differ by a factor of three from those in the DIN colour chart.

Because of the different accuracy of the colour samples in the three colour atlases used in the experiments it was expected that the codification by visual interpolation is more exact in the DIN colour chart with glossy samples than in the DIN colour chart with matt samples and in the NCS colour atlas. The experiments have shown that the accuracy of codification by visual interpolation is not alone influenced by the color differences of the colour chart used, but also by the magnitude of the colour differences between adjacent colour samples in the respective colour chart, and by the directions of the colour differences between the aimpoints and the actual colour samples. These influences will be discussed in more detail.

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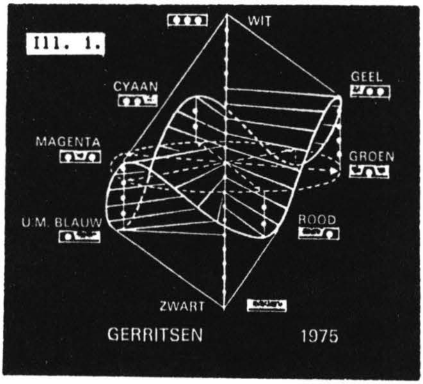
COLOR PERCEPTION SPACE 'GERRITSEN' WITH THE THREE COMPONENT VALUES AND WITH THE OPPONENT VALUES



Color perception space 'Gerritsen' (NL) with the three component values: blue, green, red; with the opponent values: black/white, blue/yellow, green/red, all in one color perception space, Ill. 1.

"Gaps" in the Opponent Color Models

Opponent color models usually have an orthogonal axis system; when these are used as computer models, they can be helpful in the determination of a color point. However, if we study color inter-relationships, with color samples in a color space model, in accordance with our color perception possibilities, the orthogonal system will not suffice because:

A The intersection of two neutral perceptions: black/white and blue/yellow, come together at the same intersection as the yellow perception: green/red

B Green and red lie opposite to each other in the color hue circle, this color pair is not complementary (green + red perception = yellow).

C The color hues are not in visually equally large color hue gradations as to their divisions on the color circle circumference. (Dr. F. Billmeyer, 'AIC-Color 85')

D The color hues are not placed according to their "own" dark/light values in relation to the lightness-darkness levels of the neutral axis between black and white, (Dr. Fred W. Billmeyer, 'AIC-Color 85').

Opponent Values and Three Component Values in One Color Perception Space.

Opponent values and three component values in one color perception space.
The color inter-relationships are ordered in accordance with our color perception possibilities in the "Gerritsen Color Perception Space".
We will explain, in this lecture, how the opponent values: black/white, blue/yellow, green/red, find their places - together with the three component values blue, red, green - in the construction of our color perception space.

The Contrast Signal Black/White

The neutral contrast signal black/white is placed on the vertical lightness axis (B + G + R values)of the color perception space (Ill. 1).

The Opponent Pair +S/-S: Blue-Yellow

The opponent pair +short -short : blue-yellow, is placed upon a schematic scale of wavelength areas.

The Opponent Pair -L/+L: Green-Red

The opponent pair -L/+L: green-red, is placed on the same scale of wavelength areas

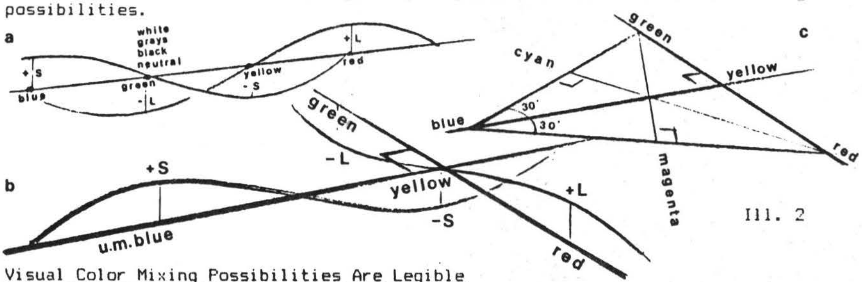
Visual Color Mixing Possibilities Are Not Legible

Shorter than M (middle)	+S/-S
M (middle)	+M/-M
Longer than M (middle)	-L/+L

We see, on the wavelength area scale, (Ill. 2a.) from left to right, the following perception possibilities:

"Plus Short"	ultramarine-blue perception
"Minus Middle"	black perception (perception darker)
"Middle"	balance or reference point, lightness adaptation -level, between black and white contrast signal
"Plus Middle"	white perception (perception lighter)
"Minus Long"	green perception, wavelength part (middle)
"Minus Short"	yellow perception (between middle and long)
"Plus Long"	red perception

From the above summery we do not get a good picture of the visual color mixing possibilities.



Ill. 2

Visual Color Mixing Possibilities Are Legible

Position: Green - Red

We will "turn" the "wavelength area scale" in order to view (understand) the perception mixing color possibilities.

The Part "Green(yellow)Red" is "turned" 90° in the "yellow" point, Ill.2b.

Color Triangle

We draw two lines from the wavelength area ""blue perception";

one line at a 30° with the line: wavelength area "blue - yellow" in the direction of wavelength "green". This line intersects the line "Green (yellow) Red" in "Green" perception area, (Ill. 2c).

One line at a 30° angle with the line: wavelength area scale blue-yellow in the direction of the wavelength area "red", intersects the "green (yellow) red" line in the "red" perception area, (also Ill. 2c).

We now have a "color triangle" blue - green - red.

Median, Position: Blue-Yellow, (Complementary color pair).

The line "Blue-Yellow" is a median from the corner point "Blue".

The Yellow Perception

Between Green and Red perception a Yellow appears, from equal green + red activation. The Opponent color pair: "Blue and Yellow", with the neutral as reference point, is also a visual complementary color pair, within the three component theory. Blue + "Blue" + "Yellow (green + red)" = B+G+R = "neutral"

Median, Position: Green - Magenta, (Complementary Color Pair).

We now draw a median line from the corner point "Green perception" to the side Blue - Red in the perception color area Magenta (blue + red perception).

Green and Magenta form a complementary color pair, the visual mixing color of equally and simultaneously activated "Green" plus "Magenta" (blue + red) perception results in neutral perception B+G+R.

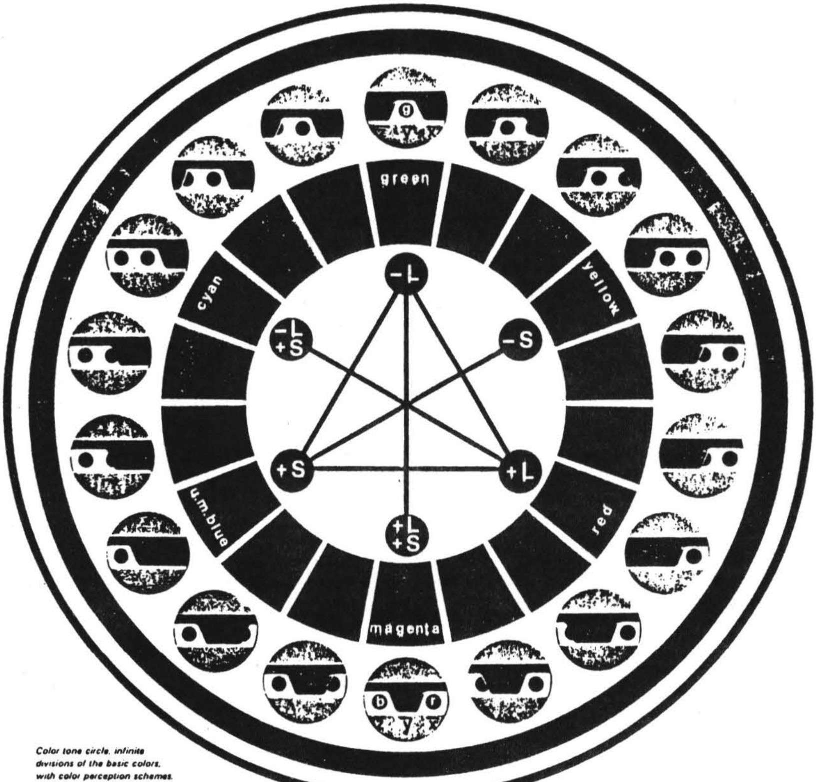
Median, Position: Red - Cyan, (Complementary Color Pair).

We draw a perpendicular bisector median from the corner point "Red Perception" on the side Blue - Green in the color perception area "Cyan" (blue + green).

Red and Cyan is a complementary color pair. The Visual mixing color of equally and simultaneously activated "Red" + (blue + green) is a neutral perception B+G+R.

All Color Hues "100" Are Equa-Distant From The Neutral Point.

Now we place all perceptible colors, color set at "100", equa-distant from the neutral center where color is set at "0".



Color tone circle, infinite divisions of the basic colors, with color perception schemes.

Ill. 3.

The Opponent Theory and the Three Component Theory in One Scheme
The total scheme of the opponent color pairs are placed in the color circle.
The color perception schemes of the three component theory (Blue - Green - Red) are placed outside the circle, (Ill. 3).
The sum of each complementary color pair (all lie opposite to each other) is equal to 1 B + 1 G + 1 R value (see the color perception schemes).

Colors are Ordered According to Their Own Light/Dark Values
All full color hues are ordered according to their own intrinsic lightness in relation to the light/dark values of the neutral lightness axis.

Ordering and Saturation
A cross section of the color perception space through the opponent and complementary color pair: blue-yellow, shows the succession of the saturation of the color hues from neutral to full color hue.

Opponents and Three Components in one scheme, Color Perception Space Gerritsen, 1975.
All colors are ordered according to our color perception possibilities (opponent and three component pairs) :
according to perception and color hue (the color of a color)
according to perception and lightness (how light or dark is a color)
according to perception and saturation (the colorfulness of a color as compared to a neutral)

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ESTIMATION OF SPECTRAL REFLECTANCE FUNCTIONS FOR MUNSELL RENOTATIONS

1. INTRODUCTION

The colorimetric values x, y, Y of the Munsell Renotation System[1] are only specified with respect to illuminant C and the CIE 1931 standard observer. However, from a theoretical and a practical point of view, its colorimetric values are often needed under illuminants D_{65} and A, and also for the CIE 1964 standard observer. For example, when the two chromatic adaptation transforms, the von Kries[2] and the nonlinear chromatic adaptation transform[3], are compared under an adaptation of illuminant A[4], the colorimetric values of the Munsell System under illuminant A are needed. However, this is impossible because the authorized spectral reflectance functions are not known in the Munsell Renotation System. The purpose of the present study is to specify its spectral reflectance functions. This was made on the basis of the measured spectral reflectance functions of 1,569 color chips in the Standard Color Atlas[5] of the Japanese Industrial Standard (JIS), which was developed to realize the Munsell Renotation System in 1977. The present study also expects to give a tentative proposal for standardizing the spectral reflectance functions of the Munsell Renotation System.

2. ANALYSIS

All the measured spectral reflectance functions on the JIS Standard Color Atlas were kindly supplied from the Japan Color Research Institute through the courtesy of Prof. G. Kawakami. The spectral data of each color were given at 31 wavelengths ranged from 400 to 700 nm at 10 nm intervals. The number of data amounted to 48,639(=1,569 samples x 31 wavelengths). These data can not be directly used for the standardizing purpose due to their enormous quantities. In addition, the spectral reflectance data of each color does not give the nominal colorimetric values of its target Munsell color notation exactly.

By considering the above, the principal component analysis was applied to all the measured spectral reflectance functions. The analysis was made for each of five color groups R, Y, G, B, and P by classifying the Atlas. The color group R includes all the colors with Munsell Hue notations from 2.5RP, through 5R, to 7.5YR, and the color group Y includes those from 2.5YR, through 5Y, to 7.5GY. This means that the colors with the intermediate Munsell Hues(YR, GY,...,RP) are always used in the analysis of the two color groups with their principal Munsell Hues. Eigen values and eigen vectors were extracted from each of the 5 color groups. Table 1 shows the averaged spectral reflectance $R_0(\lambda)$ and the first three components $R_1(\lambda)$, $R_2(\lambda)$, $R_3(\lambda)$ extracted from each color group. All the cumulative contribution factors on the first three components are always above 99.5% and quite high. Thus, the spectral reflectance functions in each group are well estimated by using the derived components.

3. ESTIMATION OF SPECTRAL REFLECTANCE FUNCTION

Based on the analysis, the spectral reflectance function with nominal colorimetric values[1] x_C, y_C, Y_C of a Munsell Colors is derived by the following procedures.

(1) The values x_c, y_c, Y_c are transformed to the tristimulus values X_c, Y_c, Z_c.

(2) The values X_α, Y_α, Z_α are derived by

$$\begin{bmatrix} X_\alpha \\ Y_\alpha \\ Z_\alpha \end{bmatrix} = \left\{100 / \sum_{\lambda=1}^{31} S_c(\lambda)\,\bar{y}(\lambda)\right\} \cdot \sum_{\lambda=1}^{31} S_c(\lambda) R_\alpha(\lambda) \cdot \begin{bmatrix} \bar{x}(\lambda) \\ \bar{y}(\lambda) \\ \bar{z}(\lambda) \end{bmatrix} \Delta\lambda \quad (\alpha = 0,1,2,3), \qquad (1)$$

where $S_c(\lambda)$ is the relative spectral power distribution of standard illuminant C and $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are the CIE 1931 color matching functions. These values can be computed in advance.

(3) Coefficients k_1, k_2, k_3 are computed by putting the values obtained in steps(1) and (2) into

$$\begin{bmatrix} k_1 \\ k_2 \\ k_3 \end{bmatrix} = \begin{bmatrix} X_1 & X_2 & X_3 \\ Y_1 & Y_2 & Y_3 \\ Z_1 & Z_2 & Z_3 \end{bmatrix}^{-1} \begin{bmatrix} X_c - X_o \\ Y_c - Y_o \\ Z_c - Z_o \end{bmatrix}. \qquad (2)$$

(4) The needed spectral reflectance function $\rho(\lambda)$ is specified by introducing k_1, k_2, k_3 and $R_\alpha(\lambda)$ $\alpha = 0, 1, 2, 3$ into

$$\rho(\lambda) = R_o(\lambda) + \sum_{\alpha=1}^{3} k_\alpha R_\alpha(\lambda). \qquad (3)$$

Notes: (1) For Munsell colors within a Munsell principal hue range, for example from 10RP(0R), through 5R, to 10R, the $\rho(\lambda)$ function is derived only by using the values in Table 1(a) for color group R. (2) For Munsell colors within an intermediate hue range, for example from 10R(0YR), through 5YR, to 10YR, the two $\rho(\lambda)$ functions $\rho_R(\lambda)$ and $\rho_Y(\lambda)$ are derived by the same procedure, but using Table 1(a) and Table 1(b), respectively. The needed function $\rho(\lambda)$ is determined by a weighted sum of $\rho_R(\lambda)$ and $\rho_Y(\lambda)$ as $\rho(\lambda) = 0.25\rho_Y(\lambda) + 0.75\rho_R(\lambda)$ for a color with 2.5YR, $\rho(\lambda) = 0.5\rho_Y(\lambda) + 0.5\rho_R(\lambda)$ for 5YR, $\rho(\lambda) = 0.75\rho_Y(\lambda) + 0.25\rho_R(\lambda)$ for 7.5YR, $\rho(\lambda) = \rho_R(\lambda)$ for 10R(0YR), and $\rho(\lambda) = \rho_Y(\lambda)$ for 10YR.

To each of the measured spectral reflectance functions of the 1,569 color chips, the corresponding $\rho(\lambda)$ function was predicted by the above procedure, but using the computed tristimulus values X_c', Y_c', Z_c' of each color chip instead of X_c, Y_c, Z_c in eq.(2). All the comparisons showed that the procedures stated above worked precisely and accurately.

4. CONCLUSIONS

The present study clarified the following items.

(1) The measured spectral reflectance functions of the JIS Standard Color Atlas are decomposed into the three principal components in each of the 5 color groups in the Atlas. (2) By using the three components, a simple method is proposed to derive the spectral reflectance function $\rho(\lambda)$ to each of the nominal colorimetric values in the Munsell Renotation System. (3) The method can reproduce the measured spectral reflectance functions used in the analysis accurately. (4) Using the derived $\rho(\lambda)$ function, colorimetric values of Munsell colors can be estimated for any illuminant and for any observer within a color gamut used in the analysis.

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Table 1. The averaged spectral reflectance (Ro) and the three components(R1, R2, R3) extracted for each color group.

(a) color group R

λ	R_0	R_1	R_2	R_3
400	0.1661	0.0823	0.0897	0.1546
10	0.2136	0.1344	0.1616	0.2168
20	0.2237	0.1499	0.1862	0.2266
30	0.7236	0.1517	0.1904	0.2204
40	0.2228	0.1521	0.1918	0.2104
450	0.2219	0.1523	0.1930	0.1991
60	0.2199	0.1521	0.1939	0.1821
70	0.2172	0.1519	0.1951	0.1562
80	0.2141	0.1515	0.1958	0.1232
90	0.2115	0.1511	0.1950	0.0824
500	0.2105	0.1511	0.1936	0.0305
10	0.2111	0.1520	0.1865	−0.0350
20	0.2120	0.1532	0.1767	−0.1023
30	0.2126	0.1538	0.1710	−0.1432
40	0.2139	0.1544	0.1667	−0.1724
550	0.2191	0.1567	0.1579	−0.2165
60	0.2337	0.1624	0.1406	−0.2893
70	0.2655	0.1747	0.1093	−0.3664
80	0.3134	0.1904	0.0555	−0.3712
90	0.3593	0.2026	−0.0218	−0.2917
600	0.3914	0.2093	−0.0953	−0.1795
10	0.4032	0.2128	−0.1489	−0.0860
20	0.4162	0.2154	−0.1807	−0.0304
30	0.4199	0.2168	−0.1975	0.0020
40	0.4231	0.2178	−0.2076	0.0319
650	0.4259	0.2182	−0.2144	0.0603
60	0.4286	0.2185	−0.2199	0.0862
70	0.4297	0.2179	−0.2233	0.1060
80	0.4307	0.2179	−0.2263	0.1200
90	0.4317	0.2183	−0.2291	0.1313
700	0.4325	0.2187	−0.2319	0.1405

(b) color group Y

λ	R_0	R_1	R_2	R_3
400	0.1294	0.0682	0.1235	−0.1311
10	0.1602	0.1011	0.1900	−0.2054
20	0.1678	0.1100	0.2095	−0.2195
30	0.1712	0.1128	0.2154	−0.2127
40	0.1752	0.1156	0,2204	−0.2022
450	0.1803	0.1188	0.2259	−0.1884
60	0.1863	0.1223	0.2315	−0.1687
70	0.1936	0.1266	0.2379	−0.1445
80	0.2021	0.1313	0.2432	−0.1159
90	0.2145	0.1374	0.2473	−0.0804
500	0.2360	0.1471	0.2479	−0.0185
10	0.2701	0.1609	0.2327	0.0908
20	0.3073	0.1755	0.1903	0.2362
30	0.3288	0.1847	0.1490	0.3366
40	0.3390	0.1893	0.1202	0.3730
550	0.3476	0.1936	0.0919	0.3598
60	0.3598	0.1979	0.0512	0.3056
70	0.3769	0.7035	−0.0064	0.2212
80	0.3902	0.2079	−0.0651	0.1273
90	0.3932	0.2107	−0.1119	0.0431
600	0.3956	0.2119	−0.1415	−0.0248
10	0.3923	0.2124	−0.1579	−0.0727
20	0.3901	0.2132	−0.1669	−0.1000
30	0.3889	0.2140	−0.1715	−0.1124
40	0.3880	0.2149	−0.1741	−0.1190
650	0.3870	0.2153	−0.1757	−0.1218
60	0.3877	0.2163	−0.1757	−0.1153
70	0.3888	0.2169	−0.1737	−0.0931
80	0.3906	0.2179	−0.1718	−0.0810
90	0.3923	0.2191	−0.1703	−0.0558
700	0.3933	0.2201	−0.1698	−0.0557

(c) color group G

λ	R_0	R_1	R_2	R_3
400	0.1418	0.0868	0.1008	0.1219
10	0.1808	0.1318	0.1530	0.2202
20	0.1945	0.1463	0.1751	0.2436
30	0.2029	0.1517	0.1875	0.2356
40	0.2122	0.1567	0.1992	0.2198
450	0.2238	0.1624	0.2132	0.1960
60	0.2378	0.1685	0.2327	0.1590
70	0.2549	0.1749	0.2571	0.1076
80	0.2708	0.1807	0.2722	0.0495
90	0.2867	0.1865	0.2715	−0.0123
500	0.3057	0.1938	0.2427	−0.0958
10	0.3281	0.2019	0.1843	−0.2148
20	0.3440	0.2085	0.1099	−0.3275
30	0.3455	0.2119	0.0527	−0.3638
40	0.3375	0.2128	0.0101	−0.3402
550	0.3239	0.2118	−0.0299	−0.2837
60	0.3073	0.2090	−0.0656	−0.2166
70	0.2901	0.2052	−0.1002	−0.1461
80	0.2717	0.2000	−0.1286	−0.0754
90	0.2508	0.1927	−0.1534	−0.0051
600	0.2286	0.1835	−0.1736	0.0573
10	0.2108	0.1752	−0.1852	0.0978
20	0.2005	0.1703	−0.1906	0.1181
30	0.1958	0.1692	−0.1923	0.1268
40	0.1933	0.1673	−0.1930	0.1318
650	0.1917	0.1668	−0.1932	0.1337
60	0.1944	0.1688	−0.1926	0.1289
70	0.2008	0.1727	−0.1895	0.1157
80	0.2092	0.1770	−0.1851	0.0995
90	0.2145	0.1809	−0.1816	0.0838
700	0.2190	0.1838	−0.1778	0.0737

(d) color group B

λ	R_0	R_1	R_2	R_3
400	0.1933	0.0925	−0.0366	−0.1440
10	0.2662	0.1610	−0.0318	−0.2399
20	0.2911	0.1864	−0.0370	−0.2661
30	0.3005	0.1911	−0.0659	−0.2676
40	0.3086	0.1933	−0.1007	−0.2628
450	0.3177	0.1951	−0.1454	−0.2512
60	0.3259	0.1964	−0.1919	−0.2079
70	0.3340	0.1973	−0.2409	−0.1403
80	0.3378	0.1977	−0.2731	−0.0637
90	0.3363	0.1980	−0.2819	0.0242
500	0.3304	0.1981	−0.2686	0.1030
10	0.3216	0.1980	−0.2394	0.1636
20	0.3083	0.1969	−0.1941	0.2296
30	0.2936	0.1951	−0.1393	0.2665
40	0.2786	0.1925	−0.0785	0.2748
550	0.2612	0.1884	−0.0130	0.2721
60	0.2419	0.1823	0.0455	0.2710
70	0.2259	0.1765	0.0924	0.2533
80	0.2154	0.1729	0.1285	0.2092
90	0.2070	0.1697	0.1605	0.1476
600	0.1981	0.1661	0.1897	0.0855
10	0.1907	0.1629	0.2090	0.0398
20	0.1876	0.1618	0.2168	0.0092
30	0.1892	0.1632	0.2171	−0.0213
40	0.1935	0.1658	0.2162	−0.0625
650	0.1979	0.1681	0.2152	−0.1032
60	0.2024	0.1704	0.2117	−0.1235
70	0.2056	0.1720	0.2044	−0.1130
80	0.2063	0.1727	0.1993	−0.0818
90	0.2070	0.1737	0.1946	−0.0535
700	0.2102	0.1757	0.1870	−0.0493

(e) color group P

λ	R_0	R_1	R_2	R_3
400	0.2179	0.0847	0.0377	−0.1405
10	0.2974	0.1530	0.1000	−0.1893
20	0.3194	0.1771	0.1331	−0.1996
30	0.3228	0.1801	0.1481	−0.2129
40	0.3234	0.1807	0.1606	−0.2193
450	0.3225	0.1809	0.1730	−0.2195
60	0.3180	0.1805	0.1827	−0.1998
70	0.3106	0.1800	0.1929	−0.1654
80	0.3002	0.1789	0.2004	−0.1151
90	0.2861	0.1772	0.1996	−0.0450
500	0.2717	0.1748	0.1948	0.0201
10	0.2582	0.1720	0.1888	0.0734
20	0.2437	0.1695	0.1776	0.1319
30	0.2334	0.1662	0.1656	0.1750
40	0.2278	0.1649	0.1570	0.1948
550	0.2229	0.1637	0.1465	0.2092
60	0.2176	0.1622	0.1270	0.2377
70	0.2228	0.1653	0.0913	0.2677
80	0.2436	0.1742	0.0240	0.2756
90	0.2680	0.1831	−0.0615	0.2418
600	0.2848	0.1883	−0.1345	0.1895
10	0.2908	0.1906	−0.1796	0.1603
20	0.2900	0.1915	−0.1978	0.1595
30	0.2920	0.1929	−0.2026	0.1438
40	0.3013	0.1957	−0.2058	0.0955
650	0.3142	0.1984	−0.2114	0.0227
60	0.3269	0.2005	−0.2221	−0.0582
70	0.3358	0.2007	−0.2366	−0.1295
80	0.3409	0.2003	−0.2541	−0.1786
90	0.3447	0.2001	−0.2690	−0.2174
700	0.3490	0.2004	−0.2746	−0.2559

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COLOR SPACE MODEL ON COLOR OF TOOTH-CROWN

In the restoration of the area of the anterior teeth, it is considered very desirable to capture the actual color of the natural tooth-crown since the anterior teeth are required to possess, as an aesthtic factor, a color tone that does not impair naturaless. We, in an effort to develop a method for making objective recording of the tooth-crown color using a shade guide with better reproducibility, and for the purpose of determining the range and position of the color tone, made a new color chart(63 colors). (Table 1)

1) The color chart(17 colors) measuring the color range of upper anterior human natural teeth was made by the three dimensinonal(Hue Value Chroma) color chart in the Munsell Color Notation. (Fig. 1) This color chart was used on a total of 42 men and women(17～53 age) to measure the color tone of the natural anterior teeth with the standard light source D_{65} and by the visual color comparison method. It was the locations measuring. (Fig. 2) Results obtained were that the human natural teeth color range extended in hue from 8.75YR to 2.5Y in value from 6.0 to 8.0 and in chroma from 1.0 to 4.0 in this three dimensional color chart.
2) Concerning the distribution of tooth-crown color presented in the above-mentioned study, in addition to the relations with Munsell Color System taken up ever widely in the color study, color chart(21 colors) was made by using psychometric quantity highly relative to the psychophysical quantity based on psycho perceptive quantity presented by HUNT, R. W. G.. (Table 2)
3) The color chart(21 colors) was used on a total of 190 men and women (10～72 age) to measure the color tone of the natural anterior teeth with the standard light source D_{65} and by the visual color

comparision method. At the same time, an examination was made of the color distribution of the natural teeth, using the metric multidimensional scale.

For the data classified by sex, by location(left or right side), and by type of tooth, we obtained average values for hue, value, and chroma and the range of deviation up to the standard$\pm 3\sigma$ and converted them into the L*a*b* uniform color scale of CIE. And as a result of showing the above-mentioned deviation range on the L*a*b* color space, the color distribution of the natural teeth, when compared with that obtained using the color chart composed of the metric multidimentional scale, had been found to fall within the range of the color chart(21 colors).

4)Finally, a new color chart(63 colors) was designed based the color chart(21 colors). The color space model on color of tooth-crown was reappeared by a new color chat(63colors).(Fig. 3)

Table 1 Standard of color chip on the tooth crown color

color chip number	CIE 1976 L*a*b* color system			color chip number	CIE 1976 L*a*b* color system			color chip number	CIE 1976 L*a*b* color system		
	L*	a*	b*		L*	a*	b*		L*	a*	b*
1	70.56	4.80	17.32	22	67.30	0.00	17.94	43	70.56	3.21	29.54
2	67.30	3.86	17.55	23	70.56	0.00	17.97	44	73.82	2.48	13.87
3	70.56	3.86	17.55	24	73.82	0.00	17.97	45	73.82	0.55	14.05
4	73.82	3.86	17.55	25	70.56	−0.97	17.94	46	73.82	3.33	21.60
5	64.04	2.91	17.73	26	70.56	0.67	6.19	47	73.82	1.40	21.80
6	67.30	2.91	17.73	27	67.30	1.10	10.18	48	70.56	2.05	9.90
7	70.56	2.91	17.73	28	70.56	1.10	10.18	49	70.56	0.12	10.11
8	73.82	2.91	17.73	29	73.82	1.10	10.18	50	70.56	3.42	13.61
9	77.03	2.91	17.73	30	64.04	1.52	13.98	51	70.56	2.48	13.82
10	60.77	1.94	17.86	31	67.30	1.52	13.98	52	70.56	0.55	14.08
11	64.04	1.94	17.86	32	70.56	1.52	13.98	53	70.56	−0.42	14.02
12	67.30	1.94	17.86	33	73.82	1.52	13.98	54	70.56	4.27	21.39
13	70.56	1.94	17.86	34	77.08	1.52	13.98	55	70.56	3.33	21.60
14	73.82	1.94	17.86	35	64.04	2.36	21.75	56	70.56	1.40	21.81
15	77.08	1.94	17.86	36	67.30	2.36	21.75	57	70.56	0.42	21.81
16	80.35	1.94	17.86	37	70.56	2.36	21.75	58	70.56	3.20	25.47
17	64.04	0.97	17.94	38	73.82	2.36	21.75	59	70.56	1.82	25.67
18	67.30	0.97	17.94	39	77.08	2.36	21.75	60	67.30	2.48	13.87
19	70.56	0.97	17.94	40	67.30	2.79	25.65	61	67.30	0.55	14.08
20	73.82	0.97	17.94	41	70.56	2.79	25.65	62	67.30	3.33	21.60
21	77.06	0.97	17.94	42	73.82	2.79	25.65	63	67.30	1.40	21.81

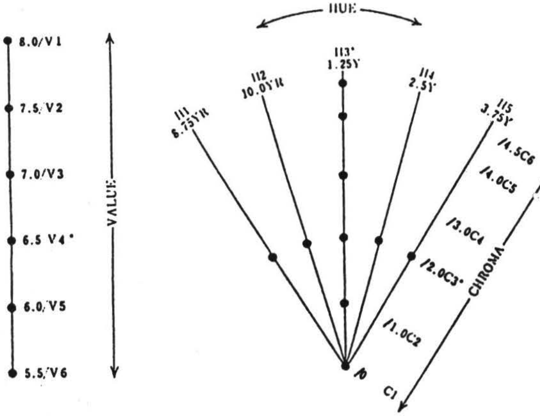

Fig. 1 The Hue Value/Chroma range of color standard used in the selection of natural teeth

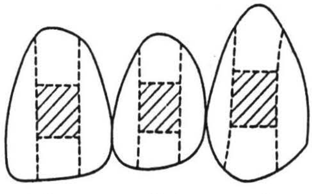

Fig. 2 Location

Table 2 Metric color standard (H°ab metric hue-angle, L* lightness, C*ab metric chroma, L*a*b*, HV/C)

		H°ab	L*	a*	b*	H	V/C
	H1 −3σ	74.5	70.56	4.80	17.32	8.57YR	6.89/2.89
	H2 −2σ	77.6	↑	3.86	17.55	9.34YR	↑ /2.80
	H3 − σ	80.7	↑	2.91	17.73	0.15Y	↑ /2.72
Hue	H4* x̄	83.8	↑	1.94	17.86	1.02Y	↑ /2.66
	H5 + σ	86.9	↑	0.97	17.94	1.90Y	↑ /2.58
	H6 +2σ	90.0	↑	0.00	17.97	2.81Y	↑ /2.51
	H7 +3σ	93.1	↑	−0.97	17.94	3.80Y	↑ /2.45
		L*					
	V1 −3σ	60.77	60.77	1.94	17.86	1.41Y	5.91/2.66
	V2 −2σ	64.04	64.04	↑	↑	1.27Y	6.23/ ↑
	V3 − σ	67.30	67.30	↑	↑	1.14Y	6.56/ ↑
Value	V4* x̄	70.56	70.56	↑	↑	1.02Y	6.89/ ↑
	V5 + σ	73.82	73.82	↑	↑	0.85Y	7.23/ ↑
	V6 +2σ	77.08	77.08	↑	↑	0.69Y	7.56/2.67
	V7 +3σ	80.35	80.35	↑	↑	0.52Y	7.90/ ↑
		C*ab					
	C1 −3σ	6.23	70.56	0.67	6.19	0.87Y	6.89/0.91
	C2 −2σ	10.14	↑	1.10	10.18	0.82Y	↑ /1.49
	C3 − σ	14.06	↑	1.52	13.98	0.81Y	↑ /2.06
Chroma	C4* x̄	17.97	↑	1.94	17.86	1.02Y	↑ /2.66
	C5 +2σ	21.88	↑	2.36	21.75	1.15Y	↑ /3.25
	C6 +2σ	25.80	↑	2.79	25.65	1.23Y	↑ /3.83
	C7 +3σ	29.71	↑	3.21	29.54	1.34Y	↑ /4.43

mean color (x̄) : L*=70.56, H°ab=83.8, C*ab=17.97

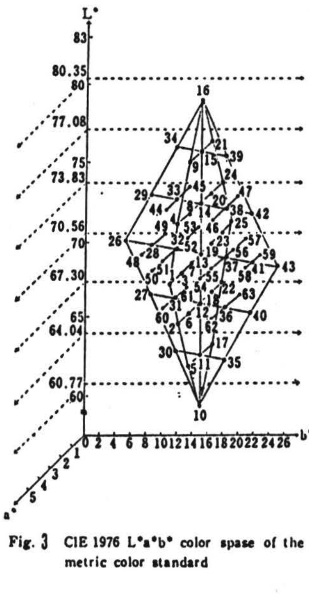

Fig. 3 CIE 1976 L*a*b* color spase of the metric color standard

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COLOUR ORDER SYSTEMS and COLOUR ATLASES

1. Introduction

In a contribution to the AIC Symposium on Colour Design, the process of colour vision was described in four phases from stimulus to percept: physics, psychophysics, physiology, and psychology (dealing with - in the same order - colour stimulus, colour valence, neural response, and colour percept).

