AIC 1994 INTERIM MEETING

IMAGES IN COLOUR

Abstracts

SUNDAY 10th APRIL

RECENT ADVANCES IN COLORIMETRY-BASED DIGITAL IMAGING

R S Berns

Professor Richard Hunter
Munsell Color Science Laboratory, Rochester Institute of Technology,
Rochester,New York, U.S.A.

Digital image processing has become the enabler of the concepts described by Neugebauer, Hardy, MacAdam and others whereby colorimetry would be an integral part of the design of colour reproduction systems. Traditionally, imaging systems have been closed loop due to their analogue nature and as a consequence, the inherent limitations of the output (or input) often determined the properties of the input (or output). Although colorimetry has been used as a tool to quantify quality, it could not be integrated into the imaging system because of this interdependence. By placing an image processor between the analysis (image input) and the synthesis (image output) stages, each stage can be independently designed or optimized forming an open system with colorimetry at the hub. These open systems have the potential for improved colour quality in comparison with their traditional closed-loop equivalents. This presentation will review research in device colorimetric characterization and design, colour appearance modelling, and gamut mapping, all necessary components of colorimetry-based digital imaging. These components can then be implemented within digital colour management systems such as Adobe Postscript Level II or Apple ColorSync.

MONDAY 11TH APRIL

ON THE DEFINITION OF 'QUALITY' OF COLOUR IMAGES

Lucia R Ronchi
INO, Florence, Italy

We must thank R W G Hunt for the most complete definition of the 'quality' of reproduced colour images. The 'quantitative' assessment of 'quality', in a multi-dimensional space, where physical parameters and their perceptual correlates are interrelated, is basically referred to normal viewing conditions, which, in a first approximation, may be classified as 'steady'. The perceptual constancy, in turn, may be called into play in a steady-state paradigm. In the present paper, an attempt is made to extend the definition of 'quality' to transient state conditions, by considering both the sensory (photic) response and the (sluggish!) adaptive response, and their mutual interaction.

Experimentally, patterns consisting of sets of patches of different grey levels of different colours (and different amounts of 'differences') are observed under sinusoidally modulated light of variable frequency and modulation depth. A definition of perceptual constancy, as related to the concept of equivalence, is proposed as the outcome of the interplay of induction effects and phase differences.

A NAME-BASED ALGORITHM FOR GENERATING MAXIMALLY DISCRIMINABLE COLOUR SETS

Darren Van Laar and Richard Flavell*
Department of Psychology, University of Portsmouth, Portsmouth
***The Management School, Imperial College, London**

To create a set of maximally discriminable colours on a computer display it is necessary to make the distance ΔE* between all pairs as large as possible whilst ensuring that all the colours lie within the monitor gamut. This may be turned into a structured problem by trying to maximise the distance between pairs of colours that are minimally separated. An algorithm is presented that will take a set of 'named' colours and then optimise them for maximum discriminability. Other workers have formulated a simplified version of this problem, although a globally optimal solution cannot be guaranteed because the constraint is non-convex.

Our algorithm is based on the idea that the naming constraints, whilst in reality unquantifiable, essentially restrict the colour to a small area of Luv space. Thus, if we can initially locate a colour within Luv space, constraints can be constructed to limit the subsequent movement of the colour to a small cuboid centred on this original point. Furthermore, because subsequent movement is small, little error is introduced by locally linearising the problem. This overcomes one of the problems suffered by other workers, namely that the constraint set of non-convex.

UNIFORM COLOUR SPACE FOR COLOUR DISPLAYS

Claudio Oleari
Department of Physics, University of Parma, Italy

Recently, a uniform-scale chromaticity diagram for the 2 degree visual field in agreement with the MacAdam ellipses, and a uniform-scale chromaticity colour space for the 10 degree visual field in agreement with the OSA samples, have been defined.

The new spaces are realized by using an angular hypothesis about two angular variables whose centres are the deuteranopic and the tritanopic confusion points respectively. In this work, we have considered the part of the colour space that can be reproduced by RGB displays. Particularly, in this sub-space, three coordinates with almost uniform scales are defined.

The chromaticity coordinates are obtained by the angular hypothesis and by two proper logarithmic transformations whose arguments are linear functions of the ratios G/R and G/B respectively, where R,G,B are the primary colours obtained from the phosphors. The chromaticity scales of this space are, to a good approximation uniform, and the agreement with the MacAdam ellipses is verified. The third dimension, the lightness, can be related to the luminance by a logarithmic function following the Weber-Fechner law.