As all models, this structure has both merits and shortcomings. Colorimetry was invented and practised long before man could understand the physiological process in the nervous system - what actually happens between stimulus and percept is treated as a "black box". Physiologists may describe the visual sense without evaluating the luminous flux into tristimulus values and chromaticity coordinates.

I would therefore now like to modify this model, with colorimetry and the neural response model beside each other as alternative links between stimulus and percept (Fig. 1). The content of each part of the model will first be repeated briefly.

COLOUR VISION

Physiology
eye + neural system
NEURAL RESPONSE

Physics
illuminant
stimulus object
COLOUR STIMULUS

Psychology
visual cortex
signal evaluation
COLOUR PERCEPT

Psychophysics
colorimetry
COLOUR VALENCE

COLOUR OPTICS

Figure 1. The four phases of colour optics and colour vision.

2 Colour optics

2.1 The colour stimulus

The spectral power distribution of the electromagnetic flux emanating from the sun, the sky or an artificial illuminant and viewed either directly or after being reflected or transmitted by an object, is a purely physical concept. If at least part of the flux is within the spectral range where the human eye is sensitive, it is called luminous, but it is still physical (".. the rays are not coloured", Newton 1730). The flux entering the eye acts as a **colour stimulus** on the visual system to produce a colour percept. The term stimulus is also used for the object emitting, reflecting or transmitting the flux towards the eye. Neither the radiant flux nor the stimulus object **are** colours, they make the observer **see** colours.

2.2 The colour valence

In colorimetry, the spectral power distribution of the stimulus is measured with physical methods. Human colour vision is simulated by an evaluation, based on a psychophysical colour-matching experiment made once for all. Using the mean values as the **CIE standard observer** (individuals may deviate noticeably without being colour deficient) reduces colorimetry to physical measurement and mathematical calculations, resulting in the **colour valence** of the stimulus, expressed as its tristimulus values and chromaticity coordinates.

The term "colour valence" (= the capacity of a stimulus to evoke a colour percept) is translated from German "Farbvalenz" (Richter 1954). The usual English term is "psychophysical colour", as a parallel to "perceived colour". Both are unfortunate, implying "colour" to be dual in character and to exist outside the observer.

Two stimuli with the same colour valence will - under equal observing conditions - look <u>alike</u>, but the colour valence does not tell <u>how</u> they look. Also, if the observing conditions are different (e.g. different surrounds), equal stimuli with the same colour valence may look different. **Colorimetry can only be used for stimuli, not for percepts.**

3 <u>Colour vision</u>

3.1 The neural response

The three-receptor theory for colour vision was first postulated by Palmer, Young and Helmholtz. We now know the sensitivity functions of the receptors, and roughly how the **neural response** is coded into three opponent signals (red/green, blue/yellow, and light/dark) sent to the visual cortex. In the final stage information from other parts of the visual field and from memory is used, which may explain colour constancy, induction etc.

3.2 The colour percept

The colour percept resulting from the visual system's handling of the incoming stimulus - including the evaluation in the cortex - should be the real sense of **colour**. When Hering devised the "natural system of colour percepts", he also emphasized the study of the colours themselves, irrespective of their physical cause. Percepts can be measured by psychometric methods as well as stimuli can be measured by physical methods.

4. <u>Colour order systems</u>

4.1 Physical

A physical colour system is defined by systematically selected mixtures of dyes or pigments or screen plate densities. No such system has any meaning unless the corresponding set of physical samples is actually produced. The selection may be made with more or less regard to the psychophysical or perceptive qualities of the samples produced.

4.2 Psychophysical

The CIE colorimetric system is <u>per se</u> a psychophysical system.

None of the colour systems in this group has any natural references (except possibly black and white). Their definition is therefore dependent on the colour valences for a set of points in colour space selected according to some rules. These may well be perceptive and the selection made in perceptive experiments, but the definition is clearly psychophysical - and only valid for a given combination of observer, illuminant and instrument.

A.Munsell originally based his system on psychological considerations, but used mathematical and psychophysical concepts in his scaling. Later on, the Munsell renotation work involved a perceptive smoothing to achieve a more equal spacing, defined by a table of colour valences.

Also the DIN system is defined by colour valences obtained from a perceptive equi-spacing of 'darkness' and hue (making the Munsell hue scale doubtful) and a judgement of equal saturation. To facilitate the use of algorithms in calculation, constant hue and saturation are defined as straight lines in CIE space.

In the Coloroid system, the hue scale is chosen on some colour harmony criteria, otherwise the system is similar to the DIN system.

An equal spacing between nodal points is a usual criterion for psychophysical systems, but can only be partially achieved in a cylindrical coordinate system necessarily connected with the hue concept. Some systems have therefore replaced the hue and chroma/saturation variables by rectangular coordinates. The CIELAB system is a mathematical cubic transformation of the CIE tristimulus values, whereas the OSA-UCS system was built on extensive perceptive experiments interpreted by a complicated algorithm. Both systems are therefore defined by colour valences. In both systems the horizontal axes (in a constant-lightness plane) are referred to by the names of unique hues. This may hold for yellow, but for other hues it gives a fairly bad description of the corresponding colour percept.

4.3 Perceptive

The NCS is based on and defined in terms of the visual properties of colour percepts. The six "elementary colours" (Hering: "einfache Farben") are easily recognizable and may be used as mental references for the "elementary attributes" in describing all other colours; no colour samples are needed. The scales of the variables are obtained by psychometric methods. The system is therefore totally within the domain of psychology. It is a general method for a verbal description of any colour percept in any viewing situation. Neither physical colour samples nor measured colour valences are needed for this description. It can also be given as an NCS notation, for which there is a standardized format.

5 Colour atlases

A colour atlas is a collection of colour samples (stimulus objects) intended to illustrate a certain colour system. The atlas is necessarily physical, and it is not the system. Even in the simplest physical colour system there must be some logical rules for the production of the colorant mixtures which form the atlas (or colour chart).

For most psychophysical colour systems (Munsell,DIN,OSA-UCS,Coloroid), the samples in the colour atlases are produced to the colour valences which define the system (for given observer and illuminant). In some cases, there are colour valence data for two or more situations, but the samples remain the same with the same notation. The strict consequence of this is that in those systems the correspondence between sample and notation is more important than between notation and appearance.

Whereas the NCS as system is quite general in character, it is obvious that an NCS Atlas - and the colour valence tables specifying its samples - must have its validity restricted in the same way as the psychophysical colour order systems and their atlases. The NCS Colour Atlas does only illustrate one special case of the Natural Colour System: that of ordinary daylight. In other viewing situations the same samples may generate other colour percepts; these can be described by other NCS notations.

6 Conclusions

The communication about colour would profit from a clearer distinction between the concepts of physical stimulus, its psychophysical specification and the colour percept. The term **colour valence** is suggested to replace the presently used "psychophysical colour". The distinction is of particular importance in dealing with colour order systems, which may be based on either of these concepts - with significantly different applications. A perceptively defined colour system has e.g. a much greater versatility than one defined by colour valence data, which are valid only for one single observing situation. Another distinction frequently neglected is that between the immaterial colour order system and the physical colour atlas illustrating the system.

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PROGRESS TOWARDS MEASURING COLOUR REPRODUCTION

Introduction

At the present time there are five major variables which are used to compare photographic systems: these relate to the speed, graininess, sharpness, tone and colour of the system. The first four of these can be characterized by well established measures: ASA speed, RMS granularity, modulation transfer function and gamma: they can also be measured in a standardized manner.

With the quest, in recent years, for higher photographic speed, lower graininess and higher sharpness, the colour reproduction of a photographic system has been assumed correct almost by default: any assessment has been made in a relative, subjective manner. This is due partly to the lack of a system for measuring the appearance of colours: such a system could be used to provide quantitative measures that assess the colour reproduction of systems.

Colour Appearance

A recent model of colour vision[1] has provided a basis for predicting colour appearance that is in good agreement with established colour order systems (for example the NCS System). The basic model has been extended to provide predictions of colour appearance using illuminants other than daylight[2] and a further extension has provided the ability to predict values for the absolute parameters associated with colour appearance, i.e. brightness and colourfulness[3]. Thus, for example, if two colours had the following colorimetric specification (computed from measurements of the spectral reflectances and using illuminant D65) and were viewed such that the photopic luminance of a reference white was 10,000 cd/m² and that of their surround was 1/5 of this value:

	u'	v'	Y
Sample 1	0.149	0.474	27.04
Sample 2	0.150	0.520	14.13
D65	0.198	0.468	100.00

applying the model gives the following relative appearance specification:

	Hue	Chroma	Lightness
Sample 1	72G 28B	68	63
Sample 2	80G 20Y	72	48

where the chroma scale has been adjusted to give values approximately ten times that of Munsell Chroma and the lightness scale has zero representing black and 100 representing white. Values can also be calculated for the absolute brightness and colourfulness.

Colour Reproduction

A colour reproduction index should attempt to provide a number that gives a measure of the differences between a 'reference' and a 'test' situation. In a suggested scheme[4] the overall index is derived from a series of twelve intermediate indices. There are four hue, four lightness and four chroma indices relating to red, yellow, green and blue respectively. These twelve indices can be considered as vectors in that the calculations provide both the mean magnitude and the mean direction of the colour differences. An example is given below:

Reference: Original Macbeth Color Checker
Test: Reproduction of original chart

	Hue Indices		Lightness Indices		Chroma Indices	
Red	96.5	R>Y	96.7	Lighter	89.4	Decrease
Yellow	85.6	Y>R	96.2	Darker	84.0	Decrease
Green	79.1	G>B	96.7	Darker	83.2	Decrease
Blue	92.9	B>G	96.4	Lighter	89.9	Decrease

Hue Index	90.7	(100 represents perfect reproduction)
Lightness Index	96.5	
Chroma Index	87.5	
Overall Index	88.4	

These results can be interpreted by saying that, on average, green colours are reproduced 21% blue, and yellow colours 14% red. The reproduction has, on average, 12% less chroma and is slightly lighter than the original.

In order to justify the indices sets of reflection prints, consisting of a normal print and a colour ring-round, were produced for four scenes including the Macbeth Color Checker Chart[5]. The prints in each set were placed in rank order according to the perceived quality of colour reproduction: ten observers were used. The results showed a reasonable correlation between the implied rank order from the colour reproduction indices and the experimental rank order.

Colour Difference

Further work[6], has investigated the size of just perceptible colour difference for each of the colours of the Macbeth Chart. Sets of reflection prints were produced such that the colour of each patch was perturbed in turn. Thus observers were asked to view prints that were essentially similar, with only small changes in the colour of one patch.

The observers were asked to compare each print with a reference print and segregate those prints where they could detect a difference in appearance. (They were told which colour had been perturbed.) An analysis of the results from twelve observers, to derive colour difference ellipses, showed that the perceptible differences could be best represented by two colour difference units in CMC (1:1) space[7].

This latter result implies a set of 18 ellipses in CIELAB space, one for each colour patch of the Macbeth Chart, orientated such that their major axes fall along lines of constant hue angle. For each ellipse it can be imagined that there is a print with the colour represented by the centre of the ellipse and four more prints with perturbations of that colour as given by the end points of each of the axes. The colour reproduction indices were calculated for each of these prints with the centre print as reference. These data should represent just perceptible differences in colour now expressed in colour appearance terms. The results showed a mean hue index of 97.6, a mean chroma index of 95.1, and mean overall index of 97.9. (The mean value is calculated over the whole 18 colours in the Macbeth Chart.) This last value implies a mean colour difference in colour appearance terms of two units, which is similar to that found in CMC (1:1) colour space terms. This suggests that there is some concordance between CMC colour difference space and the colour appearance space as defined by the Hunt appearance model.

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Colour Reproduction and Tone Scales

Density measurement was used first in photography to controll colour separations. In the meantime it is the basis of process controlling not only in colour photography but also in multicolour printing and colour television. Characteristic curves are used to describe tone scales, and experience has shown that the equidistancy of such tone scales is highly related to good colour reproduction properties, especially if it is combined with a good grey balance.
Colour reproduction is the general expression for the effect of a reproducing process on the colour appearence of a colored copy in comparison or subconscious comparison with the colour appearence of an original. To evaluate colour reproductions properties colour metrics can be used. Having in mind that the equidistancy of tone scles is one base of colour reproduction, it is an open question whether or not the identity of any reproduced colour referred to the original ones shall be the basis to evaluate colour reproduction properties.
It is shown that using colour coordinates related to tone scales (e.g. brightness scales from a real white to a real black) gives detailed information about colour reproduction properties as well as about true tone scaling and grey balance. Examples are given especially from the field of multicolour printing. The very complex problem of comparing colour transparencies or monitor pictures on one hand with surface copies on the other is also discussed.
Moreover, as evaluation of tone scaling is a problem of large colour differences, the question can be raised, if the number of thresholds will give the right values for tone scaling. A proposal for a new formula is given, which is based not only on colour contrast on the boundery line (that is the definition of the threshold used until now) but also on the influence of the surrounding field. Using such colour distance evaluation it can be shown that for small colour differences the most important influence is given by colour constrast whereas approximately up to ten thresholds the appearence difference increases very slowly more or less only by the field component.

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EFFECT OF SURROUND AND GAP ON COLOR-DIFFERENCE PERCEPTION IN PAINTED SAMPLES

Introduction

Studies of color-difference perception in painted samples have been presented for all 5 CIE color regions (1,2,3). They have been extended in order to analyse the parametric effects of the lightness of a neutral grey surround and of a separating gap between sample pairs on the perceptibility of color-differences. First results can be given for the yellow and the blue CIE color region.

Material and method

Experiments have been planned as in the previous studies. The surround of painted samples was given by cardboards, that had been painted neutral grey at lightness values of Y=12.6 and Y=65.5 (in previous study Y=20). The cardboards had a circular window of 63 mm diameter equivalent to a 10 degree field of viewing, by which the sample pairs are observed. The gap between sample pairs was produced by inserting a perpendicular stripe of 3 mm width in the window of a cardboard taken from the same material. This stripe covered the connecting line of adjacent sample pairs producing an angular seperation of 0.5 degrees.

The existing sets of high gloss paint samples had to be enlarged in order to allow for presentation of larger color-differences of sample pairs. Pairs have been selected according to measured differences of tristimulus values (x,y,Y for 45/0 measuring geometry, 10 degree oberver and D65 illuminant) and to their specific distribution in color space in relation to previous threshold ellipsoids and to some pre-inspection of 'just-above-threshold' sample pairs. This processing is critical as the selected cloud of color-differences must allow for near-to-threshold judgments by different observers and for a good coverage of all directions of color space, particularly if excentricities of ellipsoids are high.

5 observers from the previous experiments took part judging the perceptibility of color-differences in the selected sample pairs, which were illuminated by a D65 light-source under 45/0 degrees of viewing. About 60 sample pairs had to be judged for every experiment 10 times. If the observers indicated a perceptible color-difference, they were asked about the apparent main component of color-difference (lightness, chromaticness or hue).

Results

The different surround conditions did not shift threshold ellipsoids appreciably in the case of the yellow color region (see fig. 1 and 2), which is a bright color, but much more in the case of the darker blue color region, for which the light surround provoked a significant increase of threshold ellipsoids of all observers. Thus the adaptation to the brightest element of the visual field (surround or infield) was dominant in the given experimental situation.

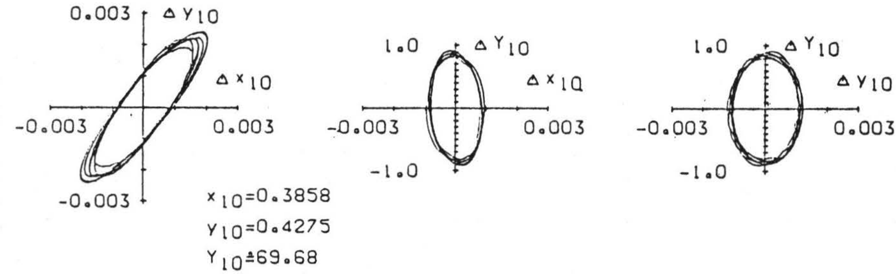

Fig. 1 Threshold ellipses in x,y,Y-planes for Yellow and light grey surround (Y=65.5), Monte Carlo treatment.

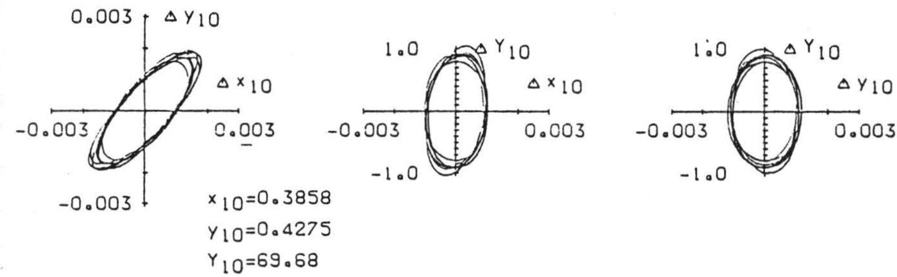

Fig.2 As fig. 1 but for dark grey surround (Y=12.6)

The gap effect was studied for the light grey surround in yellow and the dark surround in blue. It introduced an increase of threshold but not by a simple factor, e.g. the direction of the long axis in the chromaticity diagram was more affected than that of the short axis.

The indications of the direction of a perceived color-difference made some uncertainties apparent, if the color-difference was very near to threshold (e.g. mixing up of greenish or more achromatic and reddish or more chromatic). But the larger the color-differences the more consistent were the results. One prominent feature was, that the long axis of the threshold ellipse in the chromaticity diagram turned out to be a line of symmetry for the change of hue-difference perception for both color regions, that means hue-difference perception jumps from greenish to reddish or vice versa when crossing it.

Some mathematical modelling has been tried. One question was, how do threshold data look, if the optimization procedure was run in CIELAB-space (e.g. if there is no tilt of the ellipsoid in x,y,Y-space, there should be one in L*,a*,b*-space). Another question was, whether the city-block model of color-difference could be taken as an alternative equivalent to the ellipsoid model.

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EVALUATION OF COLOR DIFFERENCE

Introduction

Since the publication of the CIELAB and CIELUV formula several attempts at producing an improved color difference formula have been made . I showed that modification to the CIELAB formula gave considerably improved fits to experimental data at 5th congress . of the AIC. This modified formula is given in equation (1).

$$dE=((h*dH^*)^2+(dL^*)^2+(c*dC^*)^2)^{1/2} \qquad (1)$$

where h and c are weighted factor : h= 0.75,c=0.50
dL^*, dC^* and dH^* are calculated from the CIELAB formula.
In this paper,I discuss the result of testing the modified formula. The modified formula was tested against experimental data,obtained by visual estimation,and the results compared with those for the CIELAB,CIELUV,HUNTER-LAB and CMC(1:1).

Samples of observations

The experimental data was obtained with color series,were various samples,as matched against a given standard color in industry. Fig.1 shows samples data plotted in the CIELAB color space. Color differences are provided between 0.3 and 6.0 CIELAB units.
As shown in Fig 2,each pair of color samples consisted of two square color samples and the surrounds were matte and neutral (Munsell N/7) The distance from the samples to the observer was approximately 60 centimeters and the angular subtence of the samples at the eye of the observer was 10 degrees. Obser vation are made with approximate 45/0 geometry under the daylight ,color temperature approximate 6500 K and illuminance is 1200 lx on the samples.

Scaling technique.

This experiment was done with the magnitude estimation presented by Stevens.
Observer evaluates the ration of color difference size of the test

pair to the reference pair (consist of lightness-difference,hue-difference and chroma-difference). This ratio is called PCD,mean perceived color difference.

Sumary of results

The correlation coefficients and the correlation diagrams of the PCD to the colorimetric color difference ratio (called CCD) for CIELAB,CMC(1:1) and modified formula(1) are shown in Fig.3.
For perfect correlation the correlation coefficient should be 1.0. The lower the value,less perfect the correlation and , by implication , the poorer the formula.
The modified formula and CMC(1:1) give much better results. HUNTER-LAB and CIELUV are lower value than CIELAB. The modified formula was improved in order to obtain the color difference formula with a correspondence of each of the components of the color difference by multiplying a weighting factor ,eliminating the gaps among the lightness,hue and chroma. The use of a variable weighting factor with an object of eliminating the gaps establish a good correlation between PCD and CCD.

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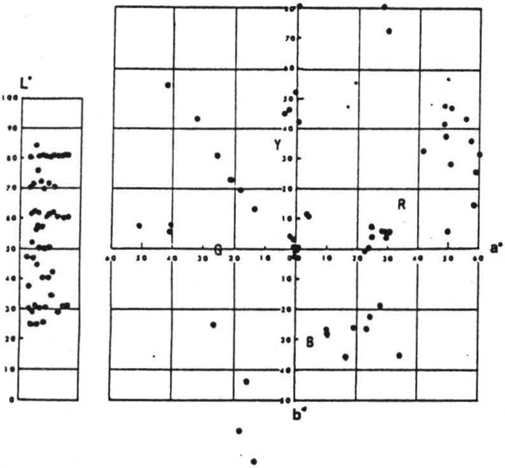


F i g. 1 Sample data plotted in the CIE1976(a*b*) diagram ;(R),(Y),(G),(B) indicate the points of CIE guide-line colors

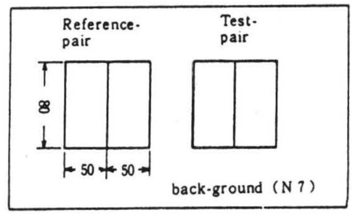
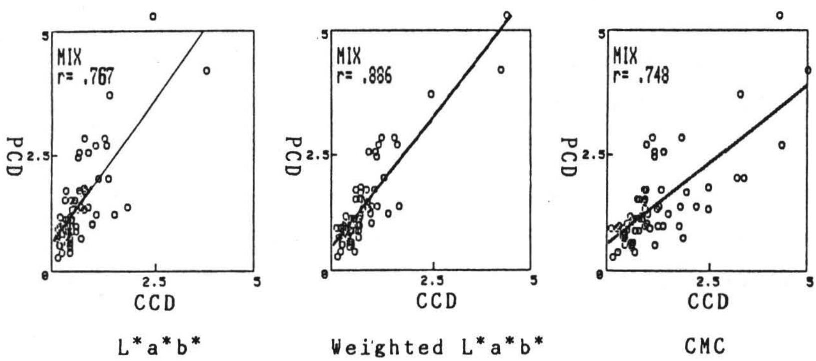


Fig. 2 Color-difference pair



F i g. 3 Relationships between PCD and CCD

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QUANTITATIVE EVALUATION OF STAINING BY COLORIMETRIC METHOD FOR USE IN COMPUTER COLOUR MATCHING WITH FIBRE BLENDS.

In general, the practice of computer colour matching (CCM) has been successful for single component fibres. However, the application of CCM is less successful for fibre blends. To produce a solid shade on a fibre blend, the individual components of the blend should be dyed to the same colour. The job of CCM is to predict dye recipes separately for each fibre component and the resulting colours of the dyed fibre components would match the standard colour. The accuracy of such technique has been analysed by one of the authors[(1)]. One of the important source of errors is the contribution of cross-stainings during the coloration process. This paper presents the findings of evaluating quantitative methods to assess the cross-stainings information of a dyed fibre blend for use in CCM with fibre blends.

Textile samples were prepared by intimately blending stained and dyed fibre substrates of Polyester and Cotton followed by a special spinning process. The quality of the samples were tested physically and chemically. In this way, the blend as well as its pure components were obtained. These samples, mounted in special format, were measured for spectral reflected radiance factors and the relevant colour information.

Selected samples and their relevant data were subjected to analysis or further treatments to evaluate the staining information. The quantitative methods of staining evaluation included the chemical burn out method, the prediction method and the method based on micro-spectrophotometric measurement. The accuracy of the results obtained by these methods were analysed and presented in this paper.

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DEPENDENCE OF CROSSOVER WAVELENGTHS OF METAMERIC PAIRS ON COLORANT ABSORPTION PROPERTIES

Introduction

The generation of sets of metamers and their analysis with respect to crossover wavelengths and degree of metamerism has been of interest to a variety of researchers [1-6], particularly since it has been proposed that crossover wavelengths identify the locations of the human visual system response maxima [1,4-6]. The results of these analyses have been inconsistent and depend on the mathematical technique used to generate the metamers and constraints on either the spectral properties of the "colorants" or the spectral and colorimetric properties of the resulting metamers. For example, the third crossover wavelength for metameric pairs which cross at only three wavelengths has varied on average from 595nm to 611nm.

The major constraints affecting crossover wavelengths are believed to be: color matching functions, spectral calculation interval, absorption properties of colorants. In the present study we restricted ourselves to the CIE 1931 2° color matching functions. By using one nanometer data, we eliminated the calculation interval effect. The major variable of this study, therefore, is colorant absorption properties.

Methodology

Colorants with a single absorption maximum were synthesized mathematically using the following logarithmic model:

$$R_\lambda = (R_{max} - R_{min}) I_\lambda + R_{min},$$
$$I_\lambda = \left[1 + e^{20BW^{-1}(\lambda - (\lambda_{min} - 0.5BW))} \right]^{-1} \quad \text{for } \lambda_{min} > \lambda,$$
$$I_\lambda = \left[1 + e^{20BW^{-1}(\lambda_{min} - \lambda - 0.5BW))} \right]^{-1} \quad \text{for } \lambda_{min} \le \lambda,$$

where R_λ is the spectral reflectance factor, R_{max} is the maximum reflectance factor, R_{min} is the minimum reflectance factor, BW is the bandwidth of the absorption trough at half height between R_{min} and R_{max}, and λ_{min} is the wavelength center of the absorption trough. For the entire study, R_{min} equaled 0.05 and R_{max} equaled 0.85. For a given BW, 31 colorants were synthesized where λ_{min} varied between 400nm and 700nm at every 10nm. Wavelength, λ, varied between 400nm-700nm at an interval of 1nm. Bandwidths of 60nm, 80nm, 100nm, 120nm, 150nm, and 180nm were selected for study. Figure 1 depicts the colorants with λ_{min} = 550nm for the six bandwidths.

The colorants' reflectance factors were converted to Kubelka-Munk absorption-scattering coefficients, $(K/S)_\lambda$.The 31 colorants' $(K/S)_\lambda$ values were input into a single constant Kubelka-Munk computer colorant formulation program based on a tristimulus matching algorithm [7].

The 1931 CIE standard observer and the equal energy spectrum were used in the calculation of tristimulus values. Three colorant metamers were generated to a non-selective standard of 0.50 reflectance factor.

For each metamer generated, the nearest integer crossover wavelength between the standard and match was calculated. Only those metamers with three crossover wavelengths were evaluated.

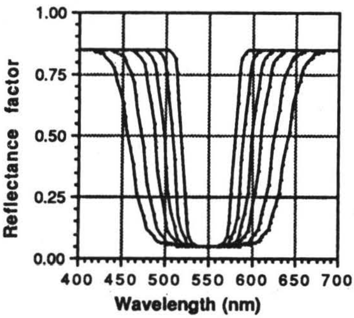

Figure 1: Colorants.

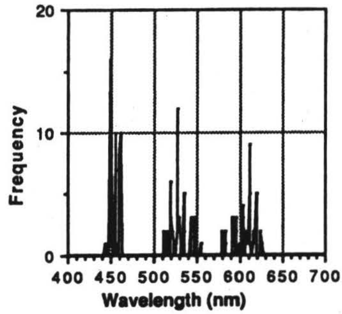

Figure 2: 80nm BW histogram.

Results and Discussion

For the six sets of metamers corresponding to the six bandwidths, histograms of frequency versus crossover wavelength were calculated. As an example, the 80nm BW histogram is shown in Figure 2. The crossover wavelengths cluster about three wavelengths and the highest expected value was calculated for each cluster (the expected value is equivalent to the mean estimate for a normal population distribution). These are listed in Table I. CIELAB color differences, ΔE^*_{ab}, were calculated for illuminant A as an index of metamerism. The average ΔE^*_{ab} for each set of bandwidths is listed in Table I.

Table I : Average results.

	Crossover λ (nm)			
BW(nm)	λ1	λ2	λ3	ΔE^*_{ab}
60	452	540	600	28.6
80	455	530	606	17.8
100	455	532	610	13.5
120	455	538	611	8.8
150	454	543	611	4.6
180	454	544	611	5.3

Table II: Selected results:

	Crossover λ (nm)			
BW(nm)	λ1	λ2	λ3	ΔE^*_{ab}
60	462	541	599	43.3
80	456	536	604	42.4
100	438	542	618	36.1
120	450	538	621	32.8
150	457	528	625	26.9
180	460	522	628	20.4

The most probable crossover wavelength for the middle and long wavelength region varied depending on the magnitude of the absorption bandwidth. Only the first crossover wavelength was invariant to colorant absorption properties. There is an obvious trend in the third crossover region: As the bandwidth increased, the most probable crossover wavelength increased accompanied by a decrease in the average color difference. It is worth noting that real colorants tend to have absorption bandwidths of 100nm - 130nm. The third crossover agrees very well with published results analyzing real metameric pairs [6].

The metamer with the greatest degree of metamerism from each of the six sets is plotted in Figure 3. It is evident how the bandwidth affects crossover wavelength. Table II lists the crossover wavelength and color differences for these six selected metamers. Again, there are clear trends between the third crossover wavelength, color difference, and colorant bandwidth.

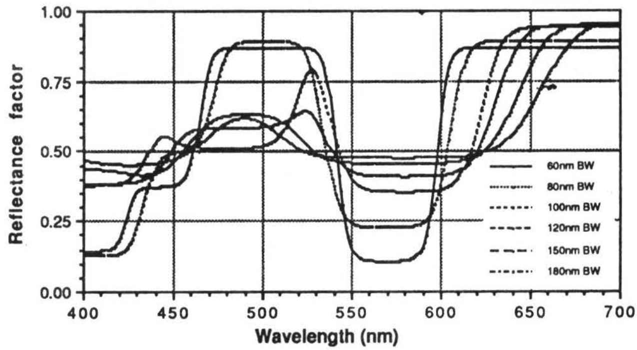

Figure 3: Metamers with greatest color difference from each BW.

Conclusions

The major constraints of determining crossover wavelengths for metameric pairs with three crossovers are color matching functions, calculation interval, and absorption properties of colorants. It was shown that when the first two parameters are fixed, the crossover wavelength is dependent on the third parameter. Therefore, it is doubtful that crossover wavelengths can reveal hyphothesized human visual system responses maxima.

Acknowledgments

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THEORETICAL AIDS TO DETERMINE COLOURIMETRIC CURVES OF BINARY POWDER MIXTURES

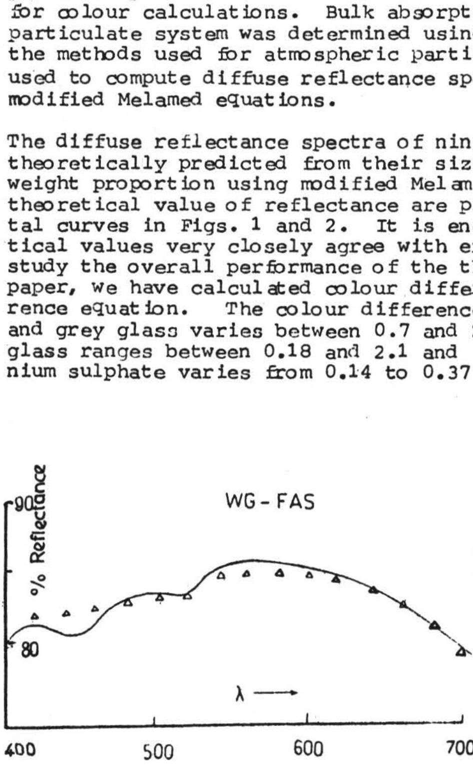
Prediction of diffuse reflectance spectra of admixtures of colourants is of great importance in the field of colour science. K.M. theory, which is a highly simplified version of radiative transfer theory is most widely used for colour matching of industrial products. The application of K.M. theory requires experimental determination K.M. scattering and absorption coefficients for all colourants at all the wavelengths required for colour calculations. Attempts are made to develop a theoretical technique to predict diffuse reflectance spectra of pigmented objects from fundamental optical and morphological (i.e. R.I. and size) characteristics of colourants. The first effort in this direction was to correlate K.M. scattering and absorption coefficient with Mie coefficients which can be calculated from size and refractive index of colourants (1,2). Recent theoretical aids to predict reflectance from size and refractive index is many flux theory proposed by Mudgett and Richard (3,4). The application of this theoretical technique is involved as it employs Mie theory and multiple scattering equations (5). Attempts are made to simplify the application of many flux theory, but even then the complexity in computation is appreciably high (6,7). Comparatively simple theoretical technique to compute diffuse reflectance spectra of single component particulate matter from the size and refractive index is proposed by Melamed and then modified by Simon (8). The expressions to compute reflectance of binary mixtures of pigment particles, from the reflectance of individual component is proposed by Schatz (9). The use of Schatz equation in conjunction with modified Melamed equation can be used to compute reflectance of admixtures of two powder samples from their fundamental optical and morphological properties. Till now no attempts are made to study the potentialities of this theoretical aids to predict the diffuse reflectance spectra of powder mixtures for colour computations. In this paper we describe some results of this study.

To study the performance of this theoretical approach binary mixtures of powder samples were prepared using powders of white, grey, pink and golden yellow glass and ferrous ammonium sulphate. Nine binary mixtures were prepared using these powders by mixing them in 80:20, 50:50 and 20:80 weight proportions. The spectra reflectance of these binary mixtures were measured in visible region using Shimadzu double beam spectrophotometer equipped with integrating sphere. The diffuse reflectance of three binary mixtures are shown in Figs. 1 and 2.

For theoretical prediction of diffuse reflectance spectra using modified Melamed and Schatz equation, the size and refractive index of each powder sample is required. The particle size in powder samples ranges from 40 to 105 mixrons. Therefore it was convenient to measure particle size using projection microscope. The average particle size in each powder sample was determined by making measurements on about 200 particles of each sample.

The complex index of refraction of a system can be expressed as $n = n_{RE} - n_{IM}$. Here n_{RE} is a real part of refractive index and is determined by ratio of velocities of light in vacuum and medium. It has been recently shown that small variation in n_{RE} do not significantly affect the reflectance of particulate matter (10). Therefore for theoretical computations in the present work, n_{RE} for all system were taken from literature and are assumed to be constant over the entire visible spectrum. n_{IM} is determined by bulk absorption coefficient of the material. As this parameter significantly varies with wavelength, n_{IM} for all powder samples were determined for wavelengths 400(20)700 nm of interest for colour calculations. Bulk absorption coefficient and hence n_{IM} of particulate system was determined using Kubelka-Munk equation following the methods used for atmospheric particles (11). These n_{IM} values are used to compute diffuse reflectance spectra in visible region using modified Melamed equations.

The diffuse reflectance spectra of nine binary powder mixtures were theoretically predicted from their size, refractive index and mixture weight proportion using modified Melamed and Schatz equations. The theoretical value of reflectance are plotted over respective experimental curves in Figs. 1 and 2. It is encouraging to note that the theoretical values very closely agree with experimentally measured values. To study the overall performance of the theoretical aid suggested in this paper, we have calculated colour difference using CIELAB colour difference equation. The colour difference for different mixtures of pink and grey glass varies between 0.7 and 2.0, for pink and golden yellow glass ranges between 0.18 and 2.1 and for white glass and ferrous ammonium sulphate varies from 0.14 to 0.37 only.



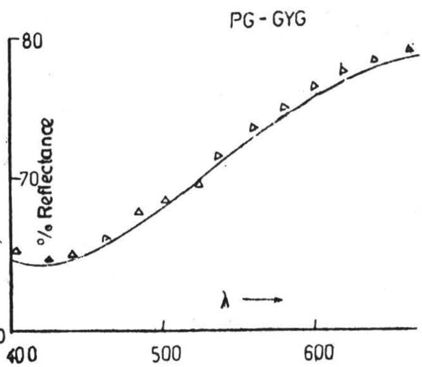


Fig.1 Comparison of experimental and theoretical diffuse reflectance of PG-GYG mixture in 20:80 proportion.

Fig.2 Comparison of experimental and theoretical diffuse reflectance of WG-FAS mixture in 80:20 proportion.

The objective of this study was to draw the attention to theoretical aids existing in literature to predict diffuse reflectance spectra of powder mixture from the fundamental optical and morphological properties of colourants. These two publications of Simon and Schatz have not been noted and utilized by the workers in this field. Though Schatz has given expressions for binary powder mixtures, we have recently derived the similar expressions for ternary powder mixtures (12). The further study in this direction will help to establish the potentiality of this theoretical aid in the field of diffuse reflectance spectroscopy.

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DEVELOPING METHODOLOGIES FOR POST-OCCUPANCY EVALULATION OF COLOR AND LIGHT FOR INTERIOR ENVIRONMENTS: ANALYSIS OF AN INTERNATIONAL SURVEY

Professionals involved with the study of color in design, science, art and industry gather for an international exchange of ideas, concepts and research. A common concern is the transfer and dissemination of information about color. The use of color and light in our interior spaces is an area that can greatly benefit from an international exchange among these experts.

During the AIC Symposium 1988, "Colour in Environmental Design". in Winterthur, Switzerland the concept of Post-Occupancy Evalation was presented. An international survey was given to the 140 participants: color researchers, psychologists, physiologists, interior designers, architects and planners representing 24 countries. The survey is reduced and included at the end of this text. For many of the participants, it was a new concept. However, some individuals have been involved with this important design tool.

This international survey documents who has been involved with Post-Occupancy Evaluation (POE) and what methodologies have been used in various countries. The international recommendations for evaluating the areas involving color and light are also included.

Post-Occupancy Evaluation (POE) is the practice of using systematic methods to determine and understand how the designed environment affects the users. The design of an environment is a hypothesis about how a future place will affect peoples' behavior and feelings. The POE is a verification of that hypothesis (Brill). The use of color and light can be studied to determine if it supports the behavior, the performance and the satisfaction of the users.

In a review of the literature, no specific methodologies are being utilized to study the use of color and light in interior spaces. Because POE methodologies are still being formulated, especially in health care facilities, the use of color has not been a priority.

The input from the international survey can provide a baseline of data to be shared with the 6th Congress to further stimulate an exchange of information. In addition, recommendations will be made to assist in POE methodologies implementing color use and application.

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POST-OCCUPANCY EVALUATIONS (POEs) - AN INTERNATIONAL SURVEY

Please take a few minutes to complete each question. Your input is very important. PLEASE PRINT CLEARLY, THANK YOU.

1. NAME ______________________________
   FIRST LAST/FAMILY
2. TITLE ______________________________
3. JOB DESCRIPTION - CHECK ONE:

___a. COLOR CONSULTANT ___b. INTERIOR DESIGNER ___c. INTERIOR ARCHITECT

___d. ARCHITECT ___e. OTHER (PLEASE EXPLAIN) ______________

4. FIRM/COMPANY NAME ______________________________
5. ADDRESS ______________________________

______________ ZIP CODE ______________

COUNTRY ______________ TELEPHONE ______________

6. How useful could Post-Occupancy Evaluations (POEs) be to your work? CIRCLE THE APPROPRIATE NUMBER.

VERY USEFUL 5 4 3 2 1 NOT USEFUL

7. Rate the importance of the following areas for POEs involving COLOR. CIRCLE THE APPROPRIATE NUMBER, PLEASE SPECIFY OTHER AREAS.

AREAS	VERY USEFUL 5	4	3	2	NOT USEFUL 1
a. CONTRAST	5	4	3	2	1
b. AESTHETICS	5	4	3	2	1
c. MAINTENANC OF SURFACES	5	4	3	2	1
d. OTHER - PL ASE SPECIFY	5	4	3	2	1
e. OTHER - PL ASE SPECIFY	5	4	3	2	1
f. OTHER - PL ASE SPECIFY	5	4	3	2	1

8. Rate the mportance of the following areas for POEs involving LIGHTING. CIRCLE THE APPROPRIATE NUMBER, PLEASE SPECIFY OTHER AREAS.

AREAS	VERY USEFUL 5	4	3	2	NOT USEFUL 1
a. LIGHT LEVELS	5	4	3	2	1
b. LIGHT SOUR ES	5	4	3	2	1
c. SPECTRAL I STRIBUTION	5	4	3	2	1
d. TYPE OF FIXTURE	5	4	3	2	1
e. OTHER - PLEASE SPECIFY	5	4	3	2	1
f. OTHER - PLEASE SPECIFY	5	4	3	2	1

POST OCCUPANCY EVALUATIONS (POEs) - AN INTERNATIONAL SURVEY (Page 2)

9. Has a Post-Occupancy Evaluation (POE) ever been done on any of your installations/projects? PLEASE CHECK ONE.

___a. YES ___b. NO If NO, you have completed the survey, please leave it at the door. Your input is very important. Thank you!

IF YOU ANSWERED YES TO #9, CONTINUE ANSWERING THE FOLLOWING QUESTIONS:

10. For what type(s) of projects have you had a POE done?

___a. HOSPITALS ___b. CLINICS ___c. OFFICES ___d. SCHOOLS

___e. OTHER (PLEASE EXPLAIN) ______________

11. How many of your projects have had a POE done? Please indicate the NUMBER done for each type of project.

___a. HOSPITALS ___b. CLINICS ___c. OFFICES ___d. SCHOOLS

___e. OTHER (PLEASE EXPLAIN & STATE THE NUMBER) ______________

12. For each element listed below, please CHECK THE COLUMN THAT BEST DESCRIBES THE AREAS COVERED BY THE POEs DONE ON YOUR PROJECTS.

Column Number	Column Description
1	COLOR = the use of color, materials and finishes
2	LIGHTING = light levels, sources, configurations, etc.
3	TECHNICAL = other than lighting such as fire safety, structural integrity, sanitation, durability, acoustics
4	FUNCTIONAL = operational efficiency, productivity, work flow, organization
5	BEHAVIORAL = social interaction, privacy, symbolism, territoriality

PLEASE CHECK:

PROJECTS	(1) COLOR	(2) LIGHT	(3) TECHNICAL	(4) FUNCTIONAL	(5) BEHAVIORAL
a. HOSPITALS					
b. CLINICS					
c. OFFICES					
d. OTHER - EXPLAIN					
e. OTHER - EXPLAIN					

13. What methodologies were used for your POEs? PLEASE BE SPECIFIC.

____

____

THANK YOU! Please leave at the door. Please write any comments on the back. Christina Burton 8100 N. MoPac, #285; Austin, TX 78759 USA

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ON A POSSIBLE ASSESSMENT OF THE PERCEPTUAL ENVIRONMENTAL COLOR

In a previous paper /1/ we have been proposing a classification of environments, based on the relationship between task and sorround. In fact, there may be situations where: a), the task prevails over the surround; b), the surround prevails over the task; c), the surround is to be (visually) damped becasuse it disturbs the task; d), task and surround are mutually balanced.

In the present work, the attempt is made to evaluate whether and how each of the above listed situations is modified by the presence of "color".

For this, we consider a number of examples (shop windows, supermarkets, offices, art exhibitions, road crosses, etc.). Each of them is flanked by a matrix obtained by applying a "grid" on the scene, and by measuring for each grid element the chromaticity coordinates and/or the local luminances. Next, for each array, in the matrix, we evaluate a number of statistics (e.g., the rms deviation) to quantify the spatial complexity of the scene itself.

Next, we wonder how it actually appears to the human observer, during the fixation pauses, for a number of glimpses. For this, the "instrumental" data are corrected by taking into account how both color perception and color discrimination change with the distance from the fovea, and, accordingly, trichromatic vision tends to become dichromatic.

The conclusion is drawn that the conspicuity of the environment may be enhanced or depressed by choosing the proper color combinations, based on physiological response characteristics.

The psychophysical check will be matter of a future research.

Reference:

/1/ Di Fraia L., Ronchi L.R., "Responsabilità dell'ingegnere illuminotecnico nell'ergonomia di moderni ambienti di lavoro". Proceedings of the IV Congresso Nazionale della Società Italiana di Ergonomia, Ischia, May 1988.

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Title: **ALZHEIMER'S DISEASE: A COLOR PALETTE FOR INTERIORS**
(Note: Consideration for oral presentation is requested; presentation method will be audiovisual.)

Global Connection. Cognitive impairment is noted in many different diseases. Unfortunately, these diseases are not confined to any one region, country, or nation. Therefore, as older populations increase, appropriately designed housing facilities are of international concern. Color theories have long been based on psychological concepts which need reevaluation for the individual with Alzheimer's disease (AD) due to the unique pathology of the disease.

Introduction. The relationship between human behavior and color within the environment is complex and impacted by innumerable variables. Color may assume particular importance, however, when considering effects upon individuals diagnosed as having AD. Such persons are particularly vulnerable to environmental impacts upon self-perceived competence and behavior due to the cognitive and motor failures associated with the disease (Shroyer, Hutton, & Anderson, 1987).

Rationale. Cognitive impairment of any kind, including Alzheimer's disease, is a primary health problem of older persons in the United States (Aging America, 1985-1986). The number of cases of Alzheimer's disease in the United States is estimated to be from two to 3.5 million (Hamill & Buell, 1982; Select Committee on Aging, 1986) and the incidence is expected to increase as the general population ages unless a cause or cure is identified. AD is age-related: risk increases from 2-3% in the 60s age group and 17-30% in 80s age group (Mortimer & Hutton, 1985).

AD is defined as a condition resulting from degenerative processes involving the brain. Four basic stages are identified which begin with forgetfulness and disorientation in new surroundings and progress through such symptoms as purposeless overactivity, disorientation in physical space and time, and total dependency and inability to communicate (Ware & Carper, 1982). According to Hutton (1987), the average length of Alzheimer's disease is ten years, although this figure varies among individuals.

The needs for research evaluating the influence of the environment upon individuals with AD and exploration of behavior ranges at different stages of the disease are recognized (Select Committee on Aging, 1985; Losing a Million Minds, 1987). Special care units are being retrofitted to many facilities in the United States in an effort to adequately accommodate the special needs of this group. The value of surroundings and social settings that support declining cognition, sensory incapacity, and decreased motor skills have been identified as an important behavioral management tool for care and treatment (Carey & Hansen, 1986; Lawton, 1970).

A dearth of empirically based research exists supporting observations of improved behavior and intuitively based statements regarding impact of color. Additionally, data which provide concrete information and guidelines for environmental manipulation are noticeably lacking in the current literature.

Objective. The overall objective of this research was determination of how the interior color of a small institutional group living area affects the behavior of individuals diagnosed with AD. Findings are being utilized in a comprehensive project establishing design guidelines based on empirical research.

Methodology. The research site was an Alzheimer's Care Unit (ACU) within the intermediate care facility of Levelland Nursing Home, Levelland, Texas. The facility housed 26 diagnosed AD patients. Researchers observed patient behaviors in an existing small group space, located in the ACU, to determine observable behavioral changes. After a specified period of time, wall color of the space was changed and modified. Upon completion of observations, data were analyzed to identify behaviors during observation periods. The multi-method study utilized photodocumentation, systematic observation, behavioral mapping, field journals, and checklists to record behaviors. Specific measurable behaviors analyzed included physical activity/inactivity, social interactions, and catastrophic and negative actions (screaming, violent acts, etc.).

Appropriate methods of analysis were utilized to identify behavioral/environmental color relationships. At conclusion of analyses a taxonomy of the relationship between Alzheimer's patient behaviors and color was developed. The project augments previous investigations by the researchers regarding the living environment of individuals afflicted with Alzheimer's disease.

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H.I.C. - HIGH-IMPACT COLOUR IN COLOUR DESIGN: THEORY AND PRACTICE

Colour is an integral part of the sensory input of our envinronment, and we are exposed to the stimulus of colour constantly. Because of that our sensitivity to colour weakens. That's why functional-colour design has to cross a high sensory barrier in order to reach an optimal effect.

We react to colour in three levels of perception:

A. Physiological level, which means the reaction of the systems of our bodies to the the stimulus of colour.

B. Intellectual level which relates to the reactions of our mind to the stimulus of colour.

C. Emotional level which relates to the psychological reactions to colour.

The perception of colour through the mentioned three levels creates reaction which consists of three stages:

A. attention.

B. interest.

C. involvement - passive or active or both.

The optimal colour-message is created when the colour-design satisfies our senses in the mentioned three levels of perception and when built so as to cause the mentioned three-stage reaction in the possible essential way.
Colour design which works and causes reactions according to these principles is defined as "having presence".
"Having presence" from point of view of colour-design, is the ability to create high levels of reaction in given conditions and defined as H.I.C. - High Impact Colour.

Colour design, which can be called H.I.C., is different from other colour design by being based on defined levels of reaction for every stage of perception. The definition of levels of reaction needed is based on the specific functional needs of every colour-design project.

In H.I.C. colour-design, the qualities and our known-reactions to colour are used to produce maximal effects in every level of perception in given conditions.

The reactions to colour can be of two types: Objective Reactions and Subjective Reactions. Objective Reactions are defined as those which are the result of the way our nervous system reacts to colour, that's why the objective reactions of healthy persons will be identical. Subjective reactions are defined as those which depend on, the emotional and mental characteristics of a person.

The balance between objective and subjective reactions is not identical in the different levels of perception: in the physiological level the reactions to colour are identical in healthy persons, in the mental and emotional levels the reactions are more subjective and depend on the characteristics of the population for whom the colour design is prepared.

Exact data on the profile of the population can help us to be more accurate and effective in designing with colour.

The mentioned above leads to the conclusion that H.I.C. - High Impact Colour - is objective colour.

The high impact-effect is created by planning colour in a way which will produce known reactions and involvement of varied population in all perception-levels.

Each colour-design project has to be based on definition of the level of reactions expected in each level of perception: physiological, emotional and mental. In order to achieve H.I.C. - High Colour Impact, the colour designer has to define in which perception-level he wants to create the highest effect, this in order to achieve a distinct and clear colour-message and colour-effect.

The distinctness of the colour-effect of the H.I.C. makes it different from the large amount of colour-information around us by creating a higher-level of presence and effect than we are used to. It breaks through our regular sensory-balance, and creates the expected planned reactions: attention, interest, involvement.

High Colour Impact projects planned according to this theory will be shown in slides, explaining the way High Impact Colour works in achieving high levels of perception and reaction in the physiological, mental and emotional levels of perception.

THE PHENOMENOLOGICAL DIMENSIONS OF THE COLOUR APPEARANCE OF THE PERCEIVED SPACE

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By definition conscience does not allow the separation of appearance from reality. Inside me appearance is reality: if I think that I see or feel something, so I do independantly of the exterior object. Reality appears complete when real being and appearance consist an entity. There is no other reality than the apparition.

Seeing a figure is getting simultaneously the exact sensations belonging to it. Each of them remains always an impression. The whole becomes "vision", picture in front of us, because we learn to pass fast from one impression on to another. Therefore the sensations and images said to start and finish all knowledge appear only in a horizon of senses and the signification of a percept, instead of resulting from a single association, is on the contrary, presupposed in all the associations, be it the synopsis of a present figure or an evocation of old experiences.

Time as an immanent object of a conscience is a stratified time or, in other words, no time at all. There cannot be time unless it is not completely unfolded: unless past, present and future do not apply to one and only sense. Therefore past is not past and present is not present. They both do not exist until a subjectiveness comes to break fulness in itself, draw a perspective, introduce the non-being. For myself I do not exist at a particular time but in the morning of the same day or at the coming night, as well. My present is this particular instant, this year, my whole life.

For empiricism "cultural" objects owe their physiognomy, their magic power to transfers, to projections of memory. Even outside empiricism we often speak of memories as of percepts.

If all this is true what happens to the colours of a very familiar passageway in our everyday living environment, differently and intensely experienced over long periods of time? Are we aware of them as an uninvolved newcomer?In other words can we, if asked,remember the real tints without a mental effort?And yet they may have been conceived by their designer to create a specific impact!What happens to that impact?For who do we design and for how long?

In the present study a minimum real space (objective) was chosen for exploration: a house entrance-hall with a coat-stand,a portrait hanging on a wall,a stool and the house main-door reflected on the coat-stand mirror.

Then was produced a story about this entrance.In it is first given information on the outdoor real space,the building main staircase and the setting where the house is located.1st time.

As a real object the entrance has in time been subject to subliminal perception.Real details were eliminated and replaced by sensations and images stemming from former experiences,as described next in the story.2nd time.

As the story goes on the entrance changes from a perceived phenomenon into an appearance with intratemporal properties.

In the story are further mentionned successive events of a growing tragicness that took place in the past which also gradually decompose into accordingly tragic sensations.

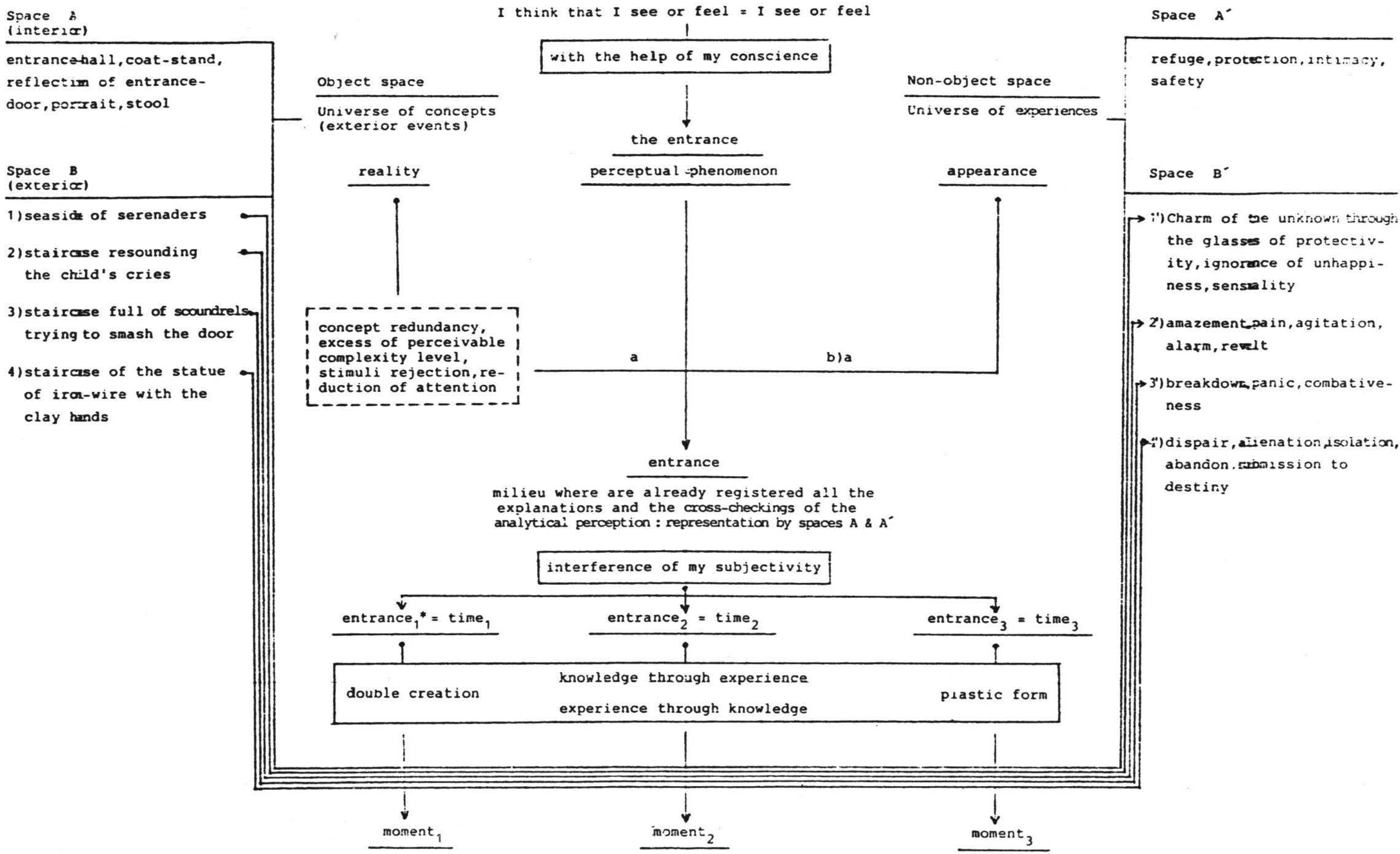
Finally the anthropological details of the real setting (entrance-hall,etc.) completely disappear and,by the interference of the observer's personality,a natural,inhuman space of light and colour on an abstract background (subjective) comes up (plastic form).3^{d} time.(See diagram)

The various stages of the entrance transformation,peak-exemplified by three creative moments,are given by colour photographs, drawings and paintings illustrating a story-telling poem on a musical background.

It is noticeable that the colour palettes of the various stages derive from one another compatibly to the psychogenetic powers of Colour but do not take into consideration real-life conditions as though detached from material.The same thing happens to Form which gradually looses its rigidness and melts into abstraction.

In conclusion is posed a new question with regard to environmental colour-pattern design calling for research: what should its degree of full statement be so that our shifting into abstraction is not impeded. So that gross restoration is not undertaken too often at the expense of continuity and safeness. So that Nature's flexibility and discreet evocativeness are as much approximated as possible in our artificial urbanscapes.

D i a g r a m



* entrance = $e_1+e_2+e_3 = t_1+t_2+t_3$ = time

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WHO NEEDS TO LEARN WHAT ABOUT COLOUR - WHY AND HOW?
with examples from education for architects and designers

Colour is an important part of everyone's life. Besides the huge amount of information we obtain by seeing colour, we make colour choices every day - on clothes, in furnishing, decoration, make-up etc. Many people make colour decisions in their jobs without any education in colour.

But there are also large groups of professionals choosing colours for different purposes, working creatively with colour. Here we find painters creating illusions of reality on a suface through describing objects and light by means of colour. Then we have architects and interior designers creating building environments with form, colour and light. We have industrial designers, textile designers, fashion designers, graphic designers etc. all working with colour in a creative way.

In our industrialised and specialised society, the creator and the producer are often not the same person. Industries producing paints, dyes, inks and coloured objects have technicians working with pigments, binders, opacity, durability, colouring processes, control etc. More and more large industries are using advanced optical instruments to check that the colours produced are the same as those specified.

Finally, we have a small group of scientists probing the factors enabling us to see colours and studying how colours influence us; physicists studying visible radiation and how instruments can be developed and used for colour measurement, physiologists studying the receptors in the eye and the nerve signals to the brain and psychologists studying how the colour percept finally develops and what this means to human beings.

Colour is involved in many professions but often to a very small extent, and colour is often a very neglected subject in all kinds of education. At a congress, such as this one, everyone would probably agree that we need more and better colour education. But what should be taught? Every profession has its own opinion of what colour is and its own views about what is important to know about colour.

In many professions, basic knowledge about colour is based on how colour is produced, on theoretical or practical aspects of colour mixing. And since colour is produced differently in different fields, there are many different theories about colour and about ways of describing colour. Colour discussions between different professions can be rather confusing.