All the new coordinates are logarithmic functions of R,G,B, are orthogonal and can be especially useful for colour displays.

DSP ALGORITHMS FOR COLOURING BLACK AND WHITE STILL IMAGES

Hussian Al-Ahmad
DSP Research Group, Electronic Imaging Unit, University of Bradford, Bradford

This paper deals with new digital signal processing (DSP) algorithms in the frequency domain for artificially colouring black and white still images. The aim of the work is to get an acceptable coloured version by associating colours with the spatial frequencies of the image.

The paper consists of three sections: the first deals with a comparison between black and white images and coloured images. The study is done on images where both black and white and coloured versions are available. The frequency spectra of a black and white image and its coloured version are compared to approximate the required transform functions to generate the three red, green and blue files.

The second section discusses the colouring algorithm. Black and white photographs can be digitised by using a scanner and stored as a computer file. The two dimensional discrete cosine transform is used to transform the image from the spatial to the frequency domain. The resultant two dimensional frequency domain file is real and can be multiplied by three filtering functions to generate three output files. Then inverse discrete cosine transformation is applied to get three files in the spatial domain. These files will be scaled and combined to obtain the output RGB, coloured file.

Finally, the frequency domain colouring algorithm is applied to several old black and white photographs obtained from the National Museum for Photography, Film and Television and acceptable coloured versions are generated. Examples will be presented at the Symposium.

EVALUATION OF A COLOUR REPRODUCTION INDEX OF IMAGES ON A SOFT DISPLAY

R E Jacobson, G G Attridge, P Parmar, and M R Pointer*
Imaging Technology Research Group, University of Westminster, London,
***Research Division, Kodak Limited, Harrow**

A colour reproduction index (CRI), derived using the Hunt colour appearance model, is applied to a series of 5 representative scenes reproduced on a soft display. Each image is perturbed by known amounts in the cyan-red, magenta-green and yellow-blue directions to provide 30 colour shifts. The applied colour shifts are calibrated using the CIE 1976 ($L^*a^*b^*$) or CIELAB colour difference formula in ΔE^*_{ab} units, obtained from on-screen colorimetry.

Correlations between the CRI and scaling, from a 5-point category scale, employing 10 observers, indicate the validity of the CRI for images reproduced on an electronic display. Correlations between the subsidiary indices for hue, colourfulness and lightness, together with their statistical evaluation, with the mean category, give an indication of the weighting factors for the overall CRI.

IMPROVING ESTIMATES OF GAMMA WHEN CALIBRATING VISUAL DISPLAYS

Darren Van Laar and Richard Flavell*
Department of Psychology, University of Portsmouth, Portsmouth
***The Management School, Imperial College, London**

There are two ways in practice that luminance and voltage data may be used to calibrate a colour monitor. The first and most accurate is to use the information as a form of look-up table held within the computer, which is consulted before a colour is displayed on the screen, and used as a basis for interpolation if necessary. Linear interpolation, however, does not recognise the inherent curvature of the relationship, and exponential interpolation may be better. The second way is to estimate the best-fit gamma function between luminance and voltage using regression. Unfortunately, whilst the fit for the data appears to be extremely good, as judged by values of r^2

(typically 0.97), the curve described persistently over-estimates the luminance for a given voltage, implying that the gamma values are too low. This difficulty arise from the logarithmic transformation used to estimate gamma, which distorts the pattern of the residuals. We present a number of numerical techniques to improve both look-up table interpolation and gamma estimation which minimise the error and which have been used practically to improve the calibration of our monitors.

SPATIAL AND TONAL RESOLUTION IN DESK-TOP PUBLISHING

R W G Hunt
Department of Optometry and Visual Science, City University, London

In continuous tone systems, the number of pixels available normally determines the spatial resolution. In half-tone processes, tonal modulation is usually achieved by varying dot-size. In digital systems, the dots are made up of different numbers of micro-dots; in this case, the spatial resolution per unit length may only be about one tenth of the number of micro-dots per unit length. To achieve high quality pictures, a resolution of about 5 cycles, or 10 pixels, per millimetre, is required, and hence micro-dots of about 1/100 mm or 1/2500 inch, are necessary. In desk-top publishing, such small dots are often not economically feasible, and therefore means have been sought whereby adequate quality can be obtained with larger micro-dots. Means for doing this include: optimizing the spacing of the digitally determined tonal levels, taking account of the phenomenon of dot gain; decreasing the number of tonal levels below optimum so as to achieve less loss of spatial resolution; 'dithering' the positions of the micro-dots so as to minimize the obtrusiveness of the half-toning; and using 'error-diffusion' to provide further reductions in the visibility of the dots. Hybrid systems, in which part of the tonal scale comes from continuous, or semi-continuous, modulation, and part from half-toning, provides further means of improving picture quality without requiring extremely small micro-dots.