On the other hand we have another tendency in colour education, which is clearly apparent in textbooks on colour and in curricula for colour education. Unable to find a direction and to choose among all options there is a tendency to end up with "a little bit of everything - everytime".

When discussing colour education, we have to accept that even though we all deal with colour, the various aspects of colour can be so totally different that it is quite natural not to be interested in all aspects. Few, if any people working with colour, really need to know about all its aspects. Yet we still need to be able to communicate and to obtain necessary information from each other.

We believe that there is basic colour knowledge that ought to be a natural part of all pre-college education. Knowledge which is aimed at developing neither artists nor colour technicians nor scientists, but knowledge based on what we all have in common as human beings, namely that we see colour, that colour gives us information, that we can use colour for different purposes and that we can describe and talk about colour in a natural way that everyone can understand.

From a basic understanding of what colour really is for human beings, it is easier and less confusing to build up a knowledge of colour in different directions and on higher levels. Theoretical colour systems, technical explanations, models and diagrams must come late in the learning process.

The direction in which the colour knowledge is developed on higher levels of education naturally depends on the requirements of the different professions. The main questions must be: What knowledge and skill is important for whom? and in what way can this be taught? Discussions about which colour system is the best? and even worse: on which of the authorities shall I build my colour teaching? are really not very fruitful in the colour education field!

Since colour is a visual phenomenon, we shall illustrate our lecture with a large number of slides. We are going to give some examples of basic colour education in primary and comprehensive schools. But mainly we shall show examples from our own colour education at the College of Art and Design in Bergen and at the architecture school of the Chalmers Technical University in Gothenburg respectively, and from various continuation courses we give to professionals.

We can distinguish two different parts in the colour training we offer. One deals with more objective and practical colour knowledge. Here we teach how to mix paint, colour possibilities and limitations in different materials, how objects vary in colour with differences in size, in different surroundings, in different light etc. To be able to teach this in a comprehensible way we need a common colour language based on visual attributes we can all see. For more than ten years we have both used the Natural Colour System NCS. With its clearly defined attributes and its simple graphic symbols, it helps the students to structure their knowledge and to discover connections that it would otherwise not be possible to see. Other colour systems based on other concepts, for instance colour mixing, can all be described from a perceptive point of view in NCS.

This "objective" knowledge can however never give a general answer to how to create good and beautiful colour combinations for different purposes. Therefore we also train creativity in colour design. The survey of all possible colours given in NCS is also a very useful tool in more free colour exercises. By simple instructions in the NCS colour circle and colour triangle we can initiate a fascinating process in which the students create and evaluate colour combinations they have previously never tried or never seen.

Colour is a subject that fascinates most people. Let us stimulate this interest by colour education relevant to each level and to each profession. And finally, to avoid confusion and difficulties in communication, let us accept that colour is primarily a visual sensation.

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THE STABILITY AND VARIABILITY OF COLOR-MEANING ASSOCIATIONS - ACROSS TIME AND CULTURES

The history of color-meaning association research stretches back to the time of Wundt at the end of the 19th century. An impressive quantity of research on this subject has been produced during these 100-odd years. Much of this research however has used color as a medium for investigating other, often purely methodological, questions. The secondary role afforded color has meant that perceptual color attributes have often been ignored entirely or been given only rudimentary consideration. Due to variations in the definitions of color stimuli the results have often been of a contradictory nature. Still some findings have found their way into popular literature and the media and have thereby contributed to the many common stereotypes about color connotations. Green, for example, is said to be calming and red to be exciting, with the implication that this applies for everyone everywhere. But does the green-calm association hold true for all greens and the red-exciting association for all reds? And do people from different time periods or different cultures have the same associations to colors?

Sivik, in a series of reports from the late 60´s and early 70´s, presents evidence which runs contrary to some of the common color-meaning association stereotypes. His reports show how colors from different areas of the color space are associated to varying degrees with different variables of meaning such as calm, exciting, warm, beautiful, etc. Rather than a simple hue-connotation relationship, Sivik found associations to color to be dependent on complex interactions between the color dimensions of hue, blackness, whiteness and chromaticness. All greens are not calming; hue alone cannot account for meaning associations.

Sivik also takes up the question of cultural differences when in one of the above mentioned reports he discusses the results of a comparison he undertook between a group of Greek subjects and a group of Swedish subjects. Although a great deal of concordance was exhibited between the two groups, a number of interesting divergences reflecting cultural differences appeared.

The question of the stability of color-meaning associations across time has not received a great deal of research attention but when studied has been limited to preference or pleasantness rankings of colors. Eysenck (1941) compared a large number of color ranking studies spanning over 40 years and found (to the extent that he could identify the often poorly defined color stimuli) that there appears to be a fairly general ranking of saturated colors among adults, independent of time. The relatively good stability and high agreement among these studies may be explained in part by the fact that comparisons were made of a very small number of very different colors. By increasing the number of colors as well as by varying color attributes the question of the stability of preferences across time becomes more complex. Further, by expanding the number of semantic variables beyond the pleasantness-unpleasantness dimension to include such words as exciting, loud, beautiful, etc. we may obtain a clearer view of where and how possible changes take place across time.

The study to be reported is an extension of Sivik´s early color meaning investigations and has as its objective to investigate the stability of color connotations both across culture and time. More specifically, we are interested in which types of semantic scales that, in connection with color, are most sensitive to changes of time and place as well as which color areas in the perceptual color space that are most likely to be experienced differently across time and culture. Data from two additional groups of subjects were collected to compare with Sivik´s original data (collected in 1968):

1) a new group of subjects from Sweden in 1988, to study the effects of time (20 years) on color-meaning associations

2) a group of subjects from USA, to study cultural differences.

The latter data collections were essentially replications of Sivik's 1968 study with the exception that the number of color samples used was reduced from 69 to 27 (the same 27 colors used in his Greek study). Each color was judged against the same 26 semantic scales used by Sivik.

Due to the fact that data collections have only recently been completed, the analyses reported below are preliminary. The means (color/scale) of the subjects' ratings form the basis of the statistical analyses performed. Correlation coefficients were calculated both by variable across colors and by colors across variables between the two Swedish groups and between the Swedish '88 group and the US group.

Table 1. *Correlations between the Swedish '68 and '88 groups (TIME) and between the Swedish '88 group and the US group (CULTURE) calculated across colors for each of the semantic variables.*

SEMANTIC VARIABLES	TIME	CULTURE
1. LIKE-DISLIKE	.69	.65
2. WINTER-SUMMER	.85	.81
3. LOUD-DISCREET	.93	.87
4. UNAPPETIZING-APPETIZING	.59	.78
5. JOYFUL-SERIOUS	.96	.91
6. HYGIENIC-UNHYGIENIC	.77	.83
7. OLD-FASHIONED-MODERN	.72	.76
8. WET-DRY	.79	.75
9. BEAUTIFUL-UGLY	.66	.85
10. SOOTHING-EXCITING	.83	.75
11. POSITIVE-NEGATIVE	.57	.86
12. SICK-HEALTHY	.68	.72
13. CULTURED-UNCULTURED	.72	.27
14. FEMININE-MASCULINE	.81	.72
15. COMPLICATED-SIMPLE	.79	.51
16. STIMULATING-DULL	.77	.83
17. COLD-HOT	.86	.72
18. LAZY-ENERGETIC	.47	.78
19. FRIENDLY-HOSTILE	.52	.69
20. ACTIVE-PASSIVE	.79	.76
21. SHAMELESS-PRUDISH	.90	.55
22. OLD-YOUNG	.91	.88
23. EXPENSIVE-CHEAP	.61	.61
24. TENSE-RELAXED	.83	.39
25. NEAR-FAR	.79	.03
26. SECURE-ANXIOUS	.51	.41

Time differences. The correlations given in Tables 1 and 2 of the mean ratings of the variables between the two Swedish groups (separated by 20 years) range from .96 to .47. 17 of the 26 correlations are greater than .70, the median being .78. *The semantic scales that show the greatest differences across time, are lazy, secure, friendly, positive.*

The same analysis was performed on the transposed data in order to identify which colors were most and least stable over time. *Among the colors having the lowest stability over time, those in the mid range on both chromaticness and blackness are well represented. Those colors that varied least over time are those at the extremes of one or more color dimensions.*

Table 2. *Correlations between the Swedish '68 and '88 groups (TIME) and between the Swedish '88 group and the US group (CULTURE) calculated across semantic variables for each of the colors.*

COLORS, NCS NOTATIONS	TIME	CULTURE
1. 0500	.93	.86
2. 4500	.93	.90
3. 9500	.73	.67
4. 0010-G90Y	.78	.72
5. 0080-G90Y	.80	.85
6. 2040-Y	.02	.85
7. 8020-G90Y	.90	.80
8. 1080-Y40R	.85	.80
9. 4010-Y30R	.90	.84
10. 0010-Y90R	.42	.14
11. 3050-Y90R	.41	.67
12. 1090-R	.97	.82
13. 7010-Y90R	.85	.77
14. 6010-R30B	.85	.81
15. 4040-R40B	.41	.08
16. 1005-B20G	.91	.79
17. 3040-B	.85	.75
18. 2060-R90B	.84	.79
19. 7020-R90B	.86	.74
20. 2050-B60G	.73	.86
21. 5020-B50G	.82	.60
22. 0005-G20Y	.73	.68
23. 4040-G10Y	.72	.58
24. 4050-B90G	.69	.29
25. 8010-B90G	.87	.82
26. 1060-G50Y	.87	.69
27. 2010-G50Y	.49	.85

Culture differences. The data from the US and Swedish '88 groups were exposed to the same analyses. Here again the between group correlations were very high, though somewhat lower on the average than those between the two Swedish groups, both with respect to variables (median=.75, .78) and colors (median=.79, .84). *The agreement between the two national groups is thus very great.* It may be remarked that because of the similarities between the two cultural groups studied correlations of these magnitudes are not surprising. However even in Sivik's Greek comparison in which greater differences might be expected to be found, correlations were of nearly equal size.

Among the semantic scales having the lowest correlations is, interestingly enough, "cultured-uncultured". This difference can be easily traced back to the fact that the US group judged highly saturated colors as cultured while the Swedish group to a larger extent considered these to be uncultured.

Also here it is of interest if some colors yield more similar associations than others for the two national groups. *Again the colors towards the ends of one or more of the color attribute dimensions were judged to be most similar by the two groups.*

As stated previously, our analysis of the data is at this point incomplete. But there is evidence of a tendency - color-meaning associations seem to remain relatively constant across time and culture. We intend to examine more closely during the coming months the differences and similarities between the judgements of the groups in question in order to present a more fine-drawn analysis of our data at the conference.

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A PROPOSAL FOR THE TEACHING OF COLOR APPEARANCE IN SCHOOLS OF ARCHITECTURE

We have been devoted in the past few years to having the order of academical teaching of color reversed, starting with empirical practice which makes students aware of the use of colors, followed by theoretical aspects related to the physics and physiology of color. This approach reflects our belief that it is more important to develop the perceptual capability of students by means of observation, rather than burden them with schematic information that may easily wear off.

This idea, perhaps valid in any area of knowledge, has significant relevance in the teaching of design. Emphasis on perception should be the watchword in this type of teaching, since no theoretical knowledge suffices to create a plastic sense, just as no theory can guarantee excellence of architectural or general design work.

For a better understanding three specific areas, at least coexist in the learning process.

a) The previous area reflecting prior knowledge required by the student in order to approach new teachings.
b) The creative area involving the student's imagination.
c) The present area in which the student tries to understand and solve the problems raised.

If any of these areas is missing or there is a partial or negative approach to any of them, the teaching process will be substantially hindered. To emphasize the imagination does not imply to ignore or disregard past experiences or concrete solution. On the other hand, to acknowledge the internal dialogues among the mentioned areas, may assist to successfully control the educational process.

An example will clarify the idea. Let us consider, for instance, the practical case of solving the chromatic design of a public office. If past experiences (a) are incomplete or distorted, the student will have no elements of judment to guide him or will use erroneous and surely stereotyped patterns. He could follow present or past fashions, as he will likely have prefixed ideas of what is "nice or ungly", or may try to please a professor or advanced fellow student. In this case, he will do what he is supposed to do, not giving a second thought to what is really convenient.

If the creative area (b) not exist, is poor or schematic, students will be unable to contribute new solutions. If finally, the present adult area (c) does not detect the weakness of the former two, students will surely arrive at inadequate or hybrid solutions.

If, on the other hand, they are fully conscious of the mistakes, they will try to overcome them and in the learning process find a solution to the problem.

It would follow from the above that education must generally aim to liberate the students from schemes, feed them experience and create discernment.

These were the stages considered in the present course. Its objetive is to introduce to and interest the student in the problems of color with special emphasis on appearance. It is a color introduction course, given during four weeks of eight hours each.

Examples clarifying the exercises and the specific purpose of each one of them are presented. For instance: the relativity of color; the vulue variable; the relate colors; the color mixture; the influence of area color connotation; the spatial color; the chromatic representation of an architectural fact; the color design in human environment.

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MEMORY FOR COLOURS : EVIDENCE FOR A UNIVERSAL COLOUR LANGUAGE ?

Abstract - The premise that the cognitive representation of colour space in its basic chromatic dimension is determined by the perceptual uniqueness of the four elementary colours, red, green, yellow and blue, was investigated in a short-term recognition task and a rating experiment. The results were that the four chromatic elementary colours were : (a) remembered more accurately than binary hues, (b) chosen more frequently to be the most "typical" of all colours. On the basis of these findings, the adequacy of a "universal colour language" is discussed, as for example presupposed in the NCS.

Introduction :

There has been a long lasting debate on the question whether language is dependent on cognition or vice versa. Different opinions culmulated in the two epistemological positions of phenomenal absolutism and cultural relativism. Since the beginning of this controversy, colour perception and colour naming has served as a "classical" paradigm (for detailed discussion see : Bornstein, 1975). While linguistic determinism (Brown & Lenneberg, 1954; Whorf, 1964; Seegall, Campbell & Herskovits, 1966) claimed that colour space is a perceptual uniform domain which language arbitrarily divides into different colour-name categories; ethnolinguistic (Berlin and Kay, 1969) and psychological (Heider, 1971,1972; Rosch, 1973; Bornstein, 1975a, 1976, 1981; Bornstein, Kessen & Weiskopf, 1976, Fagen, 1984) as well as behavioral studies in other species (Wright & Cumming, 1971) have challenged this view. Much evidence has been found that - at least in the realm of colour - perceptual-cognitive factors underlie the formation and reference of liguistic categories. Since then, attempts have been made to explain the perceptual saliency of focal colours and occurance of basic colour-name categories by physiological mechanisms of primate colour vision (Bornstein, 1973, 1975b; Rosch, 1973; Ratliff, 1976; Kay & McDaniel, 1978). But at the present state such a straightforward interpretation, even if it seems most plausible, has to be speculative (for detailed disscussion see : Oberascher, 1986). While earlier electrophysiological findings (De Valois, Abramov & Jacobs, 1966) were taken as direct evidence for the opponent processes postulated by Hering, Jameson (1985) remarks that "the particular spectral response characteristics that would identify particular types of cells as correlates of the three separate, white/black, yellow/blue and red/green mechanisms that we deduce from visual psychophysics are less satisfactorily established in the visual physiology". Recently, Mollon and Cavonius (1987) have shown that preadaptation to a blue field of only 10 Td, which should keep the desensitization of the cones minimal, has a strong effect on the discrimination of 1000 Td yellow lights. Thus they claim, "that the chromatically opponent channels revealed by recent psychophysics are not the opponent processes of classical Opponent Process Theory", as their results are in line with the predictions expected if wavelength discrimination in the yellow spectral region would depend on a (tritanopic) channel which differences the input of middle- and long-wave cones only.

However, a parallelism between perceptual and cognitive processes (compare : Shepard and Podgorny, 1978) appears to be much more compelling, than a stringent explanation of what kind of neurophysiolocial mechanisms underlie cognitive representation.

Nevertheless, the present study has been carried out under the premise that the cognitive representation of colour space in its chromatic dimension is based on the perceptual saliency of the unique hues, red, green, yellow and blue - as defined by Hurvich and Jameson (1955) - and with the implicit speculation that the unique colour sensations might be mediated by a zero-signal-detector mechanism as proposed by Zrenner (1985). The basic hypotheses were that the elemetary chromatic colours are, (a) remembered more accurately in short-term recognition task than binary hues, (b) chosen more frequently to be the most "typical" of all colours.

Methods

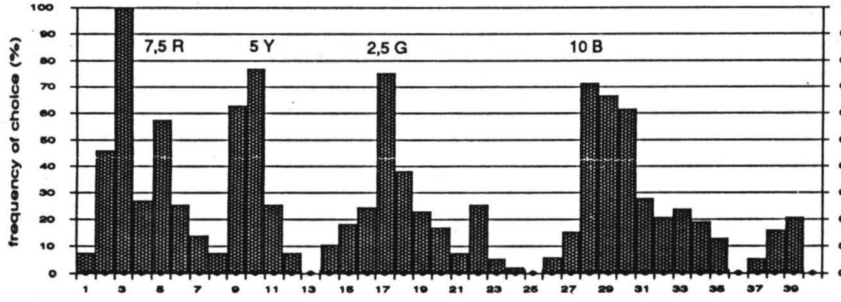
Subjects : 12 "naive" observers - 10 females, 2 males - between 21 and 35 years of age. All performed normally on the Ishihara test and the Nagel anomaloscope.

Stimuli : In experiment (1a) 20 Munsell colour chips (5R 4/14*, 10R 5/14, 5YR 7/14, 10YR 8/14*, 5Y 8/14*, 10Y 7/12, 5GY 6/10, 10GY 5/10, 5G 4/10*, 10G 4/10*, 5BG 4/8, 10BG 4/8, 5B 4/8*, 10B 4/10*, 5PB 3/10, 10PB 3/10, 5P 3/10, 10P 3/10, 5RP 3/10, 10RP 3/10 - glossy) were used as targets; 240 chips, mounted on grey cardboard, as distractors. Elementary colours (indicated above by a star) were defined as these chips which dominant wavelength came close to 575nm, 500nm, 580nm and >620nm. In experiment (1b) the whole set of 240 chips was presented.

Apparatus: As illuminant served an adjusted Kodak-Carusell S-AV projector[1], mounted vertical 100cm above a middle-grey plane of about 100x150cm. The spectral distribution of the filtered projector light was measured with an Optical Spectrum Analysator (B&W) and adjusted as close as possible to D65 (x=0,3095; y=0,3211; 1500 lx). Targets were presented under 45/0° in a box with a hand-remote controlled shutter.

Procedure: In experiment (1a), after a 40sec interval for adaptation, a target was presented for 5sec followed by a 40sec interstimulus interval after which a set of distractors were shown to the Ss for 60sec. All targets were presented in randomized order. Ss were asked to remember the presented colour as accurately as possible and to choose out of whole set the chip which appeared to be the most similar. In experiment (1b) Ss were asked to choose the "most typical" colours out of all 240 chips. In addition to that they were requested to make a second choice and to rate these colours in relation to the first ones on a 5-step rating-scale.

Results : In experiment (1a) the memory accuracy score was S's correct recognition for elementary and non-elementary colours. Results were analyzed by an analysis of variance (randomized block factorial design, type RBF-24)[2] and an *a priori* orthogonal t-test. Factor B (elementary vs. non-elementary) proved to be highly significant, $F(1, 33) = 26,37$, $p < .01$. Elementary colours were more accurately remembered than non-elemetary $t(8) = 6.5$, $p < .001$. In experiment (1b) typicallity was defined as the frequency of choice plotted against hue. As can be directly seen from the graph, the 4 elementary colours appear to be true reference points, each representing the center of a basic colour category (compare : Rosch, 1975).



General Discussion :

The present findings do not contradict the existence and relative importance of "nonprimary" focal colours (Heider, 1972) or "secondary" focal colour categories, but challenge theoretical implications (see : Whitfield, 1981), which on this basis, question the adequacy of a "universal colour-language" as, for example, it is presupposed in the NCS (Hård, 1975; Steen, 1969).

(1) The four chromatic "elementary" colour sensations, phenomenologically defined by Hering (1920), are universally salient features to cognition, as they are perceptually unique to any normal trichromat .

(2) This fact is well reflected in the choice of the "most typical chromatic representatives" of colour space without reference to colour names by "naive" observers; and these colours are most accurately remembered in recognition tasks (Oberascher, 1986; 1987). When translating the Munsell notations of the "most typical" examples into NCS, a good agreement with the NCS-elementary hues is seen.

(3) Thus a descriptive colour notation based upon the judgements of apparent degree of resemblance to perceptually unequivocal features, is rather a non-symbolic, preverbal or analogical model of basic perceptual colour dimensions than a representation

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[1] Since a second experiment (which will not be reported fere) has been carried out in the same series under different illumination, in order to allow a smooth shift from 6500 to 2000 K° and vice versa, projectors which were controlled by a multi image program were used.

[2] For the reason mentioned above the data of experiment 2 were treated in the same statistical procedure.

of all the basic colour categories which might or might not be labeled in different cultures. While hue-naming experiments (Jameson and Hurvich, 1959; Boynton and Gordon, 1965; Werner and Wooten, 1979; Sternheim and Boynton,1966; Fuld and Alie, 1985) have supported the fact that the four colour-names red, green, yellow and blue are sufficient to quantitatively describe the appearence of any given wavelength of the spectrum, von Wattenwyl and Zollinger (1979) emphasised that the linguistics of colour terms generally confirm Opponent Colour Theory, but at the same time reveal the influence of cultural environment. Suppose then that, for example, the term "orange" show all characteristics of being a lable to a "secundary focal colour category" and hence serves as a reference point in common language of a particular culture, the hue associated with the colour name orange is not unique in all aspects (compare : Sternheim and Boynton, 1966; Bartelson, 1976; Fuld, Werner and Wooten; 1983). Still it can be described in terms of its resemblance to the elemtary colour attributes red and yellow. As a consequence, wherever precise colour identification and communication is needed, also "secondary" basic colour terms could be used (in as much as the meaning a term finally aquires depends - in the sense of Wittgenstein (1977) - much on its particular use), but the colour must be specified by its elementary perceptual properties, that is by saying "This is an orange, but of the kind Y40R".

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ONE-MONOCHROMATOR TWO-SOURCE METHOD FOR THE COLORIMETRY OF FLUORESCENT MATERIALS

PURPOSE

This paper proposes a revision to the One-Monochromator Two-Source Method for the colorimetry of fluorescent materials[1]. The new method can predict the tristimulus values for fluorescent samples more accurately under a wide variety of illuminants than the conventional one-monochromator method[2].

PROCEDURE

The measuring procedure for the new method is as follows:

(1) M (measure): spectral total radiance factor (STRF) $\beta_{t,X}(\lambda)$ under polychromatic irradiation $S_X(\lambda)$, for example, a xenon lamp or an incandescent lamp.

(2) M: STRF $\beta_{t,L}(\lambda)$ under a filtered $S_X(\lambda)$ lamp.

(3) M: spectral conventional radiance factor $\beta c(\lambda)$ under monochromatic radiation.

(4) C (calculate): provisional spectral reflection radiance factor $\beta'_o(\lambda)$.

$$\beta'_o(\lambda) = \text{minimum}\,[\beta_{t,X}(\lambda),\ \beta c(\lambda)]$$

(5) C: relative spectral excitation $Q_e(\lambda)$.

$$Q_e(\lambda) = [\beta c(\lambda) - \beta'_o(\lambda)]\, s_r(\lambda)$$

where $s_r(\lambda)$ is the relative responsivity for the detector system used in step (3).

(6) C: relative spectral distribution for fluorescence $F(\lambda)$.

$$F(\lambda) = \frac{[\beta_{t,X}(\lambda) - \beta_{t,L}(\lambda)]\, S_X(\lambda)\, \tau_T(\lambda)}{\sum_{\lambda'=300}^{780} S_X(\lambda')[\tau_T(\lambda) - \tau_T(\lambda')]\, Q_e(\lambda')\, \Delta\lambda'}$$

where $\tau_T(\lambda)$ is the spectral transmittance for the filter used in step (2).

If $F(\lambda)$ is less than 0, it is set to equal 0.

(7) C: spectral reflection radiance factor $\beta_o(\lambda)$.

$$\beta_o(\lambda)=\beta_{t,x}(\lambda)-\frac{F(\lambda)}{S_x(\lambda)}\sum_{\lambda'=300}^{780} S_x(\lambda')Q_a(\lambda')\Delta\lambda'$$

If $\beta_o(\lambda)$ is less than 0, it is set to equal 0 and $F(\lambda)$ is re-calculated for these wavelengths.

$$F(\lambda)=\frac{\beta_{t,x}(\lambda)S_x(\lambda)}{\sum_{\lambda'=300}^{780} S_x(\lambda')Q_a(\lambda')\Delta\lambda'}$$

(8) C: STRF $\beta_{t,D}(\lambda)$ under an arbitrary illuminant having a relative spectral power distribution $S_D(\lambda)$ can be obtained from the following equation.

$$\beta_{t,D}(\lambda)=\beta_o(\lambda)+\frac{F(\lambda)}{S_D(\lambda)}\sum_{\lambda'=300}^{780} S_D(\lambda')Q_a(\lambda')\Delta\lambda'$$

PREDICTION ERRORS

Simulation of colorimetric measurement was carried out for the new method and the conventional method from the two-monochromator method data measured by H.Minato[3]. The procedure for the conventional method, slightly different from that in reference (2), is the above-mentioned steps (1), (3), (4), (5), (8) and the following step (6').

(6') C: relative spectral distribution for fluorescence $F(\lambda)$.

$$F(\lambda)=\frac{[\beta_{t,x}(\lambda)-\beta'_o(\lambda)]S_x(\lambda)}{\sum_{\lambda'=300}^{780} S_x(\lambda')Q_a(\lambda')\Delta\lambda'}$$

The prediction errors for each method are shown in Fig.1. In this figure, the abscissa indicates the correlated color temperatures for CIE daylights (≧5000K), Planckian illuminants (≦5000K) and 6 fluorescent lamps used as $S_D(\lambda)$. The prediction errors were represented by $CIELAB_{10}$ color differences between the values predicted by each method and the true values determined by the two-monochromator method. The illuminant used in step (1) was a filtered xenon lamp, and the filter used in step (2) was a light balancing amber filter.

Figure 1 suggests that the new method is superior to the conventional one-monochromator method.

Both the new method and the conventional method have been adopted in the draft of the Japanese Industrial Standard "Methods of Measurement for Colour of Fluorescent Objects".

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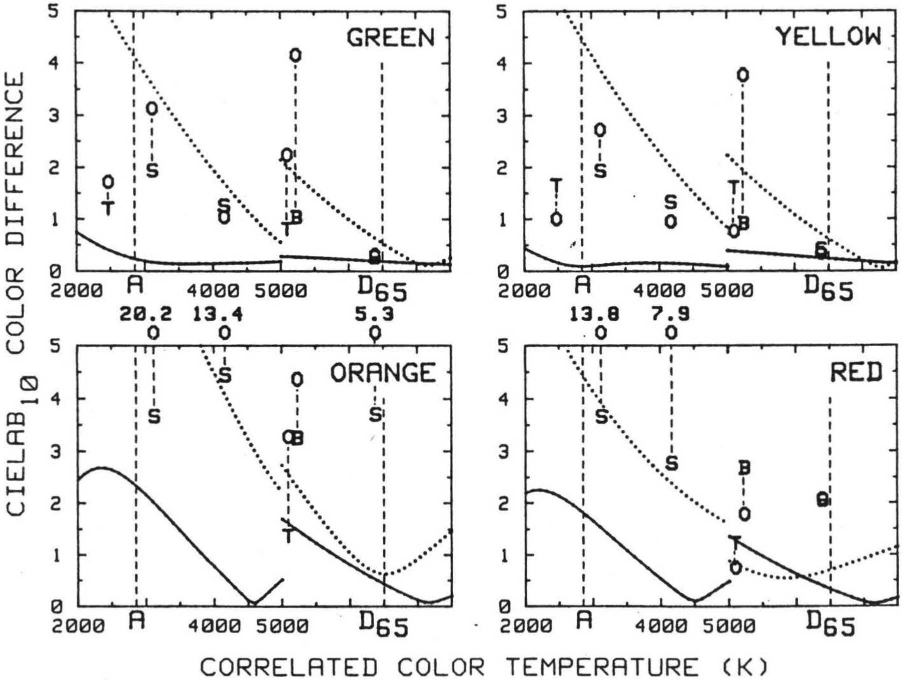

Fig.1 Prediction errors in fluorescent object colors under CIE daylights, Planckian illuminants and fluorescent lamps.

Solid lines and dotted lines indicate the prediction errors by the new method and the conventional method, respectively, under CIE daylights (≧5000K) and Planckian illuminants (≦5000K).

Characters S, B and T mean errors by the new method under standard, broad-band and three-band fluorescent lamps, respectively. Character O means errors by the conventional method under the respective fluorescent lamps.

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SOME FACTORS INFLUENCING SPECTRAL AND COLORIMETRIC CHARACTERISTICS OF DAYLIGHT IRRADIANCE

The spectral power distributions of daylight irradiances are influenced by a number of factors including solar zenith angle, cloud cover, atmospheric ozone, aerosol content and in the case of interior daylight, the spectral reflectance of building and furniture materials. In the case of measurement of the spectral power distribution of daylight, the measuring method and sampling geometry can lead to different results. Some measurement results to illustrate the effects of these parameters are presented and discussed.

Das Spektrum der spektalen Bestrahlungsstärke von Tageslicht wird durch eine Anzahl von Faktoren bestimmt. Dazu gehören der Zenitwinkel der Sonne, die Wolkenbedeckung, atmosphärisches Ozon und, im Fallevon Tageslicht in Innenräumen, die spektrale Transmission des Fensters und die spektrale Reflexion der Bau-und Möbelmaterialien. Im Falle von Messungen der spektralen Bestrahlungsstärke von Tageslicht kann die Meßmethode und die Erfassungsgeometrie zu unterschiedlichen Resultaten führen. Meßresultate welche die Auswirkung dieser Größen seigen, werden vorgelegt und besprochen.

Les répartitions spectrales des éclairements énergétiques diurnes sont influencées par un certain nombre de facteurs tels que l'angle de déclinaison solaire, la couverture nuageuse, l'ozone atmosphérique, le contenu en aérosols et à l'intérieur de bâtiments, le facteur de transmission spectrale du verre des fenêtres et le facteur de réflexion des matériaux de construction et du mobilier. La technique et la configuration géométrique de mesure influencent les résultats obtenus. Des résultats qui illustrent les effets de ces divers paramètres sont analysés.

INTRODUCTION

Because of the vital importance of daylight to life on earth many workers over decades have investigated the spectroradiometric and colorimetric characteristics of direct solar, global and diffuse sky irradiances under varying atmospheric conditions. From a colorimetric point of view, the CIE has through the years adopted a number of standard sources and illuminants to simulate different phases of daylight. Of these D_{65}, representing heavily clouded sky irradiance at a correlated colour temperature of 6504 K, is the most widely used.

In spite of the many projects undertaken in this field and because of the many variable atmospheric and climatological parameters involved, as well as the utilisation of different measurement methods, the situation arose that significantly different results were obtained, even for "standardized" conditions. If internal daylight irradiance is considered, even more complications are involved. Some years ago a "practical standard illuminant representative of interior daylight" (Clarke 1979) was proposed. This ID_{65} represented the spectral power distribution of D_{65} daylight after passing through 6 mm of float glass at 45°. This proposal was not accepted by CIE for several reasons, some of which will be touched on later.

In order to make a contribution in the daylight field and in an effort to resolve some of the problems involved several measurement programmes were undertaken in South Africa. Exterior daylight spectral irradiances were measured at Pretoria (altitude 1400 m) and Durban (sea level) (Chalmers and Kok, 1981). Some measurements on interior daylight spectral characteristics (Kok 1985) were also made.

RESULTS AND DISCUSSION

As reported earlier (Chalmers and Kok 1981), the Pretroia and Durban results for exterior daylight show considerably higher normalized values for wavelengths from 300 to 450 nm than those of the CIE standard D illuminants for the same correlated colour temperatures. Measurements made at different places both in the Northern and Southern hemispheres over the past decade, as well as data obtained from the use of reliable models, yielded results in close agreement with the South African ones for similar atmospheric parameters.

However, parameters influencing the spectroradiometric and colorimetric characteristics of daylight, such as effective air mass (solar zenith angle, latitude and altitude), aerosol and atmospheric ozone content, cloud cover etc. are highly variable. The results obtained from measurement are, amoung others, influenced by the method of sampling and the characteristics of the receptor.

The measurements performed on interior daylight showed that a number of factors, additional to those mentioned above, have a marked influence on the spectral properties. Apart from the spectral absorptance of window glass, the spectral reflectances of interior (and in some cases exterior) building materials and furniture materials influence the spectral power distribution of interior daylight significantly. Most building and furniture materials have low ultraviolet reflectances as can be derived from figure 1 which shows the spectral ratios of indoor to outdoor daylight irradiances.

The measurements were made on a horizontal plane with the spectroradiometer placed on top of an office desk made out of teak. The office contained grey painted cabinets and the walls and ceiling were painted with ordinary matt white poly vinyl acrylic paint. The office had two north facing windows, letting in diffuse skylight. The receptor of the spectroradiometer was about 1,5 m above floor level and 2 m from the windows. Measurements were made with the windows opened and closed, respectively.

Before adopting a standard interior daylight illuminant (ID), factors other than the spectral transmittance of window glass should also be considered.

Althouth the CIE standard daylight D illuminants are believed to be deficient at shorter wavelengths, they might be acceptable as a compromise between exterior and interior daylight.

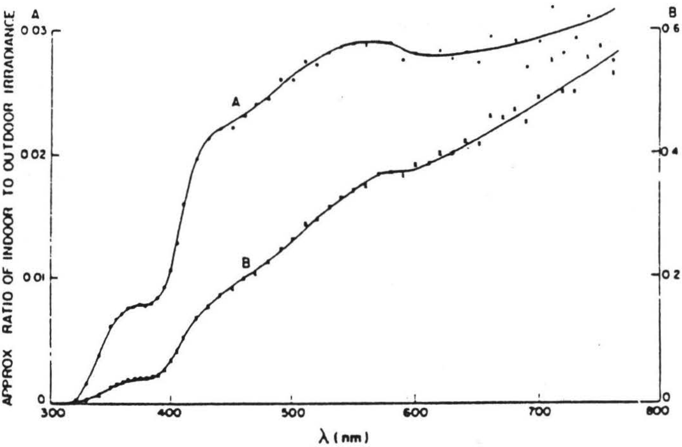

Figure 1. Spectral ratios of indoor to outdoor daylight irradiances
A. Indoor to full outdoor (left scale)
B. Indoor to north sky (right scale)

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GONIOMETRIC COLORIMETRY (1)
- Gonio-Spectrophotometric Analysis of Pearl-Mica Paints -

The relationship between appearance and optical measurement of objects with anisotropic reflecting properties had been studied by many authors. The object of this experiment is also to analyse the gonio-spectrophotometric characteristics of those surfaces.
For this experiment, two types of instrument were used; one was Model GP-1R goniophotometer with glass or interference filter, which was mainly used for measurement of precise spatial distribution of reflected light, and another was Model GSP-1 gonio-spectrophotometer, which was mainly used for measurement of directional spectral reflectance factor.

1. The preliminary experiment

a) Measurement of diffusing properties of white surfaces

At first, luminance factor and spectral reflectance factor of samples were measured. Samples prepared were various kinds of pressed white plaques, which were different in material, surface roughness and density, polished vitrified porcelain plate, BCRA tile and painted surface. For normal incidence, diffusing properties of pressed white plaques were changeable by the pressing procedure and materials, but diffusing properties of the other white plates were seemed to be more uniform, therefore some of these white plates were used as the reference standards for instrument calibration.

b) Measurement of interference color of colored metal surfaces

As a preliminary experiment, colors of directionally reflected light of colored metal surfaces were measured. Samples were stainless steel sheets which were coated by thin oxidized layer of various thichness, and were observed to be colored from the specific direction. In these measurement, interference curves and calculated chromaticities have matched to the calculated values by interference theory.

2. The experiment

As specimens, pearl-mica paints were applicated on paper. These paints were two-coat type, which mean achromatic or chromatic transparent layer including pearl-mica pigment was overcoated on each white, red, blue and black base color paint surface. Spectral reflectance factor distributions were measured in the viewing angle from -25° to 65° for surface normal by 5° step, for 45° incidence. From data processing of these spectral distributions, it was presumed that spectral reflectance factor ditribution was additive combination of intrinsic color component, pearlescence component and surface reflection component, and angular characteristics of each component changed according to the paint formulation. Among these components, intrinsic color component is the resultant of base color affected by the scattering and absorbing properties of overcoated layer. Pearlescence component indicates interference color, therefore angular characteristics of this component may be a cause of pearl-like perception. Changes in chromaticity and lightness for viewing directions were also calculated.
The same analysis for premixed type pearl-mica paint samples were also made. In case of premixed type paint, the separation of intrinsic and pearlescence components was difficult, but the degree of pearl-like perception was supposed in the same manner.

Finally the basic difference between the spatial distributions of reflected light of solid paint color, pearl-mica paint color, metallic paint color and metal surface color was referred.

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INFLUENCE OF OPTICAL RADIATION ON COLOUR CHANGE OF MATERIALS

It is known, that light sensitive materials can change their colour when irradiated with high luminous (radiant) exposure. This effect is especially important for museums, exhibitions, and show cases.

The colour change ΔE^*_{ab} of materials can be predicted, when the following data are known for:

- materials:
  - relative spectral object sensitivity (relative spectral responsivity) $s(\lambda)_{dm,rel}$
  - effective threshold radiant exposure $H_{s,dm}$ for colour change
- lighting installations:
  - spectral power distribution S_λ
  - illuminance E (irradiance E_e)
  - exposure time t

54 samples of typical museum goods were provided by the "Stiftung Preußischer Kulturbesitz", who sponsored the research project, to measure their relevant characteristics:

23 water colours
6 oil paints on canvas

3 paper samples

6 newspaper samples

16 textile samples

A special irradiation equipment with Xenonlamp and different cut-off filters was built-up. The colour of the materials was measured after different irradiation periods. The colour difference $\Delta E^*_{ab} = 1$ was used for the defintion of $H_{s.dm}$.

The colour measurements were first done, using the spectral method. For following measurements a tristimulous colorimeter with direct display of ΔE^*_{ab} was used. The colorimeter was calibrated separately for each non-irradiated sample.

The results showed different functions of $s(\lambda)_{dm,rel}$ and values of $H_{s.dm}$ for each material. For most materials $s(\lambda)_{dm,rel}$ can be described by an expontial function (fig. 1)

$$s(\lambda)_{dm,rel} = a \cdot \exp(-b \cdot \lambda)$$

For general use average functions of $s(\lambda)_{dm,rel}$ and group values of $H_{s.dm}$ were derived from these results for each type of material and for all samples.

The correlation of acceptable exhibition period at defined illuminance levels for different light sources (daylight, most common lamps) can be predicted with these results. General recommendations for museums lighting are derived from this to prevent larger damages of materials.

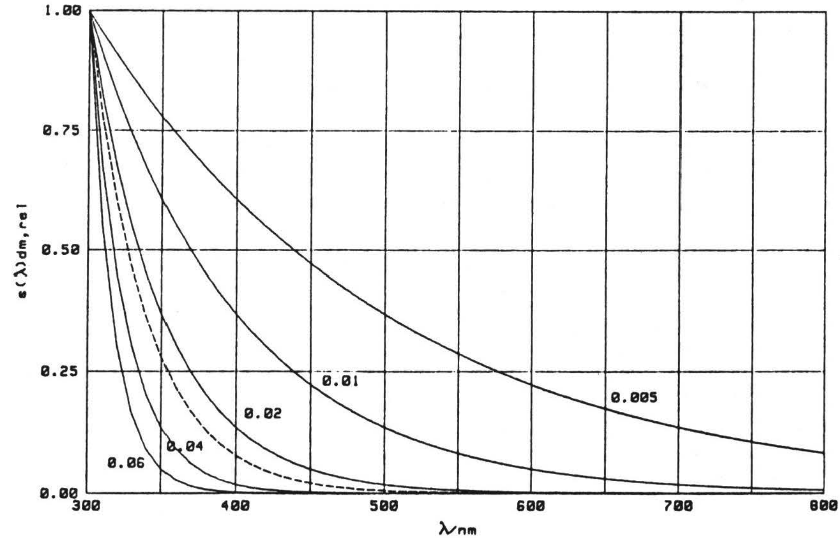

Fig. 1: Relative spectral object sensitivity of different materials

Parameter: b

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SKIN COLOR EVALUATIONS OF ULTRAVIOLET IRRADIATED GUINEA PIGS AND SUBJECTIVE EVALUATIONS BASED ON SKIN COLOR SCALE

1. Introduction

Skin color is observed under a variety of lighting conditions and its appearance is important factor in evaluating color rendering provided by a given source of illumination. Furthermore, establishing standards for the objective evaluation of skin color has the potential for providing much useful information in the fields of medicine or cosmetics(1). The conventional Munsell system skin color scale does however not provide a sufficient gauge for such evaluation.

Accordingly, this research began by using a spectrophotometer to measure changes in guinea pig skin color caused by ultraviolet radiation and evaluating these results on the basis of uniform color spaces(2). Next, an experimental subjective evaluation was carried out on the CIE-JIS test-color samples(3,4) and the skin color samples. A comparative study was then done on these results and evaluation through CIELUV, CIELAB type color spaces.

2. Experimental Method

2-1 Measuring guinea pig skin color

Nine, 6 month old, colored male gulnea pigs, weighing 600 grams each, were used in the experiment. The light source was an ultraviolet radiation fluorescent lamp (UV-A). Hair was removed from the guinea pigs' backs with clippers and shaver and a 3 cm diameter circle was drawn on this area in a location so as to be symmetrical to the median line. Ten points within this circle were examined, the average value of which was taken to be the skin color. This was repeated 3 times a week over a period of 4 weeks. The backs of the guinea pigs were then exposed to the UV-A light source from a distance of 45 cm and for a duration of 30 minutes/day. Ultraviolet radiation was 2.0 $\mu w/cm^2$.

2-2 Subjective Experiment Method

The sources of illumination used in this experiment were three types of fluorescent lamps and one incandescent lamp. The specifications of each of these lamps are shown in Table 1. Also, the incandescent lamp was a 100 watt bulb supplied with the proper voltage determined by spectrophotometry in order to approximate a standard source A. The area of the lighting booth was approximately 70cmx70cm, and light intensity was regulated by number of lamps and held at approximately 1000 lx. Fifteen colors, the spectral reflection of which approximated CIE-JIS test-color samples Nos. 1-15, as well as 6 color samples approximating the skin color of Japanese were arrived at for a total of 21 test-color samples. The size of each color sample was 5cmx8cm. The observers were a group of 6 male and female Japanese. Each observer, after first making some practice observation, made 5 subjective evaluations for each color sample and illumination type. The selection of color samples for each type of illumination was entirely at random.

The three color appearance attributes were hue, lightness, and

Table 1. Correlated color temperature and general color-rendering index for light soures.

Light source	Type	Tc (K)	Ra
Incandesent lamp	IL	2763	99.4
Fluoresent lamps	EDL	5227	97.7
	3-Band	5223	82.4
	D	6346	73.7

relative chroma, in that order; hue: evaluated as the ratio of two adjacent unitary hues (R,Y,G,B), for example R60 Y40, lightness: comparative evaluations (0-100 range) were done after juxtaposing samples against a Munsell-type gray scale (0.5 step), relative chroma: observers' greatest sense of color saturation from each hue was taken as 100, and relative chroma was evaluated as a propotion thereof.

3. Experimental Results

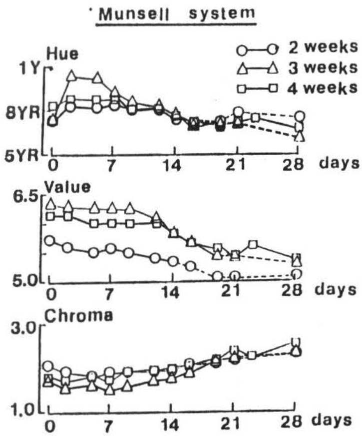
Figure 1 shows changes over time in the hue, value, and chroma in the Munsell color system. The solid line represents the UV-A radiation period, and the hatched line represents the non-radiation period. A shift in the hue towards yellow peaked after 2 to 5 days, followed by a shift towards red. Value appeared to change after 1 week of UV-A radiation following which it began to decrease day by day, whereas the opposite effect was observed in regard to relative chroma. Significant differences between radiation groups were however not recognized, thereby indicating difficulty with a quantitative evaluation.

Figure 2 shows an example of evaluation through CIELUV, as well as CIELAB uniform color spaces. The ellipse in the center shows the standard deviations obtained in the u*-v* and a*-b* directions, along the major and the minor axes respectively. Figures in the center of the ellipse show the number of days of irradiation. Ellipses representing the 2 week irradiation groups were almost identical for both color spaces. It was evident however that in the cases of 3 and 4 week irradiation, the ellipses changed with the increase in the number of days. Thus, insofar as skin color changes due to UV-A radiation are concerned, it is believed that quantitative evaluation is possible on the basis of uniform color spaces and that this is therefore superior to the Munsell color system.

Average values for the 6 observers' subjective evaluations of hue and relative chroma, were plotted on a chroma perception chart with perpendicular R-G, Y-B axes and compared to a psychological chroma chart with 2 color spaces. Figure 3 (a), (b) show examples of measurement and observation comparisons between skin color samples and 8 color moderately chroma scale. As a result of this diagramatical comparison it was found that the CIELAB system permits a more objective evaluation than does the CIELUV system. Moreover, the results of the subjective evaluations corresponded well to the relative color ares of each test lamp.

4. Conclusion

It is difficult to provide a quantitative evaluation of minute changes in skin color strictly on the basis of comparisons with the conventional Munsell color system. Uniform color spaces offer a superior evaluation method. The CIELAB type expressions are considered particularly suitable for objective evaluation.



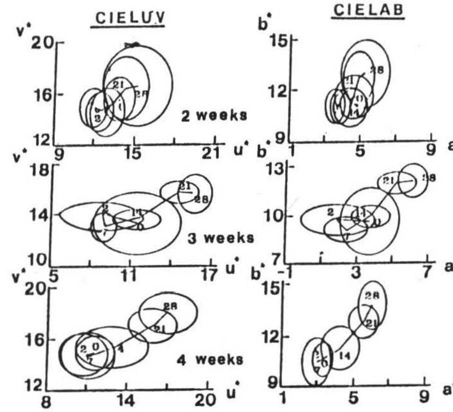


Fig. 1. Changes of HVC in the Munsell system.

Fig. 2. Evaluation of CIELUV and CIELAB uniform color spaces.

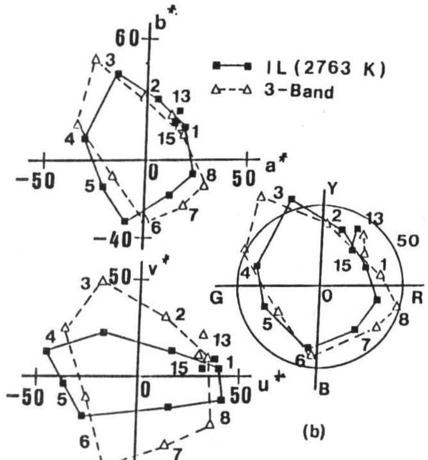


Fig. 3. Comparison of the psychometric-chroma diagrams (a) with the subjective chroma diagram (b).

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EVALUATION OF DEEP AND THIN LAYER TECHNIQUES FOR SAMPLE DIFFERENTIATION IN TRANSLUCENT HYDROLYZED CONCENTRATED CHEESE WHEY

Hydrolyzed concentrated cheese whey (HCCW), which may be used for producing a wide variety of dairy ingredients (Jelen, 1983), is very apt to develop nonenzymatic browning due to its high concentration of reducing sugars. To evaluate deteriorative changes during storage or the effectiveness of experimental treatments in controling nonenzymatic browning, accurate measurements of the extent of browning are required, which may be in accord with what is perceived.

HCCW, may be clasified as a translucent food. For some translucent samples the simple expedient of measuring a thin layer with a white background is sufficient for successful separation of samples in color space (Little, 1964; Huggart et al., 1966; Gullet et al., 1972; Huang et al., 1970). However MacKinney et al. (1966) and Little and Brinner (1981) found that calculating attenuation and scattering coefficients through Kubelka-Munk equations improved sample differentiation.

This work was undertaken with the aim to develop a suitable method to obtain color data in HCCW by testing the effectiveness of thin and deep layer techniques for separation of samples in color space corresponding to browning reactions.

Concentrated whey was supplied by SANCOR Cooperativas Unidas Ltda., Buenos Aires, and it was hydrolized up to 70% hydrolysis with Maxilact β galactosidase. Samples of different degree of browning were prepared by adding weighed aliquots of hydrolyzed concentrated cheese whey in which intense browning had been developed by heat treatment to original HCCW. The mixtures ranged from 0% browned whey to 3.9% browned whey.

Measurements were done in a Hunterlab 5100 Color Difference Meter using an aperture 4.7 cm diam. and mode of illumination which illuminated the area of aperture. Calculations were made for illuminant C, 2°. Samples were presented in plexiglass cubetes, 5.3 cm in diameter and variable thickness and backed by white and black backgrounds. Functions s_{UV}, C^*_{ab}, h_{ab}, ΔE^*_{ab}, ΔH^*_{ab}, L^*_{ab} (Lozano, 1978) and brown index BR (Buera et al., 1985) were calculated from X, Y and Z values, and also Kubelka--Munk parameters K,S, KX, SX, K/S and T_i (Judd and Wyszecki, 1975) were obtained by substituting tristimulus values and L^*_{ab} for the respectives R in the Kubelka-Munk equations.

Twelve observers evaluated visually the browned samples, according to "degree of browning", with 91.7% correct answers. The results of subjective evaluation indicated that samples 2, 3, 4 and 5 were separated by the just noticeably difference (j.n.d.).

At about 15 mm in deph, readings with white background were practicaly coinciuent with those obtained with black background, and this translucent samples may be considered opaque when they are measured at a thickness ≥ 15 mm.

Color functions and Kubelka-Munk parameters obtained for each sample at 1, 2, 3, 4 and 17 mm in deph, were correlated with concentration of browned HCCW added to the original whey.

Black background considerably reduced distance in color space among samples and only measurements with white background were considered for analysis of color functions. The more commonly color function used to evaluate color differences is ΔE^*_{ab} and is represented in Figure 1. It can be observed that slopes of curves (which may be considered a measure of sensibility to distinct between two samples) decreased as thickness increased, and the same was observed for s_{uv} and C^*_{ab} functions. For h_{ab} (hue) function correlation was not linear for 3, 4 and 17 mm thickness sample, due to a change of sign of "a" value.

As tristimulus value Z had a big variation between samples, 1/Z was also correlated with pigment concentration (Fig. 2).

For ΔH_{ab}, BR, 1/Z and ΔL^*_{ab} functions slopes for 1, 2, 3 and 4 mm were quite similar and except for 1/Z and L^*_{ab} they decreased for 17 mm thickness.

For all functions tested except 1/Z (Fig. 2) and ΔL^*_{ab}, the effective separation of samples was not adequate in the opaque system (17 mm deph) and reducing thickness resulted in an expansion of color space. However, for the thinnest samples (1 mm deph) values were more erratic.

Fig. 3 shows the results obtained for Kubelka-Munk parameter K (attenuation coefficient) calculated with tristimulus value Z. Similar curves were obtained for K calculated through tristimulus values X and Y and L_{ab}, and the same was found for the rest of Kubelka-Munk parameters.

In Fig. 4 it can be seen that ratio K/S resulted to be a sensible function to differentiate samples.

The results of this investigation indicated that the color measurements of HCCW to browning reactions by the j.n.d.may be conduced succesfully in the following ways:
a) In opaque systems (sample deph ≥ 15 mm) by functions 1/Z or ΔL^*_{ab}.
b) With sample deph from 2 to 4 mm backed by white, by functions ΔH^*_{ab} and 1/Z or c) With sample deph from 2 to 4 mm with Kubelka-Munk treatment by coefficient K/S.

Kubelka-Munk treatment was advantageous in differentiating samples separated by small color differences and K/S gave the best sensibility and good correlation coefficients related to pigment concentration.

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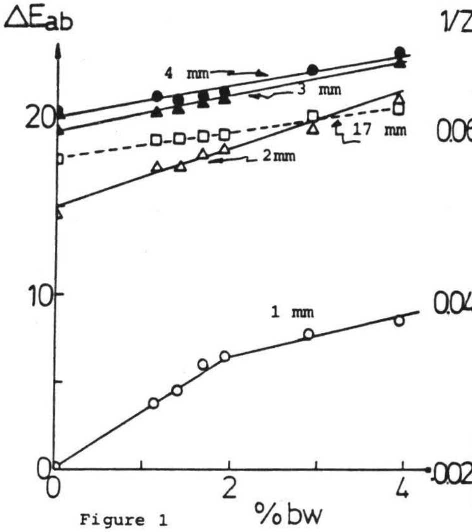

Figure 1
E_{ab} function obtained with white background for different thickness.

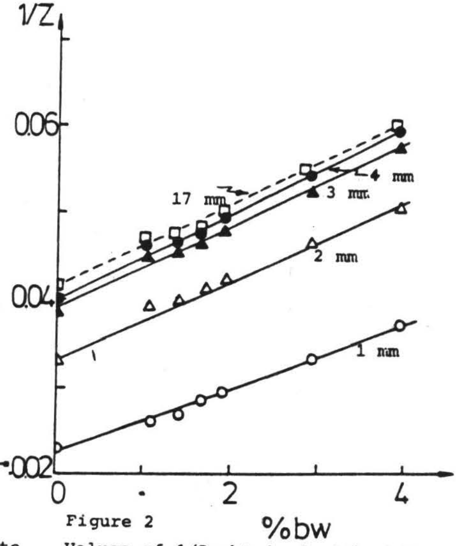

Figure 2
Values of 1/Z obtained with white background for different thickness.

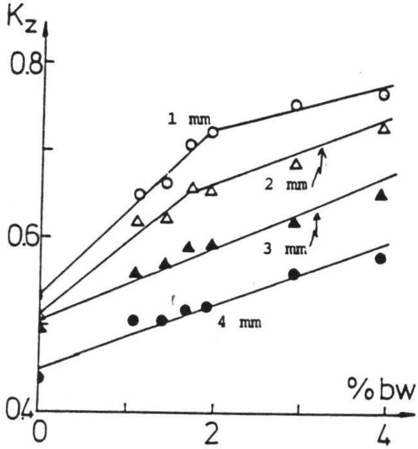

Figure 3
Attenuation coefficient obtained at different thickness.

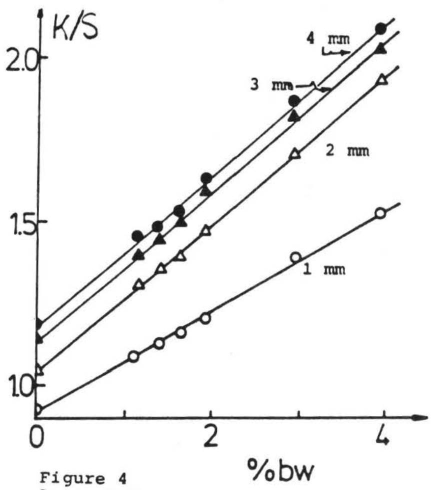

Figure 4
Ratio K/S obtained at different thickness.

%bW= % browned whey added

LA QUALITE DE LA COULEUR DU BOIS DE CHENE DE FRANCE

FRENCH OAK WOOD COLOR QUALITY

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- 1 - INTRODUCTION

Les utilisations les plus valorisantes du bois sont les utilisations en décor pour lesquelles le critère déterminant est la qualité de l'aspect.

L'aspect inclut l'esthétique du dessin et l'état de surface du matériau mais il dépend en premier lieu de la couleur du bois.

- 2 - VARIABILITE GEOGRAPHIQUE de la COULEUR du BOIS de CHENE de TRANCHAGE en FRANCE .

Les mesures de couleur ont été exprimées dans le système CIELAB 1976 (DECARREAU, 1988) .

Des mesures non destructives de couleur, à partir de carottes de sondage (JANIN-MAZET, 1987) prélevées en forêt domaniale d'Amance (FRANCE) dans des conditions homogènes de milieu ont montré :

- une différence d'angle de teinte entre chênes sessiles (plus roses) et pédonculés (plus jaunes);

- aucune différence de luminance entre ces deux espèces;

- un déplacement de la teinte vers le rose lorsque le bois vieillit.

Les analyses de 20000 mesures de couleur sur des placages de 554 arbres issus de 130 forêts francaises, ont montré (fig.1) (FLOT,1988) :

- une grande variabilité à l'intérieur de chaque forêt;

- une différence de teinte entre les chênaies sur sable et argile du Centre de la FRANCE (bois plus rose) et les chênaies sur marne et limon de l'Est de la FRANCE (bois plus jaune);

- une baisse de la luminance et donc de la qualité en présence d'hydromorphie des sols.

- 3 - INFLUENCE de la LUMIERE du JOUR et des RAYONS U-V sur la COULEUR du BOIS de CHENE .

La couleur naturelle d'un bois est susceptible de se modifier sous l'effet d'agents extérieurs et en particulier la lumière du jour. Dans le cas des placages de chêne, une meilleure connaissance de ces modifications et des mécanismes photochimiques qui y président est particulièrement importante, compte tenu du rôle essentiel joué par la couleur de ce type de produit d'un point de vue de sa valeur commerciale .

Des irradiations d'échantillons de chêne (aussi bien Duramen qu'Aubier) ont été réalisées avec une lampe à vapeur de mercure haute pression (= 290 nm) et les changements de couleur ont été suivis par la mesure des différents paramètres du système CIELAB 1976.

Durant les premiers jours d'exposition, temps supérieur à 100 heures, les échantillons commencent par s'assombrir rapidement (L* diminue) et s'éclaircissent ensuite lentement jusqu'à devenir plus clairs qu'initialement. Parallèlement, un jaunissement progressif se produit (b* augmente). D'autre part, l'écart total de couleur entre l'aubier et le duramen (δE), déjà important au départ (environ 6 unités) ne fait que s'accroître pendant l'irradiation (jusqu'à $\delta E = 14$).

Enfin, l'utilisation de techniques spectroscopiques d'investigations (absorptions U V - visible et infrarouge) nous a permis d'apporter une contribution à la meilleure connaissance des mécanismes de photodégradation du bois tout en s'intéressant au comportement photochimique particulier du chêne (MAZET 1988).

- 4 - INFLUENCE de l' ANATOMIE et du PLAN LIGNEUX du CHENE sur la COULEUR du BOIS .

Le PLAN LIGNEUX de chaque espèce végétale est constitué par des proportions différentes d'éléments anatomiques : fibres, vaisseaux, rayons ligneux et tissus de parenchyme répartis dans les trois directions principales de la tige d'un arbre : l'axe longitudinal, radial et tangentiel. Cette disposition des éléments anatomiques qui diffère entre espèces et individus apporte au Bois par leur orientation lors du débit des Variations d'Aspect et de Couleur qui s'ajoutent au rôle des constituants chimiques accumulés dans le Bois de Coeur et qui donnent la Couleur prépondérante au Bois (JANIN, 1985, 1987) .

Cette couleur est la résultante de l'absorption de tous les constituants en mélange.

Cependant, les observations des différences importantes de luminance L* et des coordonnées chromatiques a* et b* mesurées en fonction des angles d'incidence de la lumière sur la surface des placages ont montré qu'elles provenaient de la présence plus ou moins abondante des éléments anatomiques à la Surface des placages (HOFMANN, 1987).

Ainsi par ordre d'importance dans ce rôle pour le bois de CHENE :

- les Rayons ligneux par leur morphologie constituée de cellules dressées longitudinales perpendiculaires à la direction des fibres ont des tailles très petites à très larges, de densité élevée chez certaines espèces (KELLER -THIERCELIN, 1975), (POLGE-KELLER, 1973) riches en amidon, et pour ces raisons offrent des surfaces réfléchissantes lorsqu'ils sont mis à découvert dans le débit longitudinal radial. Ce sont eux qui par leur présence ou leur absence font varier le plus la luminance L* en fonction de l'angle d'incidence de la lumière par rapport à l'observateur
- les Vaisseaux par leur différents diamètres en section transversale ou par leur ouverture longitudinale au cours du sciage ou du Tranchage créent à la surface du placage des

dépressions qui agissent comme des pièges à la lumière et qui entrainent une diminution de la luminance et donc un assombrissement de la couleur (HOFMANN, 1987). Les Vaisseaux, par leur position en zone poreuse initiale dans l'accroissement annuel, provoquent des striations et dessins caractéristiques correspondants aux limites des accroissements annuels (JANIN-MAZET-DECARREAU-HOFMANN, 1988).

- les fibres qui donnent l'orientation du fil du Bois qu'elles soient droites (droit fil), ou sinueuses (fil ondé) appartenant à la zone de bois initial ou finale apportent aux placages une texture caractéristique du dessin de l'espèce.

- les tissus de Parenchymes (tissus de réserves nutritives) disséminés dans le bois, diffus, accompagnant les cellules, et aux parois minces jouent un rôle dans la clarté locale du fait de sa présence autour des vaisseaux, des rayons ligneux et des fibres.

- 5 - CONCLUSION

L'étude sur la qualité de la Couleur du Bois de CHENE de FRANCE montre qu'elle est liée aussi bien à la position géographique des Forêts en France, et des espèces de Chênes (QUERCUS PETRAEA -QUERCUS SESSILIFLORA), à la modification par les agents extérieurs (lumière, U-V), à l'anatomie et au plan ligneux soumis à des variations de structure imposées par les méthodes de sylviculture. La technologie du débit du Chêne en placage influence aussi l'Aspect et la Couleur finale du Bois de CHENE pour l'Industrie du meuble et de la décoration.