MAGNITUDE ESTIMATION TECHNIQUE FOR COLOUR APPEARANCE RESEARCH

M R Luo
Design Research Centre, Faculty of Art and Design, University of Derby, Derby

Colour appearance is an important research area in colour science and has been investigated by many researchers in the literature. A review of various experimental techniques will be given such as magnitude estimation, memory matching, and haploscopic matching.

A set of experimental data (LUTCHI) has been obtained, over the last seven years, using the magnitude estimation method. This data set includes about 100,000 visual estimates from three media: reflection, monitor and transmissive. This set of data was used to test the predictive performance of three types of colour model: uniform colour spaces, models of colour vision and chromatic adaptation transforms. The Hunt colour appearance model was verified using this data set. Its error of prediction is equivalent to the typical error seen by a panel of observers. This model is recommended to be used for industrial applications such as the assessment of colour fidelity between various colour reproduction systems.

TUESDAY 12TH APRIL

COLOUR SCIENCE IN PHOTOGRAPHY

G G Attridge
Imaging Technology Research Group, University of Westminster, London

A parallel relationship is drawn between trichromatic vision and photographic colour reproduction. The mechanisms of common photographic systems are described in terms of the analysis of the spectral input and the synthesis of the output colour reproduction. The colour science of photographic images is reviewed. The objective evaluation of colour reproduction by colorimetry and sensitometry is discussed in relation to the colour gamut. The subjective evaluation of colour reproduction is introduced by an account of the examination of acceptability of colour prints as a function of colour balance. The relation between objective colorimetric colour differences and subjective assessment is shown using a recent model of colour appearance in the generation of a colour reproduction index.

TESTING COLOUR APPEARANCE MODELS IN CROSS-MEDIA IMAGE REPRODUCTION

Mark D Fairchild and Karen Rybarczyk
Munsell Color Science Laboratory, Center for Imaging Science, Rochester Institute of Technology, New York

The reproduction of colour images in various media typically changes in viewing conditions as well as the more obvious changes in the physical properties of the imaging systems. Basic colorimetry, typified by the CIE 1931 XYZ system, can adequately predict colour matches across various physical media as long as viewing conditions are identical. However, once changes are made in factors such as illuminant colour (white point), illuminance level, surround, and mode of viewing, colour appearance models are required to predict and produce matching images. Several colour appearance models have been proposed. This work concentrates on those that have been published by Fairchild and Berns (RLAB), Hunt, Nayatani et al., and the CIE (CIELAB). The quality of the colour appearance matches predicted by each of these models is quantitatively scaled for the CRT (D65) reproductions of printed images (A and D50) using a two-alternative paired-comparison paradigm. The data are analyzed using the law of comparative judgements to determine an interval scale of prediction quality for the various models. The experiments are presented for 5 different viewing arrangements: haploscopic, successive haploscopic, successive binocular, simultaneous binocular, and memory. The surround and luminance levels are matched for these preliminary experiments. The results indicate which viewing technique is most appropriate for psychophysical evaluation of cross-media image reproductions as well as providing some insight as to which models perform best. Further experiments will be carried out for a wide range of viewing conditions once a single viewing technique is decided upon.

LEARNING COLOUR CONSTANCY

A C Hurlbert and W Wen
Physiological Sciences, Medical School, Newcastle-upon-Tyne

The colour constancy problem may be phrased as: given the triplet of receptor responses to a surface under an unknown illuminant (the 'test' appearance), recover the response triplet of the surface under a known illuminant (the 'standard' appearance). The standard triplet then provides a constant description of the surface under changing illumination. We have employed neural network models to ask whether it is feasible that the human visual system solves the colour constancy problem by learning the appropriate transformation from test to standard appearances for a set of commonly encountered illuminants.