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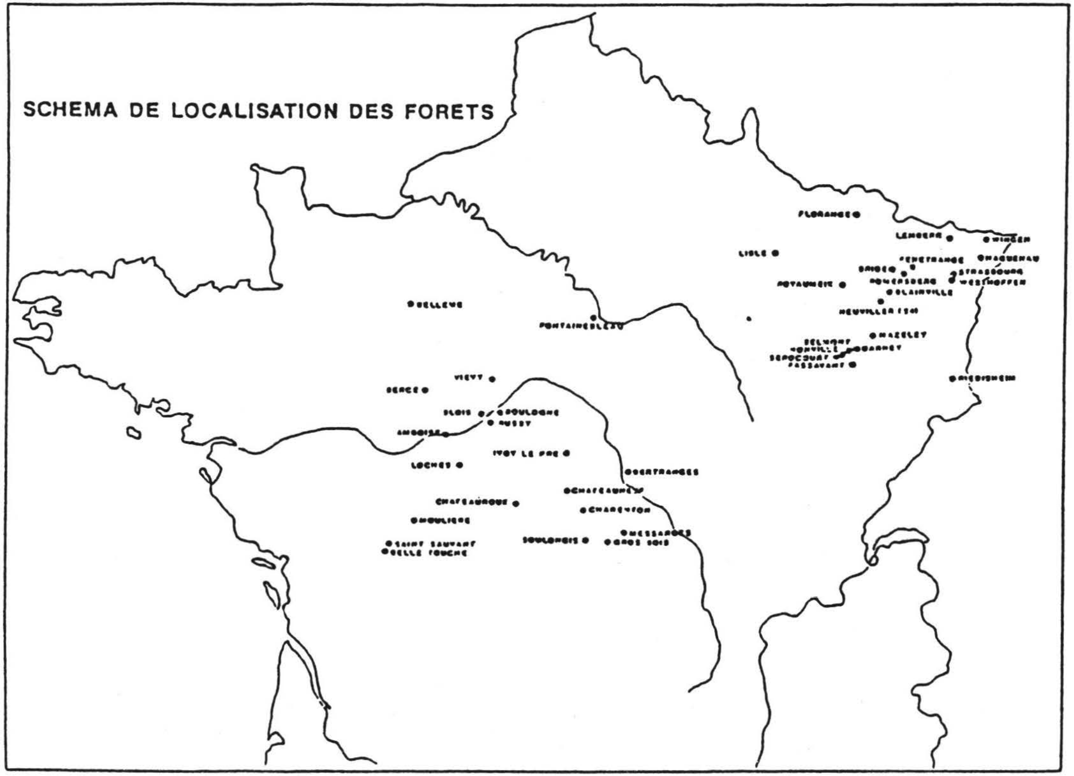
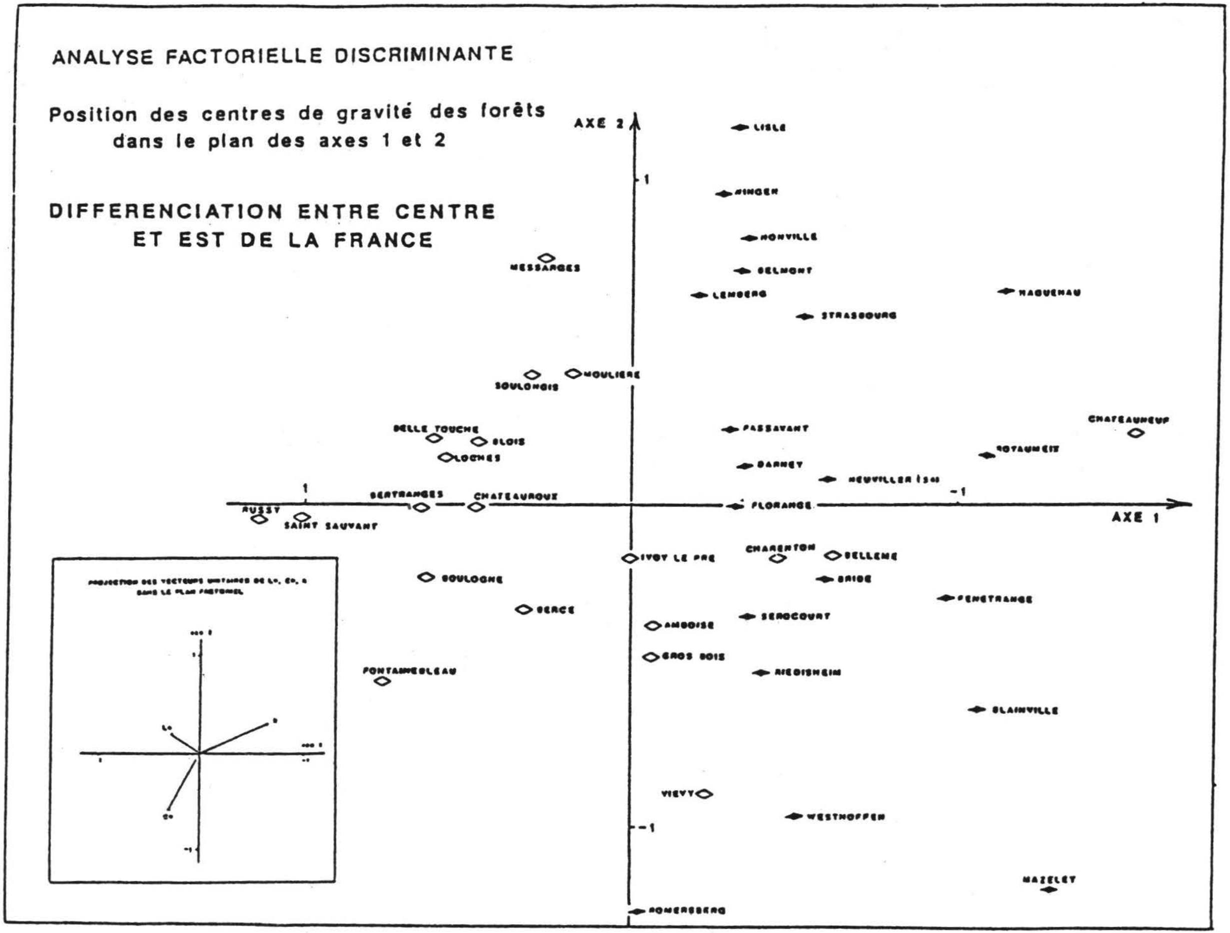
VARIABILITE GEOGRAPHIQUE DE LA COULEUR DU CHENE DE TRANCHAGE EN FRANCE

Figure 1





Jean Luc FLOT, Mémoire de 2ème Année ENITEF, 1988

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AN EASY COLORIMETRIC METHOD TO DETERMINE ANIONIC DYESTUFFS AFFINITIES ON LEATHER:

I]INTRODUCTION: A typical problem of Leather dyes is colour reproductibility, as well as leveling.
Experience shows that if a dye has a very quick build-up, it will have very low penetration; if it is slow, penetration will increase.
After analysing the dye of some dyestuffs with well-known affinities, I arrive to this working method.

II]DYEING METHOD: The substract is Crome tanned Shoeupleather 1.2\1.4, neutralized with Sodium Bicarbonate up to blue cut with Bromcresol Green.
The sample, of 20grs.on shaved weight, must be dyed in an experiment drum of 2000cc. of capacity.
Pour 350% of water at 35 Celsius Degrees, and add 0.5% of the reference dyestuff and 0.5% of the one to compare. The solution must be homogeneous, and the pH of 7.0 +\- 0.2. Take 0.5 cc.of this solution, and pour it in a 25 cc.flask adding: distilled water to complete volume.
Leave the drum roll during exactly 5 minutes, in a thermostatizated dyeing machine, and make another extraction of 0.5 cc.with the same dilution as the first one.
Make a scan betwen wavelenghts 400nm and 700nm, in a spectrophotometer.

III]CHOOSING THE DYESTUFFS: To choose a reference dyestuff I suggest using a low penetrating one, with a zone of valueless absorption in its Absorbence curve (see graph by)

Curves of the Relative Spectral Compositions of Ac.Red 423 and Ac.Yell 194.

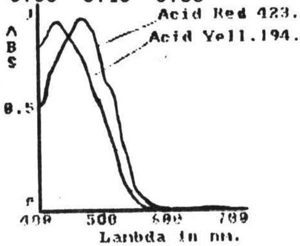
IV]COMPARING THE DYESTUFFS: To make up the comparision betwen dyestuffs, some aditional experiments must be made:

a)Relative Spectral Composition: Is the absorbence with the maximum point of the curve as 1, each 20 nm.
To make up this essay, just prepare an appropiate solution of the dyestuff and make a scan betwen 400 and 700 nm
This is an example for Acid Yellow 194 and Acid blue 349:

Wavelenght-	700	680	660	640	620	600	580	560
Ac.Yell.194.-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0,02
Ac.Blue 349.-	0.07	0.21	0.47	0.75	0.88	0.96	1.00	0.93

Wavelenght-	540	520	500	480	460	440	420	400
Ac.Yell.194.-	0.03	0.09	0.26	0.62	0.94	1.00	0.94	0.84
Ac.Blue 349.-	0.82	0.68	0.58	0.49	0.44	0.39	0.40	0.53

b)Comparision itself:Dyestuff to compare must be of contrasting colours .Preferably the dyestuff to compare must have a maximun in the zone of minimum absorbence of the reference and vice versa.(see the example by)



Comparision betwen Ac.Yell 194,Ac.Blue 349 and a mix of both.

To know the exact proportion of each dyestuff on the graph,we must resort to a system of 4 equations with four unknown quantities.

$$\begin{cases} \text{ABS } 440 = \text{ABS BL } 440 + \text{ABS YE } 440 \\ \text{ABS } 580 = \text{ABS YE } 580 + \text{ABS BL } 580 \\ \text{ABS YE } 580 = \text{ABS YE } 440 * \text{R.S.C. YE } 580 \\ \text{ABS BL } 440 = \text{ABS BL } 580 * \text{R.S.C. BL } 440 \end{cases}$$

Where ABS 440 = Absorbence of Mix.440nm.
ABS YE 580 = Absorbence owing to Yellow in
R.S.C. BL 440 = Portion of the Relative Spectral Composition of the Blue at 440 nm.
and so on.

3)Relative Affinity Coefficient:To calculate this coefficient,these two factors must be figured up:

$$\frac{\text{ABS YE 440 (T=5Min.)}}{\text{ABS YE 440 (T=0Min.)}} = \frac{0.135}{0.303} = 0.446$$

$$\frac{\text{ABS BL 580 (T=5Min.)}}{\text{ABS BL 580 (T=0Min.)}} = \frac{0.257}{0.602} = 0.427$$

Taking Acid Yellow 194 as reference Dyestuff and assigning it the value 1,we arrive at these values for other ones:

ACID YELLOW 194-----------1.00
ACID BLUE 349-------------1.04
ACID RED 423--------------1,00
ACID BROWN MIX------------0.98
ACID BLACK 1--------------0.84
ACID ORANGE 7-------------0,76

These dyestuffs are widely used in Leather Industry,the first four are used in many countries for computer color matching on leather base.
Acid Blue 349 farer of the other three in its coefficient has more reproductibility problems than the others.
About Acid Black 1 and Acid Orange 7 are worldwide used as a mix to obtain a high penetrating black,if we look at the cut of the leather, we can see that the inside part is orange.
This method must be used with a very strict control of temperature and for each kind of leather,and each process.Any change in the tanning,retanning or fatliquoring of leather may bring about changes its affinity.
Otherwise it may be useful in determining the most suitable component for a dye mixture.

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OPTIMUM DENSITY-DIVISION IN COLOR IMAGING SYSTEM

1. Introduction

Color imaging systems using digital processing are successfully used in every-day life due to a rapid progress of modern computer technology. Computer memory in particular has accomplished a large scale of integration (LSI) thus leading to a great decrease in cost. However the computer memory is not cheap enough when applied to two-dimensional color images. Therefore it is of vital importance to most properly allot a limited number of memory to each component color. In this talk, I will describe how to optimize the color imaging system such as color hard copying from the viewpoint of the optimum division of color information.

2. Method of Optimization

Digital color imaging systems use only discrete values. Therefore the problem is then to find an optimum density-division when the optimum allotment of levels is done in an optical density scale. When we employ the optimum density-division, we can expect that color images thus obtained are most satisfactory from the viewpoints of tone and color reproductions. Therefore, if we allot more levels to lower densities deviating from the optimum density-division, for example, the density gaps tend to be greater at higher densities, thus resulting insatisfactory tone and color reproductions for dark colors.

As an objective of optimization, I have selected to use a color difference ΔE between adjacent colors. If I can make ΔE equal for all the adjacent colors, the result will really be satisfactory. However it is likely that the average color difference ΔE for a cyan color series, for instance, may be different from that for magenta or yellow color series under the gray condition. Therefore I have optimized the density-division in such a way that the sum of variances of ΔE for selected color series are minimized simultaneouly.

To increase the validity of the method, I have employed in the optimization seven color series ; cyan C, magenta M, yellow Y, red R, green G, blue B, and black (gray) K. As mentioned above, I have minimized the variance of color differences between adjacent colors for C,M,Y,R,G,B,K in the optimization. Therefore the objective function F of the optimization is written as

$$F=\sum_{i}\sum_{j=1}^{N-1}(\Delta E_i-\Delta E_i^j) \quad , \quad i=C,M,Y,R,G,B,K$$

with $$\Delta E_i=(\sum_{j=1}^{N-1}\Delta E_i^j)/(N-1). \qquad (1)$$

where N is the number of levels produced by the density-division and ΔE_i^j is the color difference between the j-th and (j+1)-th levels for the i-th color. The problem is then to minimize the nonlinear objective function F given by Eq. (1).

I have used in the optimization the three dyes currently employed in actual color photography. For colorimetric computation, I have used the CIE standard illuminant D65, the color matching functions of the CIE 1931 standard colorimetric observer, and CIE 1976 $L^* a^* b^*$ color space.

3. Result of Optimization

As an example, I have selected N=8 (3bits) and D_{max} =2.0. I have started the optimization from an equal-density division. Then I have optimized the objective function F of Equation (1). Figure 1 shows the optimized result : the variation of L^* of the gray(K) series with the number of levels N. The variation of L^* of the equi-density division and the line connecting L^* =100 (white) and L^* =9(maximum density) are also shown. It is remarkable that the optimum density-divison is accomplished by equally dividing the CIE psychometric lightness scale L^* of gray(K) scale.

The color differences ΔE_i for the seven colors are different each other among them. However this is inevitable since the density balance among C,M,Y is prescribed to exactly fulfil the gray condition, and R,G,B are supposed to be obtained by subtracting C from K, M from K, Y from K respectively.

The color reproduction quality of the color imaging system may be generally evaluated by the average color difference $\overline{\Delta E}$ defined by

$$\overline{\Delta E}=\sum_{i=1}^{7}\Delta E_i /7. \qquad (2)$$

Next I have computed the average color difference $\overline{\Delta E}$ for a series values of N and D_{max}, and found the following relation between them

$$(N-1)\overline{\Delta E}=(100-L^*_K), \qquad (3)$$

where L^*_K is L^* for the black obtainable by the combination of maximum densities of the three dyes. Then from Eq.(3), for a color imaging system with D_{max} =1.0 and $\overline{\Delta E}$=1.0, for example, we need

$$N-1=(100-L^*_K)/\overline{\Delta E}$$
$$=62, \qquad (4)$$

and

$$N=63$$
$$\ln_2 N=6. \qquad (5)$$

Therefore we can conclude that 6 bits are necessary to accomplish the average color difference $\overline{\Delta E}$=1.0 for this color imaging system.

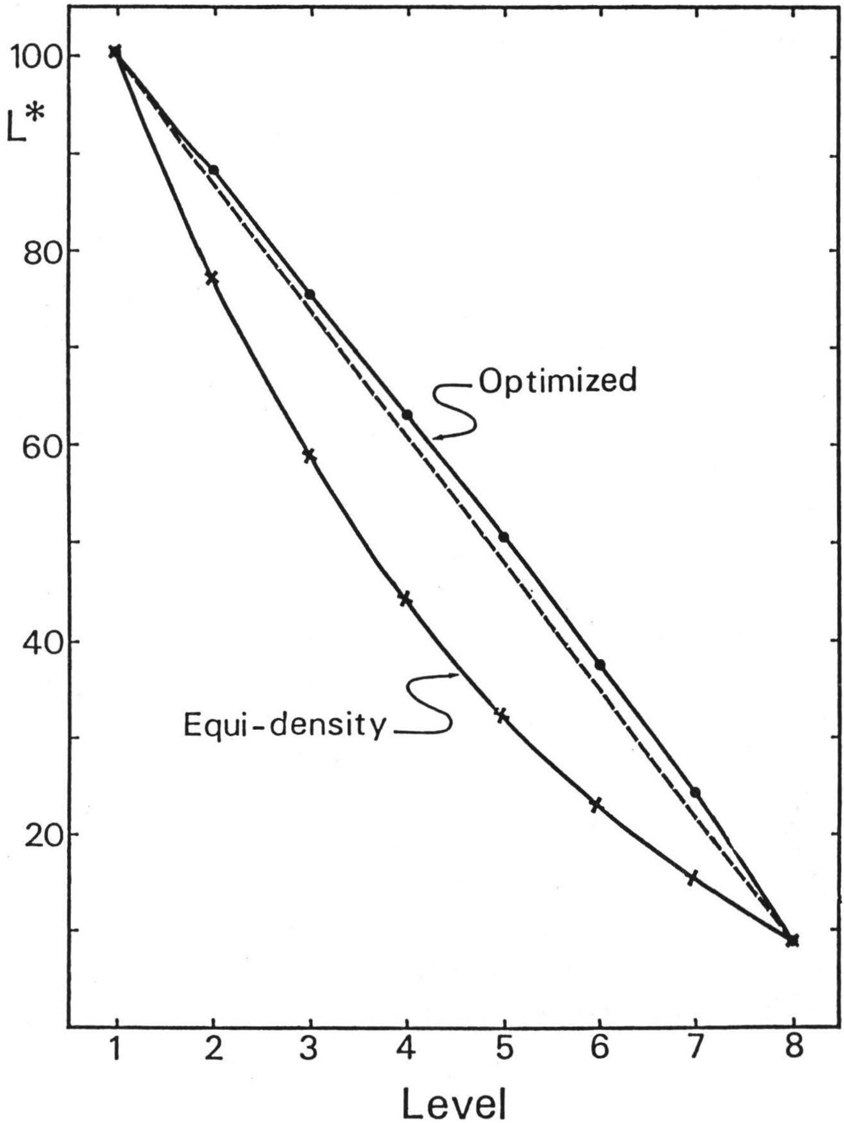

Figure 1 (→)
Variation of L* of gray(K) sereis with number of levels N. Broken line connects L*=100 and L*=9.

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COLORMEASUREMENTS ON FLASHLIGHTS WITH TRISTIMULUS COLORIMETERS

The use of Xenon-flashlamps in several branches of the industry has been increased. Wherever incandescent lamps with switching electronics or rotating lens mirror-systems have been used in former times, Xenon flashes do the job now.
Examples are anti-collision lights on aircrafts, warning lights on emergency and police vehicles, as well as marking lights on life-wests.
In most of the applications, the chromaticity coordinates of these lights are calculated by using the spectrally measured values of the covering materials such as glass or plastic lenses, windows, hoods, etc., and the theoretical spectral power distribution of Xenon.
A special application in using Xenon-flashes is photo-printing.
The values most of the users are interested in are light intensity, chromaticity coordinates and, maybe, correlated color temperature.
A very suitable and handy device to evaluate these data is a tristimulus colorimeter with high-accurate adaption of the detectors to the $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ functions.
Because of the relative short burning time and very fast time response of the measurement system, the use of large area detectors such as they are used for high precise partial or mosaic filtered colorimeter heads, is not possible.

The newly designed full-filtered colorimeter heads with excellent accuracy and time response have been used for the tristimulus flash meter.
The photocurrents of the three channels $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ are

lead to very fast amplifiers and then into 12-bit 10 MHz analog-to-digital-converters.
The managing circuitry including a microprocessor and a 16-bit wide 1Kbyte very fast dual port RAM-memory allows to store all data including time base for a selected time period.
Pre-trigger, external trigger and trigger output allow a wide range of applications.
Further treatment of the stored data inclusive all calculations and graphics are made by a built-in MS-DOS compatible computer system.
Detailed information on all technical data of the new system will be given in the paper.

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A PHOTOELECTRIC INSTRUMENT FOR THE ASSESSMENT OF COLORIMETRIC AND STRUCTURAL DEFECTS IN FABRICS

In the instrument the image of a slit is focussed on the fabric mounted on a rotating disc and either reflected or transmitted radiation analysed. Reflected radiation is collected by an integrating sphere and detected by two phtomultipliers, one sensitive to the green (for colorimetric analysis) and the other to the infrared (structural analysis). A transistor is used for transmitted light. It is possible to obtain a quantitative measure of certain colorimetric and structural defects influencing fabric appearance.

In dem Gerät wird die Abbildung eines beleuchteten Spaltes auf das Gewebematerial fokussiert. Letzeres ist auf einer rotierenden Scheibe montiert und entweder die reflektierte oder die durchgehende Strahlung wird analysiert. Die reflektierte Strahlung wird mit Hilfe einer Ulbrichtschen Kugel erfasst und durch zwei Photomultiplier angezeigt, wovon einer grün - empfindlich (Farbanalyse) und einer infrarot - empfindlich (Strukturanalyse) ist. Ein Phototransistor wird zur Anzeige der durchgehenden Strahlung verwendet. Es ist möglich, eine quantitative Angabe von bestimmten Farb - und Strukturdefekten suerhalten, welche das Aussehen des Gewebematerials beeinflussen.

Dans l'instrument, l'image d'une fente est mise au point sur le tissu. Ce dernier est posé sur un disque tournant. La radiation réfléchie ou transmise est analysée. La radiation réfléchie collectée par une sphère d'Ulbricht est détectée par deux tubes photomultiplicateurs, l'un sensible au vert (pour l'analyse colorimétrique), l'autre à l'infra-rouge (pour l'analyse structurelle). On utilise un transistor pour la lumière transmise. Il est possible d'obtenir une mesure quantitative de certains défauts colorimétriques et structurels qui affectent l'apparence du tissu.

INTRODUCTION

In practice, fabric appearance is normally assessed by viewing it by means of reflected or transmitted light or both, and on this basis it is accepted or rejected. Although acceptable in certain cases, such subjective methods are of low reproducibility and accuracy.

The instrument to be discussed (Kok et al. 1975) was intended to measure barré (stripiness due to diffences in dye depth) and also streakiness and other structural characteristics. It consisted basically of an optical system in which the illuminated image of a slit is focussed on the fabric which is mounted on a rotating disc to allow scanning. Reflected radiation is collected by an integrating sphere having a green sensitive and infrared sensitive photomultiplier as detectors. Transmitted radiation is analyzed by a photo-transistor. The green and infrared detectors are used to obtain a difference signal that is not affected by structural irregularities but only by shade differences when the dye is infrared-insensitive.

Although it is possible to have a narrow slit image focussed sharply enough to resolve single threads, it is sometimes desirable to scan a wider area, say, the width of four threads or more. This can be accomplished by opening the slit or de-focussing.

RESULTS AND DISCUSSION

Measurements were made on locknit nylon fabrics dyed to different depths and also on samples of undyed jersey fabric. Figure 1 shows a green and infrared scan (sharp focus) on a locknit sample, showing barré. The infrared scan shows weave characteristics only while in the green scan dye differences as well as weave characteristics can be seen. When de-focussed the infrared scan (A in Fig.1) showed a practically straight line while the green scan (B) showed a line going up and down. The green- minus-infrared signal showed the same characteristics as that of the green scan, the infrared scan giving a constant signal. By using a counter of which the counting rate was determined by the deviation of the signal from a constant value, it was possible to obtain a measure of the variation in dye depth. In this way, a simple linear relationship between instrument count and visual assessment of barrè was found (seven observers were used).

Streakiness is a more complicated problem. It can be caused by a single type of defect or a combination of parameters (colorimetric as well as structural). If however, an observer is requested to give a quantitative assessment of the overall streakiness, his judgement will be based on the integrated effect of all parameters. An attempt to obtain a quantitative measure of streakiness was based on this reasoning. For streakiness measurements, the differenct signal was /green-constant/ instead of /green-infrared/, the "constant" being an "average" value, yielding an integrated "postive" deviation equal to the integrated "negative" deviation. Six samples of plain-jersey fabric, ranging in shade from undyded to dark and of different degrees of streakiness, were investigated. Measurements were also made of the average relative visible reflectance of each cloth by recording the average value of the photo-multiplier signal during each scan. This was done because it was expected that the visual rating would be influenced by the widely varying relative luminances of the samples under equal illumination. A simple almost linear relationship was found between instrument count and the product of visual rating (7 observers) and relative reflectance.

Other "irregularities" like puckering and differences due to the chemical compositions of different types of fibres were also qualitatively investigated.

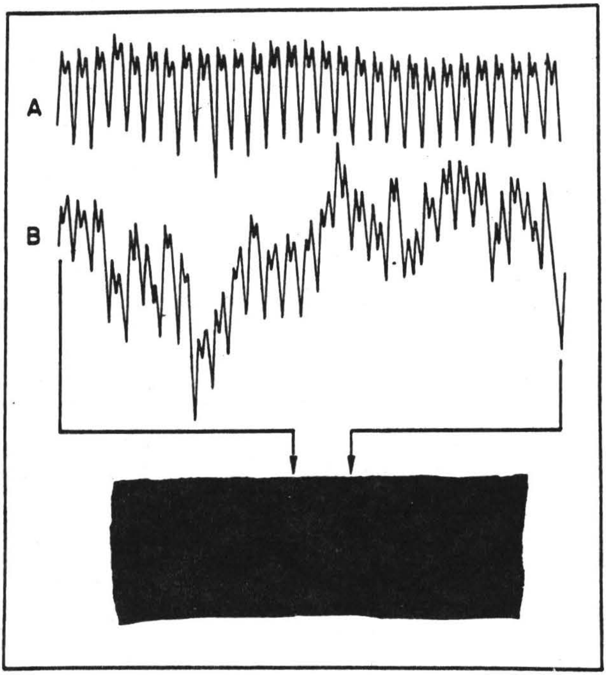

Figure 1.
A: Infrared scan showing weave characteristics only
B: Green scan showing dye differences as well as weave characteristics

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A NEW TRISTIMULUS COLORIMETER FOR MEAUSUREMENTS OF RETROREFLECTIVE MATERIALS

The color measurement on retroreflective material is very difficult because of several circumstances.

To give an idea on them, here are some of the points which have to be covered by the measuring device:

(i) Different geometries to fulfill national or international standards such as ECE, SAE, DIN, etc.

(ii) Illumination with standard illuminant A with high uniformity

(iii) Low intensity of the reflected light

(iv) A wide variety of colors from blue to dark red

but:

(i) excludes normally the use of spectral measurement equipment because of the lack to adapt monochromators to the geometries needed,

(iii) need specially designed detectors and amplifiers to handle low light levels.

The use of photomultipliers is not recommended because ageing and fatigue can cause errors in the spectral and absolute calibration.

(iv) leads to the necessity of very accurate adaption of the $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ functions

The newly developed device uses a high-stable projector for the illumination with standard illuminant A.

Because of a regulating circuit which uses a portion of the luminous flux projected to the test area, the projector shows excellent short- and long-term stability.

To separate the reflected light into the x-y-z-channels, two methods are possible:

(1) Using beam-splitters to split the incoming light into 3 (or 4) beams.

(2) Using a filter wheel which brings one filter after the other in the light path.

Method (2) has been choosen because it brings the full energy of the reflected light to the detector instead of dividing the light in portions as to method (1).

The measurement of x-y-z-signals one after the other is possible because the projector provides a very good long- and short-time stability of the illumination and the tested objects do not change within the measuring period of only some seconds.

Especially designed glass filters are used to achieve best adaption of $x(\lambda)$, $y(\lambda)$, and $z(\lambda)$.

The complete measuring head inclusive filter wheel can be moved to angular positions between 12' and > 2°30' by a servo-motor.

The position is measured by an absolute encoder and displayed on digital readouts.

A complete description of the measurement system inclusive technical data will be given in the paper.

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COMPARISON OF COLORS PRODUCED BY STANDARD FLUORESCENT LAMPS AND BY PRIME-COLOR LAMPS

By now most people are aware of some differences that can be readily seen in the visual color rendering of standard fluorescent lamps and the commonly called "tri-phosphor" or "three component fluorescent lamps. The difference in color rendering can be identified as: some increase in saturation, but more importantly, shifts toward Judd's preferred chromaticities (Ref. 6); increased discrimination allows a greater number of small differences in Hue and Value (lightness) to be recognized, besides the aforementioned saturation and hue shifts. These occur not uniformly throughout the spectrum. For instance, the color of butter, tea, bread and potatoe chips are not shifted, but are, in fact, preferred right as they are usually rendered. Saturation of purple is not increased either. Of interest are pleasing shifts (in hue and saturation) of identifiable objects: Complexion of Caucasians, indigenous Indians and Africans, but also grass, spinach, meat, reproduced "blue sky" color etc. Oddly enough, Prime-Color lamplight shifts these and other object colors to a preferred rendition. In short, we are seeing an enlarged gamut. Fig. 3 and 4 show the changes that may be perceived in the Munsell Color Solid, illuminated by Prime-Color light instead of the Standard Source "C" (North Daylight). Fig. 5 shows this gamut change plotted in the u, v, Chromaticity Diagram (1960).

Less obvious is the resulting Visual Clarity (Ref. 5), a term first coined by Aston and Bellchambers (Ref. 1). It extendes discrimination of contrast between light and dark parts of a scene, including print material etc. and increases texture and form recognition, and spatial comprehension at lower levels of illuminance than that encountered with light from standard fluorescent lamps (Ref. 2). This effect can be recognized easily if adjacent spaces, lighted by standard fluorescent on one side and by Prime-Color lamps on the other, are available for simultaneous inspection and testing. Some successful commercial installations will be described below. As it was proven that a majority of users found that lower levels of illuminance from tri-phosphor lamps produced comfortable working conditions, fewer lamps could be used, resulting in substantial savings in power consumption and airconditioning requirements.

A look at the origin of these lamps may assist in the comprehension of the phenomenon: During the 1960's Dr. William Thornton, then Senior scientist for Westinghouse Lamp Division, studied the possibility of creating a lamp that would concentrate its spectral output in those wavelengths to which the visual system is most sensitive. According to established theory and found correct by physical testing, peaks of visual sensitivity to stimuli of radiation occur near wavelengths of 450, 540 and 610 nm (nanometers). The entire CIE Chromaticity System is based on color mixture functions that peak near these wavelengths (Fig. 1). Individual differences amongst humans humans are overcome by agreeing on a "standard observer (Ref. 4). By 1966 Dr. William Thornton had combined rare earth phosphors that produced a light from fluorescent lamps whose spectral output was concentrated near these wavelengths (Fig. 2). The white light from these lamps resulted in a color appearance that had never been encountered before: Colors in an expanded gamut were shifted toward more pleasing ones, greater saturation and smaller color differences appeared to be recognized. "Visual Clarity" was so much enhanced that a completely blind study, conducted in an office building (Ref. 9) led management to lower the light level and so save large amounts in energy costs. In another office building (Ref. 10) several offices were rewired so that the occupants could switch on either two or four lamps in each fixture. In the areas lamped with Standard Cool White lamps, four lamps per fixture were lighted most of the time; in the areas lamped with Dr. Thornton's Prime Color lamps of equal color temperature, two lamps were lighted most of the time. In the time when the pure Prime Color lamps were made, a major retail chain (Ref. 11) re-lamped most of their stores and achieved energy savings of $10 million and a sharp reduction in the return of merchandise because of color problems, estimated to cost $50 million annually.

Unfortunately, Dr. Thornton's phosphor formulation was changed by Westinghouse and by others to compete in the "lumen market". This degraded the color rendering and good-seeing characteristics of the lamps. This thrust to increase lumen output, following the "Luminous Efficience" curve V_λ (Fig. 1) disregards the new and proven findings explained here. By now many manufacturers make "tri-phosphor" lamps, none as good in coloration or good-seeing capabilities as the original. Current efforts by the inventor may eventually lead to renewed production.

Let me take you back once more to the time when the first Prime-Color lamps came on the market: A major financial institution (Ref. 8) had asked their lighting consultant to study how they could reduce their cost of electricity used in all of their buildings. At that time the consultant heard Dr. Thornton present a paper on his invention. It did not take longer that a personal experience of the visual effect created by the new lamps at the Westinghouse Lab to suggest a trial installation to his client. It resulted in the re-lighting of a 22-story building and a saving of 50% of electricity. Above all, it resulted in better seeing conditions and well pleased employes.

It has always been firmly believed that Color (partially reflected light from objects or scene)(Ref. 3) aids greatly in the sensory process of vision-perception-comprehension. We have now ample proof that enhanced appearance improves the visual process and this, in turn, behavioral response and performance.

* * *

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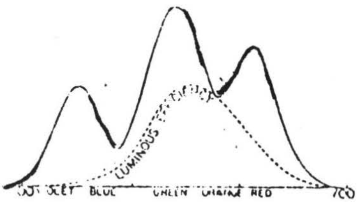

Fig. 1: The Luminous Efficiency Curve (dashed line) is the basis for the definition of Lumen (or Lux) as measurement for the intensity of light emitted, and the foot candle (or candela per sqmeter) for light received on a surface. The solid line represents the human visual response system in three distinct peaks of wavelengths.

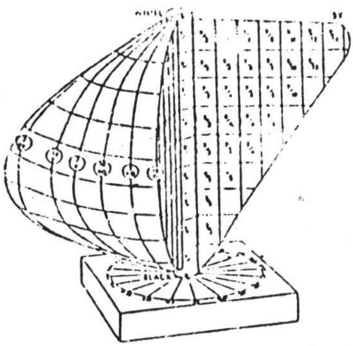

Fig. 3: The Munsell Color Solid with one quarter removed to show section at 5Y. Illuminant "C".

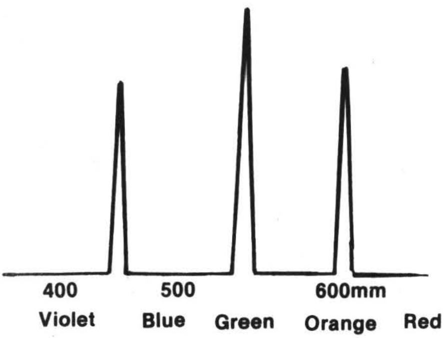

Fig. 2: Schematic radiation output of aprime color lamp.

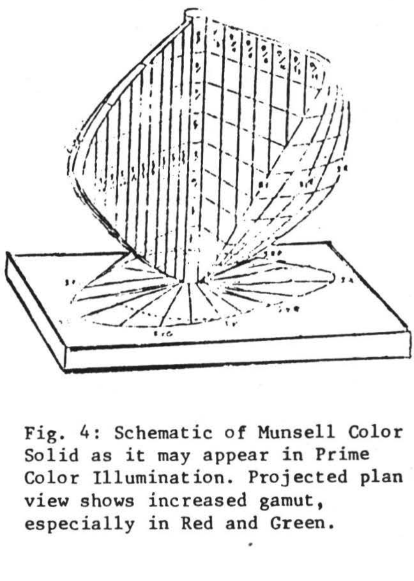

Fig. 4: Schematic of Munsell Color Solid as it may appear in Prime Color Illumination. Projected plan view shows increased gamut, especially in Red and Green.

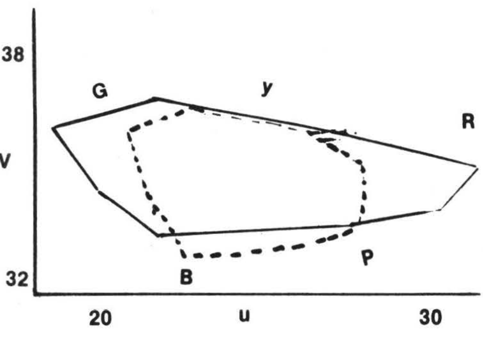

Fig. 5: Comparative Color Gamut in Warm white fluorescent and Prime Color of the same Kelvin rating platted in the 1960 u, v Chromaticity diagramm.

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IMPROVEMENTS IN THE SOURCE CONFORMANCE FACTOR AND ADJUSTMENT METHOD IN FLUORESCENT COLORIMETRY

SOURCE CONFORMANCE FACTOR

It is important in the colorimetry of fluorescent objects to determine the source conformance factor[1] (SCF), which represents the degree of approximation between the CIE standard illuminant D_{65} and an instrument light source. The root-mean-square error[2] (RMSE) for the spectral power distribution or the metamerism index[3] (MI) has been used for this purpose.

In this report, two kinds of fluorescent error indices are adopted as the SCF. They are the ultraviolet range fluorescent error index (Fuv) and the visible range fluorescent error index (Fvis), defined by

$$F_{uv}=\sum_{i=1}^{3}\Delta E_i/3 \quad , \qquad F_{vis}=\sum_{i=4}^{9}\Delta E_i/6 \quad ,$$

where ΔE_i ($i=1\sim9$) are the CIELAB color differences derived from the D_{65} spectral power distribution and the spectral total radiance factors for 9 fluorescent test colors (Fig.1) under D_{65} and the instrument source.

Table 1 shows the correlation factors between F, RMSE and MI for 13 D_{65} simulators, which are illuminant C, 2 actually measured daylights, 3 filtered xenon lamps, 2 filtered incandescent lamps and 5 fluorescent lamps. The correlation factors between F and RMSE are low, so the conventional RMSE values are inappropriate to represent the degree of approximation between the fluorescent colorimetric values under illuminant D_{65} and the values under an instrument source.

ADJUSTMENT METHOD

There exists an adjustment method, proposed by P.Blaise and reexamined by F.W.Billmeyer,Jr. and Y.Chen[4], by which it is possible to predict the spectral total radiance factor (STRF) $\beta_{t,D}(\lambda)$ under illuminant D_{65}, utilizing only an instrument light source $S_M(\lambda)$, differing extremely from illuminant D_{65} $S_D(\lambda)$. The STRF $\beta_{t,D}(\lambda)$ is derived from

$$\beta_{t,D}(\lambda)=\frac{\sum_{i=0}^{n} a_i \tau_i(\lambda)\beta_{t,i}(\lambda)}{\sum_{i=0}^{n} a_i \tau_i(\lambda)}$$

where a_i ($i=0\sim n$) are coefficients, n is the number of filters, $\tau_i(\lambda)$ are the spectral transmittance values for the filters, and $\beta_{t,i}(\lambda)$ represent STRF values measured under sources $\tau_i(\lambda)S_x(\lambda)$. The $\tau_0(\lambda)$ annotation means no filter, namely $\tau_0(\lambda)=1$.

The prediction accuracy of $\beta_{t,D}(\lambda)$ by this adjustment method depends on the kind of filter and coefficients a_i.

Billmeyer and Chen[4] used 7 filters and a xenon lamp with an integrating-sphere and determined a_i which minimizes the RMSE for $S_D(\lambda)$ and $\Sigma a_i \tau_i(\lambda) S_x(\lambda)$ over the excitation wavelength range. Their results were color differences of 2.88 to 4.85 CIELAB units with 3 filters, and 0.66 to 1.88 CIELAB units with 7 filters, as shown in Table 2.

In order to minimize the fluorescent error index, the coefficients a_i can be obtained from the following equation

$$A=(T_x{}^t T_x)^{-1} T_x{}^t T_D$$

where $A=[a_0 \ \cdots \ a_n]^t$,

$T_D=[T_{D0} \ T_{D1} \ \cdots \ T_{D9}]^t$,

$T_{D0}=[X_{D0} \ Y_{D0} \ Z_{D0}]$: tristimulus values (TVs) for S_D,

$T_{Dj}=[X_{Dj} \ Y_{Dj} \ Z_{Dj}]$: TVs for j'th test color under S_D,

$T_x=[T_{x0} \ T_{x1} \ \cdots \ T_{xn}]$, $T_{xi}=[T_{xi0} \ T_{xi1} \ \cdots \ T_{xi9}]^t$,

$T_{xi0}=[X_{xi0} \ Y_{xi0} \ Z_{xi0}]$: TVs for $\tau_i S_x$,

$T_{xij}=[X_{xij} \ Y_{xij} \ Z_{xij}]$: TVs for j'th test color under $\tau_i S_x$,

for $i=0\sim n$ filters and $j=1\sim 9$ fluorescent test colors.

The authors' results were color differences of 0.11 to 0.55 $CIELAB_{10}$ units with 3 filters and an incandescent lamp, at Fuv=0.15 and Fvis=0.17 fluorescent error indices, as shown in Table 2. The present results by minimizing Fuv and Fvis seem to be superior to the results reported by Billmeyer and Chen by minimizing RMSE.

It is concluded that the fluorescent error index concept is effective for the colorimetry of fluorescent objects. A committee in the Color Science Association of Japan drafted a Japanese Industrial Standard "Methods of Measurement for Colour of Fluorescent Objects" in 1987-1988. In this draft, the adjustment method and the authors' fluorescent error indices Fuv and Fvis have been adopted.

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Fig.1 Spectral total radiance factors for 9 fluorescent test colors used for fluorescent error index under illuminant D_{65}

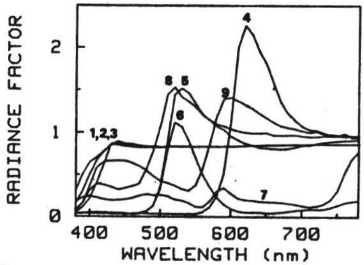

Table 1 Correlation factors between F, RMSE and MI

	RMSE	MIuv	MIvis
Fuv	0.47	0.88	0.22
Fvis	0.29	0.38	0.91

Table 2 CIELAB color differences by the adjustment method

Instrument light source Method for determining a_i	Filter n	Fluorescent samples Green	 Yellow	 Orange	 Red
Unfiltered xenon lamp	no	6.95	13.15	20.76	—
with integrating-sphere	3	3.72	4.85	2.88	—
Minimizing RMSE	7	0.66	1.88	1.22	—
Incandescent lamp	no	16.17	18.54	36.10	31.67
Minimizing Fuv and Fvis	3	0.11	0.11	0.43	0.55

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A SCIENTIFIC MEASURING DEVICE FOR TOOTH COLOUR - AN ACCURATE SHADE DETERMINATION FOR DENTISTS

Accurate shade matching has always been a problem for Dentists seeking perfection in Aesthetic Dentistry.
E. Bruce Clark identified this problem in 1931. Fifty-six years later we still have no real solution. In 1973 Sproull proved the insufficiency of shade guides with his spectrophotometric studies. Today wel still use the same shade guides. Muia (1982) in his Four Dimensional Tooth Colour system constructs a Customized Tooth Colour Guide. Leon (1982) described his "What-Where-Porcelain" formula to improve results and Riley (1986) used his "apples to apples" comparison by actually fabricating a shade guide tooth using organic liquid binders mixed with porcelain powder. Unfortunately no improved results were shown using the methods.
In 1983 O'Brien et al. used a fibre optic probe to directly measure the shade of teeth in terms of the three primary colours. They came to the conclusion that experienced human observers perceived colours more accurately. Jack D. Preston (1985) suggested a unit for measuring tooth colour intra-orally that employs a reflectance spectrophotometer, a microprocessor and a fibre optic linked probe.
The author agreed with J.D. Preston that colour matching is now elevated to the level of a true science and the further progress seems justified. He is convinced that the only solution lies in developing an improved measuring device for tooth colour. This electronic device will not be influenced by individual artistic ability, perception of colour, a good technician or any special lighting or other effects in the Dental Surgery. Dentists will now be able to match shades quickly effectively and with confidence using this simple portable clinical tool.

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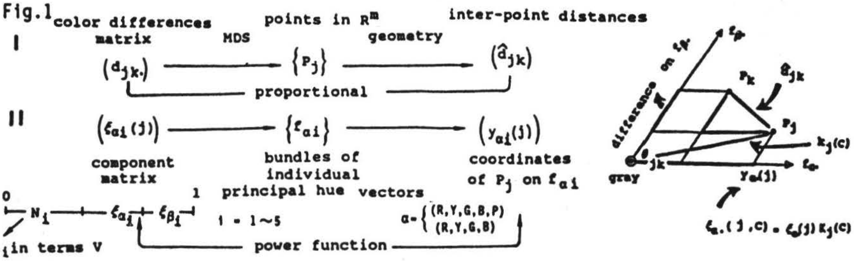
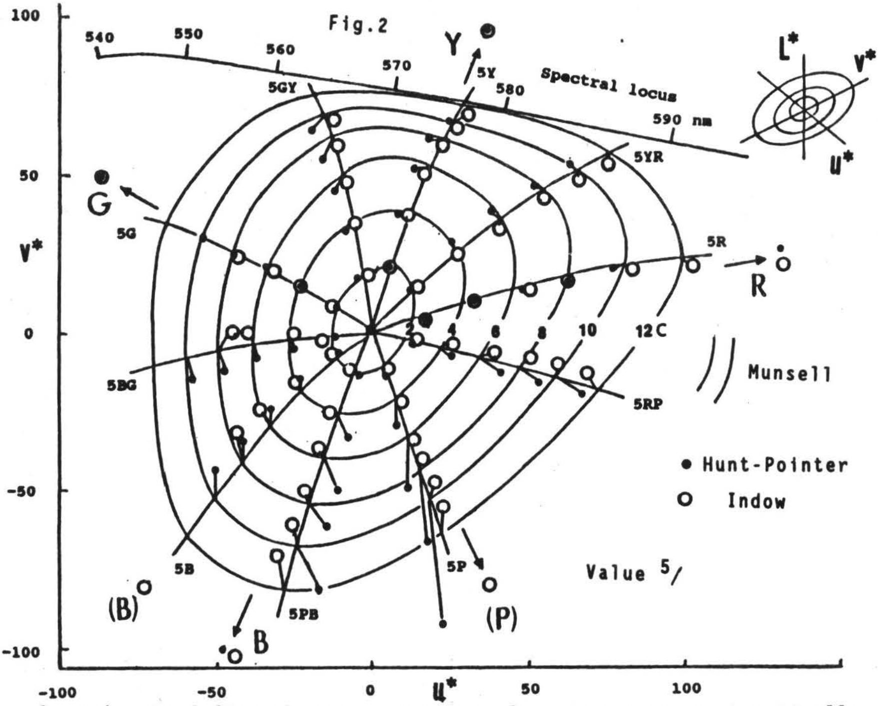
GLOBAL STRUCTURE AND CHROMATIC RESPONSE FUNCTIONS OF MUNSELL COLOR SPACE

Through a series of applications of multidimensional scaling (MDS), it has become clear that Munsell color system can be fairly well embedded in a 3-D Euclidean space. As illustrated in I of Fig.1, the consistency of result of MDS is tested by the proportionality between $d_{jk\cdot}$ (means over observers of assessed differences between colors j and k) and $\hat{d}_{jk}$ (corresponding inter-point distances in the configuration $\{P_j\}$ constructed). As shown in II, one more set of data was used in my recent studies: individual values of $\xi_{\alpha i}(j)$, principal hue components α in a color j assessed by an individual i. The results, $\{P_j\}$ and $\{f_{\alpha i}\}$, bundles of individual hue α vectors, were presented before (1). Main findings relevant to this presentation are as follows.

1. Colors denoted as 5B are not real blue for observers including both Caucasian and Japanese. Other 5H's are in good agreement with respective hue vectors.
2. Individual differences of hue vectors are considerably larger in Y and P (when included) than in R, G, and B. It is understandable. Because there are no cones for Y and P, activities of two channels from the retina have to be combined for these hues and individual differences in the respective channels will be superimposed.
3. Purple P is not indispensable. When it is excluded, however, the B-bundle is shifted slightly toward R and individual differences in R and B become larger.
4. Intervals between adjacent equi-chroma contours tend to shrink at higher levels of C. The tendency becomes less conspicuous when $\{P_j\}$ is embedded in an eliptic space than in a Euclidean space. The difference, however, may not justify introducing an additional parameter, curvature, and complication in directly defining inter-point distances $\hat{d}_{jk}$ from the figure.
5. Unfilled circles in Fig.2 indicate $\{P_j\}$ projected to CIE (u^*, v^*) plane of V5. Munsell color spacing and its prediction from Hunter-Pointer model (2) are given by curves and dots respectively.

Fig.1





In order to define chromatic response functions more systematically than in (1), a new set of $(\xi_{\alpha i}(j))$ were obtained in 1987 with collaboration of Ogawana for larger number of Munsell colors. Herefafter means over 5 observers, $\xi_{\alpha\cdot}(j)$, $N_\cdot(j)$, and $L_\cdot(j)$, and

$$h_\alpha(H\ {}^V/_C) = \frac{\xi_{\alpha\cdot}(H\ {}^V/_C)}{1 - N_\cdot(H\ {}^V/_C)}, \qquad h_\alpha(H) = \underset{V,C}{\text{mean}} \text{ of } h_\alpha(H\ {}^V/_C)$$

are dealt with.

6. $L_\cdot(H\ {}^V/_C)$, the lightness of achromatic portion N, are linear functions of V with the same slope for H and C, intercepts of which change slightly according to H. As a matter of course, $1-N_\cdot(H\ {}^V/_C)$, the size of chromatic portion, increases as a function of C, but its pattern depends heavily upon H and V.

7. Best estimations of $h_\alpha(H)$-curves are given in Fig.3, which may be called chromatic response functions for surface colors. Most intermediate hues such as 5YR consist of the same amount of the two components. The facts stated in 1 and 3 are confirmed again. The peak of h_B is shifted toward P and, when P is not included, h_P splits equally into h_R and h_B.

8. It is an important question to ask whether $h_\alpha(H)$ are functions of H only and all $\xi_\alpha(H\ {}^V/_C)$ are obtainable from these through multiplication by constants which correspond to V and C but are independent of H. This logic is implicit when the curves were originally obtained by Hurvich and Jameson for aperture colors through the cancellation method. As shown by examples given in Fig.4,

Fig.3

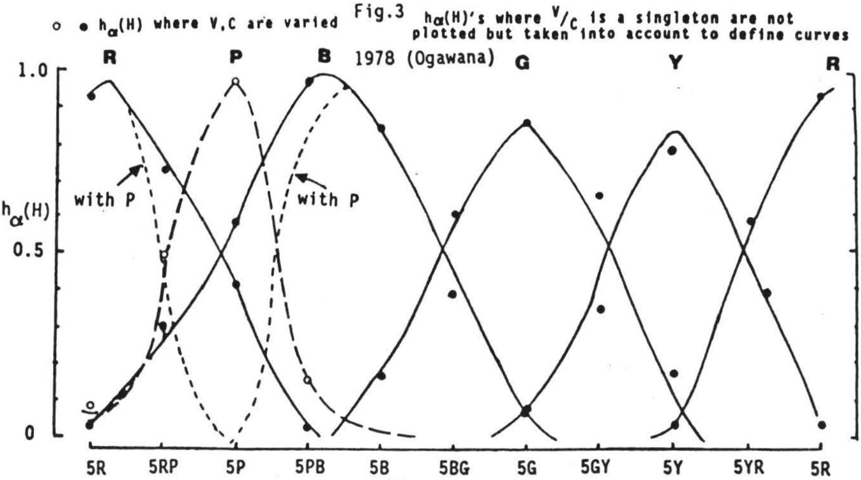
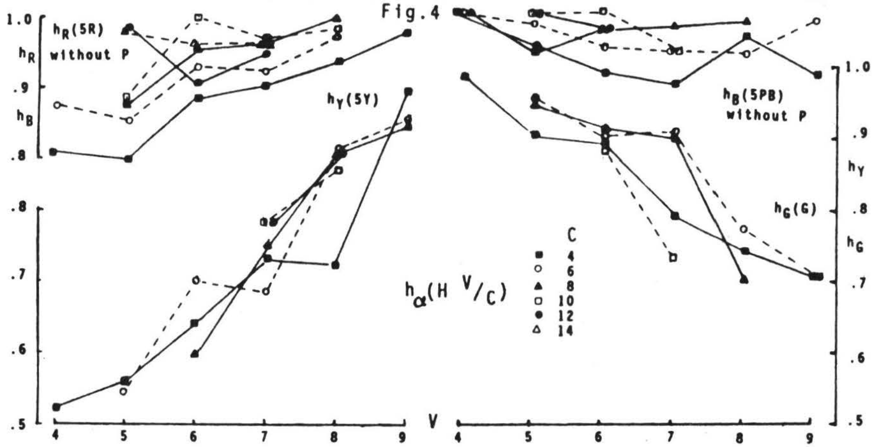


Fig.4



the behavior of $h_\alpha(H\ ^V/_C)$ is very complicated.

9. Following problems will be discussed. a. What is the best way to estimate ξ_α for any given color from the $h_\alpha(H)$-curves. b. Comparison between $h_\alpha(H\ ^V/_C)$ and the corresponding values which are calculated by the use of (x, y, Y) of Munsell colors from the table of chromatic response functions for aperture colors given by Werner & Wooten (3). c. How d_{jk} is related to differences between j and k in the two components involved, α and β. d. Why P_j is located in a given position in the configuration $\{P_j\}$.

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THE DISCOVERIES OF COLOR SPECIFICATION, COLOR BLINDNESS AND OPPONENT THEORY OF COLOR VISION IN ANCIENT CHINESE LITERATURE

INTRODUCTION (as abstract): Due to the difference of written language and character, the achievements of color science in ancient China are rarely known by world science society. As a remedy, this paper describes the discoveries of color specification, color blindness and opponent theory of color vision from extensive trustwarty ancient Chinese classical literature as an evidence to substantiate the history of color science. The actual year of these discoveries all were earlier than the European discovered.

1. FIVE-COLOR (CHROMATIC & ACHROMATIC) SPECIFICATION

In the early of 19th century, Thomas Young had contributed much to the development of trichromatic theory, his red-yellow-blue system was proposed in 1802 initially. After several modifications, Young's original system was amended into the well known red-green-blue system and named by Young-Helmholtz in 1866.[1]

In ancient China, earlier than 7th century BC, a FIVE-COLOR specification consisted of chromatic blue-red-yellow and achromatic white-black was formed and generally recognized. Its chromatic part (blue-red-yellow) was just as same as Young's proposal-1802.

The ancient Chinese FIVE-COLOR specification was based on the philosophical concept — metaphysics and the FIVE-ELEMENT theory, without scientific meaning. Their corresponding symbolizations were:

FIVE-LOCALITY (metaphy.)	FIVE-ELEMENT theory	FIVE-COLOR specification
East	Wood (Tree)	Blue
South	Fire	Red
Centre	Earth	Yellow
West	Metal	White
North	Water	Black

As we know, Greek scholar Empedocles (492-431 BC) had declared that "the colors were a mixture of the four elements and distinguished with reference to the four elements four primary colours: white, black, red, yellowish-green."[2] The Greek four elements — fire, water, earth and air, they were very similar to the Chinese one, though they were independently!

Confucius (孔子, 551-479 BC), a most great scholar in politics, education and thought, as well as the founder of Confucianism in ancient China, had written and edited a lot of famous classic books of Chinese history and social systems since remote antiquity to his own era. The authors choice some representative short paragraphs about FIVE-COLOR and its definition from Confucius's books as:

(1) In Vol.5 (annals 21-16th century BC) of THE HISTORY OF REMOTE ANTIQUITY (尚书, Shangshu)[3]: 以五采彰施于五色，作服. Translation: "Using five colors make five types of clothing to grade the officers' rank." Original annotation: "The specified five colors are blue, red, yellow, white, and black."

(2) In Vol.29 (The Adornmental System of Kingdom, 玉藻 Yuzao) of THE BOOK OF RITES (礼记 Liji)[4]: 衣正色,裳间色. Translation: "Coats with primary colors, trousers with mixed

colors." Original annotation:"Five primary colors are blue, red, yellow, white and black. Five mixed colors are: blue mixed yellow is green, red mixed white is pink, white mixed blue is cyan, black mixed red is purple and yellow mixed black is dark yellow." Taking a circumstantial evidence for primary and mixed colors, that great ancient Chinese strategist Sun Zi (孙子, about 4th century BC) had said:"色不过五,五色之变不可胜观也。Translation:"Colors five only, the varieties from five colors are mass!

(3) In Vol.5 (Annals 711-710 BC) of THE SPRING & AUTUMN ANNALS (春秋 Chungqiu)[5]: 五色比象,昭其物也. Translation:"Displaying the object by FIVE-COLOR specified." Original annotation:"FIVE-COLOR are blue, red, yellow, white and black respectively."

(4) The authors have counted the Chinese characters of color that were used in the total 305 poems of the ancient Chinese first poetry anthology THE BOOK OF SONGS (诗经 Shijing, 1,100-500? BC)[6] which was edited by Confucius. 96 Chinese characters of six colors (and their synonyms) are appeared. Their frequencies are: white 33, yellow 23, blue 15, red 12, green 10, and black 3. It is interestful that the appeared characters were very closely to the general recognized FIVE-COLOR specification at that time.

2. COLOR VISION & COLOR BLINDNESS

On color vision and color blindness, Professor Fletcher R had wonderly written[7]: Plato (429-347 BC) was probably one of the earlier speculators on colour vision...... It is unlikely that colour blindness was recognised by the ancient and mediaeval writers on optics and vision since colour as a specific attribute of vision was not discussed......Even the great optical writers of the seventeenth century, Kepler, Gassendi, Huygens, and Newton made no reference to abnormal colour vision. The first published work on 'Colour Blindness' was probably by Tuberville (1684) involving a young girl from Banbury. This was probably an acquired colour disturbance, vision being confined to black and white.

Faulty color vision obviously is not only as a result of a gene mutation, but also by the acquired pathogenic factors, because a perfect eyesight involving the color vision is a health person's natural capability. Due to the reason of color vision is a psychologic perception and color blindness is a feelingless syndrome, therefore, it may be diagnosed out only by special inspection.

In ancient China, both color vision and color blindness were discovered earlier than in Europe, according to the following evidences:

(1) On the pathology of eyesight and color vision, the classical traditional Chinese medical textbook THE YELLOW EMPEROR'S CANON OF INTERNAL MEDICINE (黄帝内经 Huangdi Neijing, summaried from 722-221 BC)[8]:肝气通于目,肝和则目能辨五色矣。Translation:"The liver supplies energy to the eyes, if the liver energy is running orderly, one could discriminate the five (various) colors."

(2) On the philosophic concept of eyesight & color vision, the ancient Chinese thinker Wang Fu-Zhi (王夫之, 1619-1692) in his book THE INTRODUCTION OF THE HISTORY OF REMOTE ANTIQUITY (尚书引义, Shangshu Yinyi)[9] writing: 由目辨色,色以五显. ——天下固有五色,而辨之者人人不殊. Translation: "Using eyes to discriminate the colors which will be appearing five......Naturally there are five colors, color discriminaters all are seeing same hue."

(3) On the ophthalmology, the ancient Chinese ophthalmologist Wang Ken-Tang (王肯堂, 1549-1613) first time detailly described the syndrome of color blindness whose ancient Chinese term was "see red like white" (视赤如白, jian-chi-ru-bai) in his book STANDARD OF DIAGNOSIS AND TREATMENT OF SIX CATEGORIES OF DISEASES (六科证治准绳 Liuke Zhengzhi Zhensheng, completed in 1602)[10,11] writing:"谓视物非本色也,因物着之病与视瞻有色空中。气色不同,或观太阳若冰轮,或睹灯火反粉色,或视粉墙如红如碧,或看黄纸似蓝似绿等类……。" Translation:"The viewed objective color is not as its original one. Due to individual condition, someone sees sun like an ice-wheel, someone sees flame like white, or someone sees white like red or green, or sees yellow like blue or green."

Summary: From any point of view, the discoveries of color vision and color blindness in China were earlier than in Europe.

3. THE OPPONENT THEORY OF COLOR VISION (AND AFTER-IMAGE)

After a long time disputing about the mechanism of color vision and by the mediation of zone theory, the opponent theory was recognized generally in 1970s.

Opponent theory of color vision was initially proposed by Hering, E. in 1878.[12,13]

In 1773, Chinese scholar Bo Ming (1730?-1789?) completed his book THE ESSAY OF WEST READING-ROOM (博明：西斋偶得, Bo Ming: Xizhai Oude), a section entitled FIVE-COLOR (五色 Wuse) was included, which expressed the phenomena and theories of both opponent and after-image. It is a meaningful sciential writing in extensive ancient literature. Bo's book was published formally in 1800.

In the FIVE-COLOR section, Bo wrote the opponent theory of color vision briefly. This writing and its related part after-image were the only literature of these topics in writing form since ancient China, so that it was valuable to all later scientists in history of science. The first part of this section was:[13,14]

"五色相宣之理,以相反而相成,如白之与黑,朱之与绿,黄之与蓝,乃天地间自然之对。待深则俱深,浅则俱浅,相杂而间色生矣。"

Translation: "The reason of inter-sensing between five colors, is based on the complement of each other and also on the opposition of each other, as well as the by-color will be grown, such as white opposites black, red opposites green, and yellow opposites blue, and vice versa, they are natural pairs in the universe. If viewing dense, both will be dense; if viewing pale, both will be pale; if mixing, mixed color will be formed.

To verify the sound reasoning of his opponent color vision, Bo proposed a consequent psycho-physiologic phenomenon of after-image in the second part of the section:

"今试注目于白,久之目光为白所眩，则转目而成黑晕，注朱则成绿晕，注黄则成蓝晕，错而愈彰,黼黻文章之所由成。"

Translation: "If sighting to white, after a long time the sight will be disturbed by white and reversed into black halo when eye is moved to other place, sighting to red will be reversed into green halo, and yellow into blue, and vice versa. More long sighting, more definited reversible will be.

4. CONCLUSION

Add to the above mentioned discoveries, ancient Chinese scholars also did initially discovering research topics with valuable achievements in color science,[15] such as: light source and sight in 1st century AD; color temperature in 2nd c.AD; color of natural rainbow in 7th c.AD and of antificial rainbow in 13th c.AD; and the dispersion of dew droplet and of sun in 12th c.AD.(the dispersion of sun by Newton was in 1666 AD)

Basically, most of discoveries and investigations in ancient China were in the field of inferring or analogic humanities, therefore, they were the preludes of further experimental or analytic natural science, thus their contribution and influence to the world were not as great as the four-invention (paper, printing technology, compass and gun powder) by ancient China, but they could fulfil the early history of color science.

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(Due to the limited space, no translation to Chinese leterature.)

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BRIGHTNESS PERCEPTION OF CHROMATIC OBJECT COLORS

1. INTRODUCTION

It is well-known that brightness perception is different between two object colors, one is achromatic and the other chromatic, even though they have the same CIE Y value (the Helmholtz-Kohlrausch or the brightness-luminance ratio effect[1]). All the researchers on this phenomenon suspect that the brightness of chromatic color consists of its achromatic-brightness perception related to Y value and a contribution of its chromatic component to the brightness. However, the problem is complicated, because the contribution of chromatic component is different for different hues. The Munsell colors with the same Munsell Value and Chroma, but with different Munsell Hues, do not give the same brightness. In the present study, an interesting hypothesis is proposed by Nayatani to overcome this difficulty. The hypothesis was well confirmed by using two kinds of experimental data. Further, based on these analyses, so called, the contour lines on B/L(brightness/luminance) ratio were derived.

2. HYPOTHESIS

A special feature of the Swedish Natural Color (NCS) System[2] is a decomposition of total color perception of any object color into whiteness, blackness, and chromaticness. Then, its hue perception is determined by the proportion of its two neighboring unique hues existing in the chromaticness. The former three attributes whiteness, blackness, and chromaticness are quantitative perceptions related to intensity. The latter hue attribute does not imply any concept of intensity, but is a qualitative perception. The perceived brightness of a chromatic object color under study is considered an integrated attribute of intensity, which consists of achromatic and chromatic intensity component; such as, NCS whiteness, blackness, and chromaticness. These discussions may derive the hypothesis below.

Hypothesis: When two chromatic object colors with different hues have the same values for each of three attributes whiteness, blackness, and chromaticness, the two colors have the same perceived brightness including chromatic-component contribution irrespective of their hues.

3. EXPERIMENT

(1) Experimental Test of the Hypothesis using NCS Color Atlas. The experiment was done by a method of heterochromatic brightness matching between an achromatic scale and each of all the samples on four constant hue planes with Y10R, R10B, B10G, and G10Y in the NCS Color Atlas[3]. The data were given by the Munsell Values Vn of the corresponding samples on the achromatic scale. The

corresponding achromatic sample with Vn means that it matches in brightness with the NCS sample compared. The experimental conditions used are as follows: Illumination, fluorescent lamps with 6500k and with Ra=95; illuminance 1000 lux; two male observers YU(21years) and HK(22years); a white background of Munsell Value 9/; three repetitions on different days for each observer and for all the samples.

The range of three repetitions by observer YU and HK is shown in Fig.1 to each of NCS blackness (s) 10 and 50 and of NCS chromaticness (Cr) 10 to 80 for the four NCS hues used. The abscissa shows the NCS chromaticness Cr, and the ordinate shows the Munsell Value Vn of the achromatic sample assessed at brightness match. By inspecting Fig.1, it is confirmed that the differences of the observed data between the four hues are not significant, even if they exist, at each s value. Similar results were observed for other s values. We conclude that these results may confirm the effectiveness of the hypothesis.

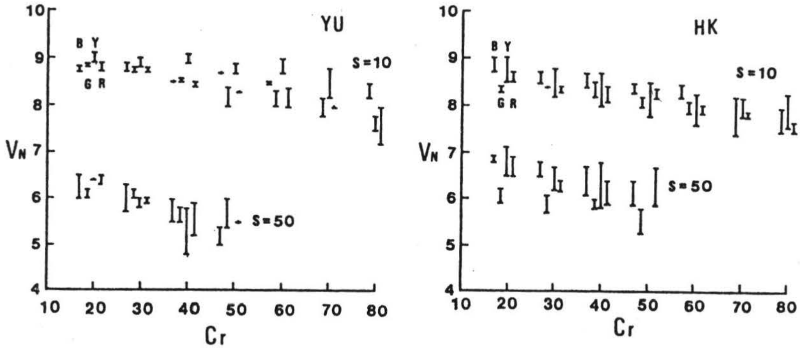

Fig.1 Experimental results on Vn and Cr for four hues, s=10 and 50, and observers YU and HK.

(2) Test of the Hypothesis using Chromatic-Tile Experiment. Wyszecki reported the brightness-matching experiment by using 43 chromatic tiles and 76 observers[4]. The data are summarized by the colorimetric values x, y, Y of each chromatic tile under illuminant C and by the average Yn value of its corresponding achromatic tile[5]. The chromatic tile and the corresponding achromatic one are at match in brightness. By using the nonlinear color appearance model[6] by the present authors, the chroma C and the whiteness-blackness response on chromatic color Qc were derived from the colorimetric values of chromatic tiles. The quantities C and Qc have the concepts similar to NCS Cr and s, respectively, and are independent of hue perception. The values of achromatic whiteness-blackness response Qn are derived from the Yn values of achromatic tiles again by using the model. Based on the values of C , Qc , and Qn , the following predicting equation was estimated with a correlation coefficient 0.904.

$$Qn = 11.02 + 0.2178Qc + 0.1262C$$

Again the effectiveness of the hypothesis is confirmed, because the above prediction equation gives a good estimation irrespective of sample hue.

4. CONTOUR LINES ON B/L RATIO

Based on each of the analyzed results on the two experiments, contour lines on brightness/luminance ratio were derived for various Munsell chromatic colors with Munsell Value 5/. The two kinds of contour lines derived are quite similar in shape and also similar to those already reported[5,7]. Figure 2 shows one of the contour lines based on the first experiment using the NCS color atlas.

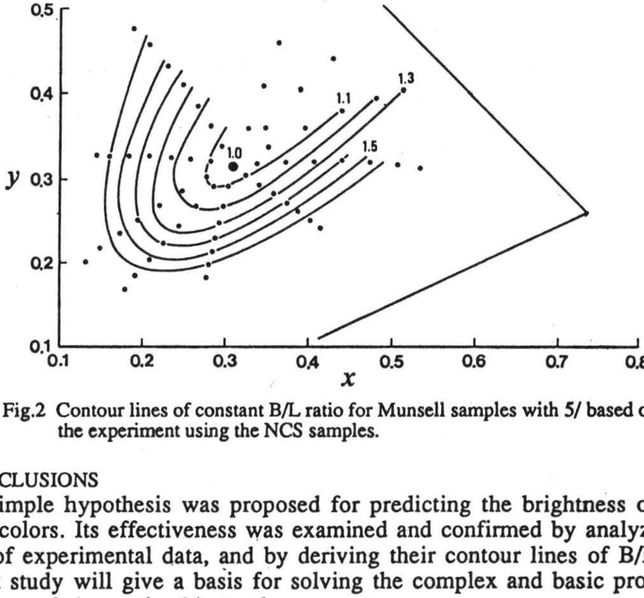

Fig.2 Contour lines of constant B/L ratio for Munsell samples with 5/ based on the experiment using the NCS samples.

5. CONCLUSIONS

A simple hypothesis was proposed for predicting the brightness of chromatic object colors. Its effectiveness was examined and confirmed by analyzing the two kinds of experimental data, and by deriving their contour lines of B/L ratio. The present study will give a basis for solving the complex and basic problem of the brightness of chromatic object colors.

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ON THE TOTAL NUMBER OF DISCRIMINABLE VDU COLOURS

Abstract

In the last few years, colour video display systems with the possibility to simultaneously display 256 out of 4096 "technical colours", i.e. digital R, G, and B values, have come into use.
The most recent colour VDUs are even more advanced as they technically allow about 16 million different digital R, G, B combinations to be used. For interactive colour selection, on most systems such a mass of data is not "user-friendly". Moreover, lots of the different RGB-combinations are not even discriminable. The theoretical limit for the total number of discriminable colours has been estimated to about 7 million by Chapanis (1965).

To estimate the total number of discriminable VDU colours, we have displayed the colours of 4096 digital RGB combinations in two perceptually based colours spaces: the CIELUV and NCS spaces. For a colour computer system that has the facility to display 256 * 256 * 256 different digital levels, we have spectrophotometrically measured the CIE 1931 X,Y,Z tristimulus values for each electronic gun (the red (R), the green (G), and the blue (B)) at each of the 256 digital values. The differences between these digital levels have been evaluated with respect to the CIELUV metric. The colour differences between many of the different digital levels are not discriminable. This implies that the figure 16 million "colours" is a figure empty of meaning in terms of colour appearance.

Introduction

In developing a colour atlas for graphical displays (Derefeldt & Hedin, 1987),we realized that many of the 4096 digital RGB combinations possible to display with our colour VDU would have the same colour coordinates when transformed to perceptually based colour spaces such as the CIELUV (Derefeldt & Hedin, in press) and NCS (Derefeldt, Hedin & Sahlin, 1987) spaces. Thus 4096 digital RGB combinations did not correspond to 4096 different colours. In the last few years, colour video display systems with the possibility to simultaneously display 256 out of 16.7 million digital RGB combinations have come into use. As the theoretical limit for the total number of discriminable colours has been estimated to be about 7 million by Chapanis (1965), the figure 16 million seems very high. In this paper we have tried to find out the real number of discriminable VDU colours for an advanced colour VDU.

The colour video display system

The colour video display system, which is used to display the colour stimuli, is a VAX 11/750 with an image memory Raster Technologies, Inc. Model One/80. With the Raster it is possible to simultaneously display 256 out of 16.7 million R, G, B combinations. The resolution of the image memory is 1280 X 1024. The colour display monitor used is a Sony Trinitron , GDM-1901, (1280x 1024/ 60 HZ non-interlace, 19 inch visual size). Spectrophotometric measurements were made with a Photo Research, PR-713/PC, Extended Range, Spot Spectrascan.

Method and Results

The CIE 1931 X Y Z tristimulus values were measured for each digital level and each electronic gun as shown in Figure 1. The gamut of chromaticities of the colour VDU is shown in Figure 2. The three intersecting lines within the triangle represent change in chromaticity as a function of digital value. The point of intersection represents the lowest digital value. For each gun, the delta E*uv differences (CIE, 1986) between the colour stimuli of each digital value were calculated. In Figure 3, the delta E*uv differences are plotted for the red gun. As shown in Figure 3 for lower digital values the differences are very small. They seem so small that their perceptual relevance may be questioned. In addition to the spectrophotometric measurements a threshold experiment was performed, where the just noticeable differences between the colour stimuli of the different digital values were estimated. For the red gun the results are shown in Figure 4. For most levels a difference of at least two digital values is needed for colour discrimination. The question as to whether this applies to all parts of the colour space will be studied further. However these results clearly indicate that from the point of colour discrimination, 16 million colours are not clearly discriminable on a VDU.

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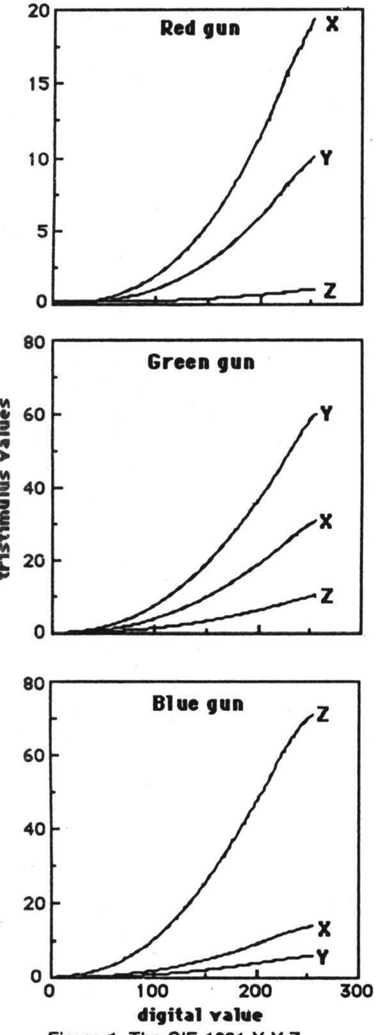

Figure 1. The CIE 1931 X Y Z tristimulus values plotted against digital values for the red gun, the green gun, and the blue gun.

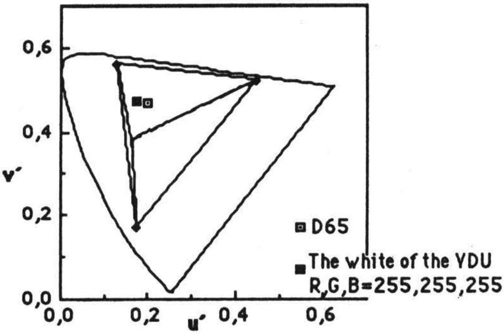

Figure 2. The gamut of chromaticities of the colour CRT on the 1976 u'v' diagram

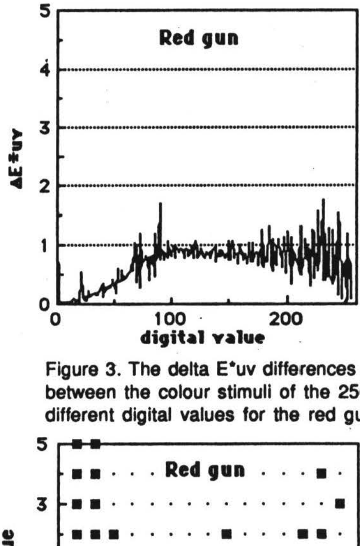

Figure 3. The delta E*uv differences between the colour stimuli of the 256 different digital values for the red gun.

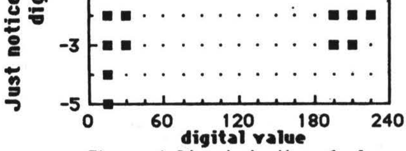

Figure 4. Discrimination of colour stimuli for digital values of the red gun. Failures are indicated by (■)

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VISUAL CLARITY AND AFFECTION OF CONTRAST OF OBJECT COLORS UNDER THE LIGHT SOURCES WITH DIFFERENT COLOR-RENDERING PROPERTIES

1.Introduction

"Brightness sensation", or "visual clarity", of lighting environment is affected significantly by changing the color rendering property of its illumination. This effect has been studied by a number of researchers, e.g. Aston et al.[1], Bellchamber et al.[2], Kanaya et al.[3], and Fuchida et al.[4] However, the cause of this effect has not been thoroughly studied. Based on the careful inspection of the above studies , our experimental results[5] of brightness perception of object colors illuminated by each of high Ra lamps, and a related study by Tsujimoto et al.[6] we now understand "brightness sensation", or "visual clarity", as follows.

(1) Bellchamber suggested that "visual clarity" used by Aston et al. means "clear distinction between the surfaces of various objects" under their illuminants.[7]

(2) The change in "brightness sensation", or "visual clarity", of lighting environment by changing the color-rendering property of its illumination can be judged very easily and instanteneously. However, it takes a little more time for assessing the brightness perception of chromatic color by using an achromatic scale.

(3) Apart from the above stream, Tsujimoto et al. studied an affection of contrast under illumination with each of various Ra values by using a number of two-color combinations, and found that the affection of contrast changed significantly by changing the color-rendering properties of the illumination.

(4) By cosidering the above informations, the present authors now suspect that "brightness sensation", or "visual clarity" is different from "brightness perception" and considered the affection of contrast.

The purpose of the present study is to confirm whether "brightness sensation", or "visual clarity", is closely related to the affection of contrast between colored objects under illumination.

2. Prediction of Affection of Contrast under Illumination with Various Ra Values

The change in affection of contrast caused by changing color-rendering property of the illumination was observed by using a number of two-color, four-color, and eight-color combinations. Finally, it was concluded that the change in affection of contrast could be estimated most effectively by using a four-color combination composed by red(5R4/12), yellow(5Y8/10), green(5.5G5/8) and blue(4.5PB3.2/6). This four-color combination was used for the succeeding observation.

We used two lighting booths set side by side. The standard cool white fluorescent lamp (Ra=63,Tc=4100K) was used for illuminating the left booth (the reference), and each of seven kinds of lamps was set in the right booth. The same four-color combination was set in each of the two booths. By using the haploscopic matching technique, the illuminance of the test booth was adjusted untill the equality of affection of contrast was established between both the booths. The reference illuminance was kept at 1000lx throughout this experiment. The observed illuminance (Ea) for equal affection of contrast under each lamp is determined.

Then, the illuminance value for equal affection of contrast in the above experiment was predicted by using a gumut area (G) made by the component colors of the four-color combination under each of the seven test lamps. It was already studied by the present authors that the affection of contrast can be estimated by using the measures similar to the gamut area.[8] The gamut area was derived by the following procedures.

(1) Under each of the reference and the test illumination, the component colors of the four-color combination were specified in a three-dimensional space consisting of brightness and colorfulness (red-green and yellow-blue) on the nonlinear appearance model.[9]

(2) By considering the subjective importance of the red color 5R4/12 in the assessment on the affection of contrast, the gamut area in the space was determined by the area sum of the following two triangles ; one is consisting of 5R4/12, 5Y8/10, 5.5G5/8, and the other of 5R4/12, 4.5PB3.2/6, 5.5G5/8.

(3) By changing the test illuminance and the corresponding gamut area, the test illuminance for equal affection of contrast is determined for equality of the gamut area between the reference and the test lamp.

In Fig.1, the predicted illuminance (Ep) is compared with that observed (Ea) for each of the 7 test lamps. It is found that a good correlation exists between the predicted and the observed illuminance values. This may suggest that the "brightness sensation", or "visual clarity", of illumination is closely related to the affection of contrast on object colors under the illumination.

3. Visual Clarity and Affection of Contrast

The illuminance (Eb) of equal "brightness sensation", or "visual clarity", was summarized for each of twenty kinds of lamps used by various researchers.[1)-4)] These illuminance values were compared with those predicted (Ep) by using the gamut area for equal affection of contrast to the corresponding lamps considered. Figure 2 shows the results. By inspectiong Fig.2, it is also found that the illuminance for equal "brightness sensation", or "visual clarity", well correlates to that for equal affection of contrast.

In conclusion, the change in "brightness sensation", or "visual clarity", of lighting environment is caused by an affection of contrast between object colors under the illumination, and estimated effectively by assessing the affection using the four-color combination specially selected.

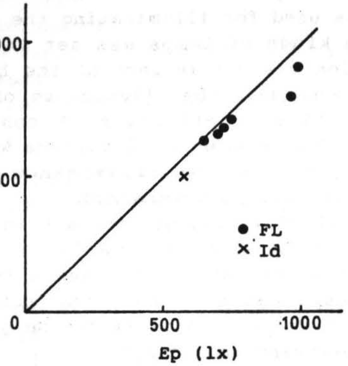

Fig.1 Relation between predicted (Ep) and observed (Ea) illuminace for equal affection of contrast

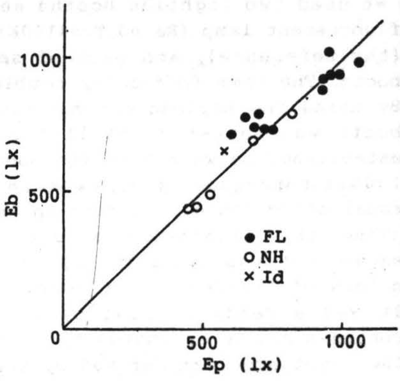

Fig.2 Relation between predicted illuminance (Ep) for equal affection contrast and the illuminance of equal "brightness sensation", or "visual clarity"

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The Spectral Luminous Efficiency of Small Light Sources

Introduction

The spectral luminous efficiency of the human eye V(λ) is the base of the whole photometry and therefor standardized by the CIE. It is known, that luminous eficiency depends on several parameters. The V(λ) curve of the CIE is based on photopic vision at a field size of 2° and foveal perception. With this research the influence of field size (≤ 2°), luminance and angle of perception (between fixation axis and testfield) was investigated with a group of testpersons.

Investigation

The measurement of the luminous efficiency was done by heterochromatic flicker photometry with brightness matching of a monochromatic light and a white reference light. The main components of the experimental setup were the flickerphotometer, a monochromator with interference filters and a photodetector.

The following parameters could be adjusted:

size of testfield:	11' to 2°
angle of perception:	0° to 45°
luminance of testfield:	up to 850 cd/m²
luminance of surrounding:	up to 350 cd/m²

At any parameter combination and wavelength the testperson had to adjust the flicker minimum. The optimum flickerfrequency was chosen by the testperson. Because of the Troxler's effect at extrafoveal perception the luminance of the testfield was periodically set to zero.

Conclusions

The results show that the spectral luminance efficiency changes for decresing field sizes down to 11' espacially at wavelengths shorter than 520 nm. The luminous efficiency also differs more and more with increasing angle of perception from the V(λ) curve of the CIE.

Visualizing Color Transformations

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Recently interest has focussed on the problems of transferring image data prepared for one medium into data suitable for another medium. An important example of this general problem is transferring data representing monitor images to data representing a print of the same image in a manner that preserves appearance. Analysis of the effects of any proposed color transformation is difficult. The problem is exacerbated by the difficulty of visualizing the effect that a color transformation will have upon a color gamut. Previous attempts to visualize the gamut have used two dimensional projections which are always unsatisfactory. One fairly successful approach is to build a physical solid model. However it is difficult to determine where the outer limits of solid models do not coincide.

This paper and demonstration illustrates that computer generated animations of solid models is an effective tool for comparing color gamuts or observing important effects of transformations. Using this technique for example, a solid model of a monitor color gamut represented in an appropriate color space, for example L^*,a^*,b^*, can be presented from a variety of strategic viewpoints, or *flown around* in the same manner as one might use a flight simulator to fly over a computer generated landscape. By locating two gamuts on the same set of axes, and rendering the surface of each in a transparent, stained-glass-like material, important interpenetrations can be spotted easily.

Animation need not be confined to simulated orbits of the solid models. The parameters of interesting color transformations can be changed smoothly to produce animations that reveal the focus, sensitivity or stability characteristics of a color transformation or even reveal software bugs! This technique often identifies problems that other representations miss, and the hardware and software that support this technique are becoming more widely available and moreover, relatively inexpensive.

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INFLUENCE OF COLOR -BACKGROUND IN THE DETERMINATION OF THE VISUAL REACTION TIME WITH DISPLAY-MONITORS.

It is generally recognized that the establishment of color vision models is one of the main areas of interest in Color-Science. The existence of chromatic and achromatic channels has extensively been accepted (1-3). To obtain information of the color-vision-mechanisms, experimental techniques, such as hue-substitution or flicker photometry in measuring visual reaction time (VRT) and visual latency (VL), have been usually employed, (4-10).

In this communication, the influence of the chromaticity of adapting-color-background on VRT have been evaluated at experimental situations near those of actual practical utility by using color-monitor-displays. The VRT to stimuli placed at different retinal zones (0.6 to 18° excentricity) for five color-adapting backbrounds have been measured. This experimental conditions set allows us to compare our results with those obtained by others authors (5,6,9) in order to evaluated the reliability of our experimental method and to extract charactistics of color-vision-mechanisms.

The experimental device consists essentially of an IBM PC-XT STD computer with a color RGB (mod 5153) monitor, that works as a tachistoscope by implementating an adequate program. This program allowed to control the temporal and spatial generation of the stimuli, also the direct measurement and evaluation of VRT. This parameter was measured by the computer-internal-clock (Timer 8253) with a preciseness of 840 ns. The computer also controlled the developement of each experimental sessions, that were never longer that 20 min. After a previous 4 min period to dark-adaptation the observer was subjected to another 4 min period of adaptation to the chromaticity of the backgraound, afterwhich the measurements started. These consisted in the exposure to the observer of succesive dark stimuli (off-stimuli) after each he had to pulse a key in the computer keyboard, when he perceived it. The stimuli substended a visual field of 40' and were placed at different retinal zones (0.6 to 18° excentricity). Their sequence of presentations was always at random, also the time between the presentations of two consecutive stimuli (2 to 4 min). A red-fixation central point (40'x20') appeared during the whole experimental session. For a same stimulus (retinal zone and chromaticity background) a total of 100 measurements were performed.

Figure 1 shows the background chromaticities in the 1931-CIE color-driagram. The luminance level remained constant for all the backgrounds at 14 cd/m^2.

Figure 2 shows the experimental results for observer PMC being the same in all essentials for all observers. It has been represented the VRT at different excentricities versus the dominant-wavelength of the adapting backgrounds studied. As it can be observed a general increase of the VRT for excentricities out of the foveal zone appears and it is reasonable to be proved by the photorreceptors distribution in the retina. This fact agrees with other author's data (11-12) which confirms the reliability of our method. On the other hand, no-significative dependences of the VRT with the dominant-wavelength of the backgrounds have been found. This can be explained based on King-Smith and Carden's results that show how the achromatic channel of color-vision-mechanisms appears faster in the stimulus-detection than the chromatic ones, although their experiments were performed with chromatic stimuli and dark-backgrounds, thus the inverse situation. In the same way our results would agree with those of Ueno et al and Bowen using a "hue-substitution" technique when they worked with near to dark-backgrounds.

Thus, we may reasonably conclude that our experiments put forward the existence of a predonimant achromatic channel involved in brief color stimuli detection under the experimental situation studied by us (off-stimulus and chromatic backgrounds) and using a versatil color-monitor display method.

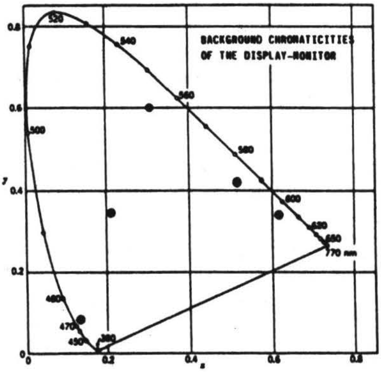

FIGURE 1

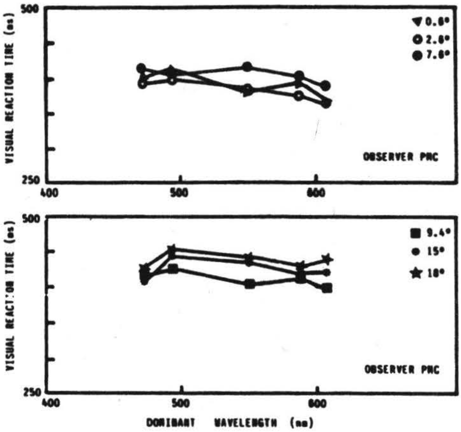

FIGURE 2

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IMAGE IDENTITY AS SEEN IN TWO- AND THREE-COLOR COMBINATIONS - Verification Using Image Simulation -

1. Aim

The aim of this study has been to clarify the psychological background underlying two- and three-color combinations in terms of image theory and look into methods of using colors for specific purposes. In continuation of studies presented at the 1977, 1981, and 1985 meetings of the AIC, we intend on this occasion to investigate the equivalence of two- and three-color combinations in image space.

2. Method

(1) Samples

i) Color systems used: A total of 130 colors, including 120 ten-hue and twelve-tone chromatic colors and ten achromatic colors. These colors were input as data into a personal computer.

ii) Three color combination database: 10 three-color combination samples were created for each of 180 image terms*. The resulting 1,800 color combinations were classified and distributed in the image space along the image axes warm/cool (W/C), soft/hard (S/H), and clear/greyish (K/G). These classifications were input into a personal computer and used as a database.

iii) Two color combination samples: 8,385 samples were obtained by combining each of 130 single colors with each of the remaining colors [(130 x 129)/2]. The resulting color combinations were classified in terms of their images over seven categories ranging from clear (K) to greyish (G), and the results were input into a personal computer.

iv) The color image terms of 130 single colors were also input.

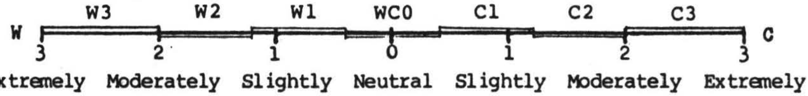
(2) Research Method

i) Basic research into the above-mentioned topic has been published in a paper entitled "The Aim and Method of Color Image Scale" in the journal "Color - Research and Application", Vol. 6, No. 2, summer 1981. Reference should be made to this article.

ii) Development of methods of classifying image color combinations: Although a method exists for systematically classifying large numbers of single colors, there is no method available for classifying differences in color combinations in physical or physiological terms. We therefore attempted to classify the virtually infinite number of color combinations that exist (the population of color combinations) by applying a method based on cognitive science that involves classification according to the image associated with the combination. We first conducted a pattern classification with combinations of three colors employing a color image scale method based on three image axes: warm/cool (W/C), soft/hard (S/H), and clear/greyish (K/G).

iii) Development of a color combination method employing personal computer: After creating software to generate the 8,385 two color combinations and displaying the combinations on the monitor screen, we attempted to classify the combinations according to image pattern for each of the image boxes mentioned below using a color printer.

iv) From image boxes to a color combination database: We created seven categories, W3, W2, W1, WC0, C1, C2, and C3, on the warm/cool axis. The scale values were 1.0 for categories W3 and C3 and 0.8 for all the other categories. By dividing the soft/hard and clear/greyish axes using the same scale, we obtained 343 (7 x 7 x 7) image boxes.



1,800 three-color combinations were accumulated inside these image boxes, thus allowing reference according to image.

v) Creation of a database for two color combinations (8,385 samples): In brief, this involved the following operations:
- Determining the image coordinates for two color combinations;
- Distributing two color combinations among the individual image boxes;
- Pattern classification of the images of two color combinations using 180 image terms.

vi) Investigating the identity of two- and three-color combinations in specific image boxes using 180 image terms.

3. Results

(1) Panel display of image spaces divided into seven categories from K3 to G3: 130 single colors, 8,385 two color combinations, 1,800 three-color combinations, and 180 image terms were displayed separately on an equivalent basis. Representative samples of the two- and three-color combinations were arranged in patterns on the panels on the basis of image, and the image terms were distributed according to the 16 image categories.

(2) The following conclusions were reached through comparison of the panels:

i) For categories K3 and K2, the tendancy toward warm/soft (W/S) is more pronounced in two-color combinations than in single colors, and more pronounced in three-color combinations than in two-color combinations. Patterns such as these are also evident in other panels. This means that three-color combinations can evoke images which cannot be produced by single colors and two-color combinations.

ii) Separation and gradation effects are hard to obtain with two color combinations. Three color combinations thus make it possible to express image concepts inexpressible with two color combinations, such as clarity and delicacy. However, there is a fairly strong degree of equivalence between two- and three-color combination patterns.

iii) The contrast of hues in the case of two color combinations is strong, and so similarities between two- and three-color combinations in the central part of the image space (WCO, SHO, KGO and the vicinity) do not readily appear.

iv) Order and balance are easily obtained with three-color combinations, and the 180 images can be produced with no difficulty. A sense of psychological balance is thus easy to obtain.

*The table of 180 image terms is included in the study entitled "Japanese Color Preferences".