We have developed and compared two techniques based on (1) the theory of Generalised Radial Basis Functions (GRBFs) and (2) multi-layer perceptrons (MLPs). Given the tristimulus values, XYZ, of a surface under an unknown illuminant, the colour constancy network successfully recovers the tristimulus values of the surface under a known, standard, illuminant. We recovered the mapping performed by the MLP network as its equivalent polynomial, and demonstrated that it is approximately linear for certain classes of illuminants. The linearity of the transformation lends support to models of human colour constancy that require only von Kries-type scaling of receptoral responses and suggests that the human visual system could plausibly learn and apply a set of linear mappings for commonly encountered illuminants. The small number of training examples required to learn the mapping renders both HyperBF and BP networks good candidates for achieving colour constancy on artificial visual systems. The technique may also be used to calibrate and customize colour images on CRT screens, and colour printers, by deriving the appropriate linear transform after collecting small samples of colour matches from individual users.

PAUL KLEE: IMAGERY AND IMAGINATION

Roy Osborne

Early in this century, many artists expressed a desire to reject the traditional, pictorial role of colour. The challenge they addressed was what to replace it with. Paul Klee was one such artist who wanted to combine an experience of the 'reality' of the painted surface (e.g. that a red square be appreciated as a red square) with the possibility that it might also represent something else, such as a house or a flag.

Some 2,500 pages of Klee's teaching notes survive, including substantial sections on colour. We learn from them his awareness of the perceptual investigations of Goethe, Fechner, Mach and others, and how he adopted Runge's colour sphere as the basis for a mathematical exploration of colour.

Klee rapidly established a passage from the theoretical to the practical by exploring abstract relationships between hue, value and chroma using subtractive colour mixing as embodied in the watercolour glaze technique.

For Klee, however, the construction of abstract imagery was rarely an end in itself but functioned significantly as a springboard for the artist to consider how such images might be brought back to the pictorial without losing an appreciation of their abstract colour foundations.

Klee expressed interest in the Gestalt laws for the organisation of form. My proposal is that the strategies he employed, notably in his watercolours of 1921-23 (with which the talk is illustrated), contribute significantly to what one might consider a pictorial 'Gestalt' of colour.

COLOUR IMAGES DIRECT FROM PAINTING: APPLICATIONS IN CONSERVATION

David Saunders
The National Gallery, London

During the EC supported VASARI (Visual Arts: System for Archiving and Retrieval of Images) project, a scanner system was developed which is capable of making accurate colour images with a resolution of 10-20 pixels per millimetre directly from paintings. This paper will describe the technique and explore the ways in which it has been applied to conservation related issues at The National Gallery. The project was designed to provide a method by which the colour change in paintings might be monitored over time. The accuracy of the colour calibration technique used and the ability of the system to detect colour changes will be presented. Using the colour software developed during the project, the change in appearance of paintings as they undergo conservation treatment has been followed. From these studies it has been possible to develop methods of modelling changes in colour so as to predict how a painting might appear after cleaning or if some fugitive pigment has not altered over time. Lastly, colour images have been superimposed on images made in the infrared region. This technique gives improved 'readability' to the infrared images and allows points of similarity and difference to be seen between the final painted image and its preparatory drawing as seen in the infrared image.

MODELS FOR CHARACTERISING FOUR-PRIMARY IMAGING DEVICES

M C Lo and M R Luo*
Loughborough University of Technology
***Design Research Centre, Faculty of Art and Design, University of Derby, Derby**

The accurate colour reproduction of images across various electronic imaging devices is desirable for industry. Colour specification in a computer-based system usually uses the coordinate system of the output device, such as RGB for a monitor or film recorder, or CMYK for an electronic printer. Poor colour fidelity occurs when colours are reproduced using the same set of device coordinates for two different devices. This is known as the problem of <u>device dependency</u>. This problem can be overcome by deriving mathematical models to express device coordinates in terms of CIE systems. Thus a colorimetric match between colours presented on different media can be achieved.

This paper describes the derivation of the mathematical models based upon a limited number of samples and reports their predictive performance. The models derived here are capable of predicting a set of CMYK primaries from a given set of CIE tristimulus values, and vice versa. In practice, these can be applied to characterising the graphic arts scanner and four-colour primary printing devices.

EXTENDING THE COLOUR GAMUT OF PRINTED IMAGES

L W MacDonald and J M Deane
Crosfield Electronics Limited, Hemel Hempstead, Herts

Conventional graphic arts reproduction of coloured images involves the generation of four separation films from which the four "process colour" inks (cyan, magenta, yellow and black) are printed. An important aspect of the reproduction of original scenes, or photographic transparencies, in print is that the colour gamut of the original is invariably much wider than the colour gamut achievable by the pigments of the four process printing inks. Therefore, the reproduction process always involves some form of tone and colour compression to map the grey scale and colour gamut of the original to that of the print.

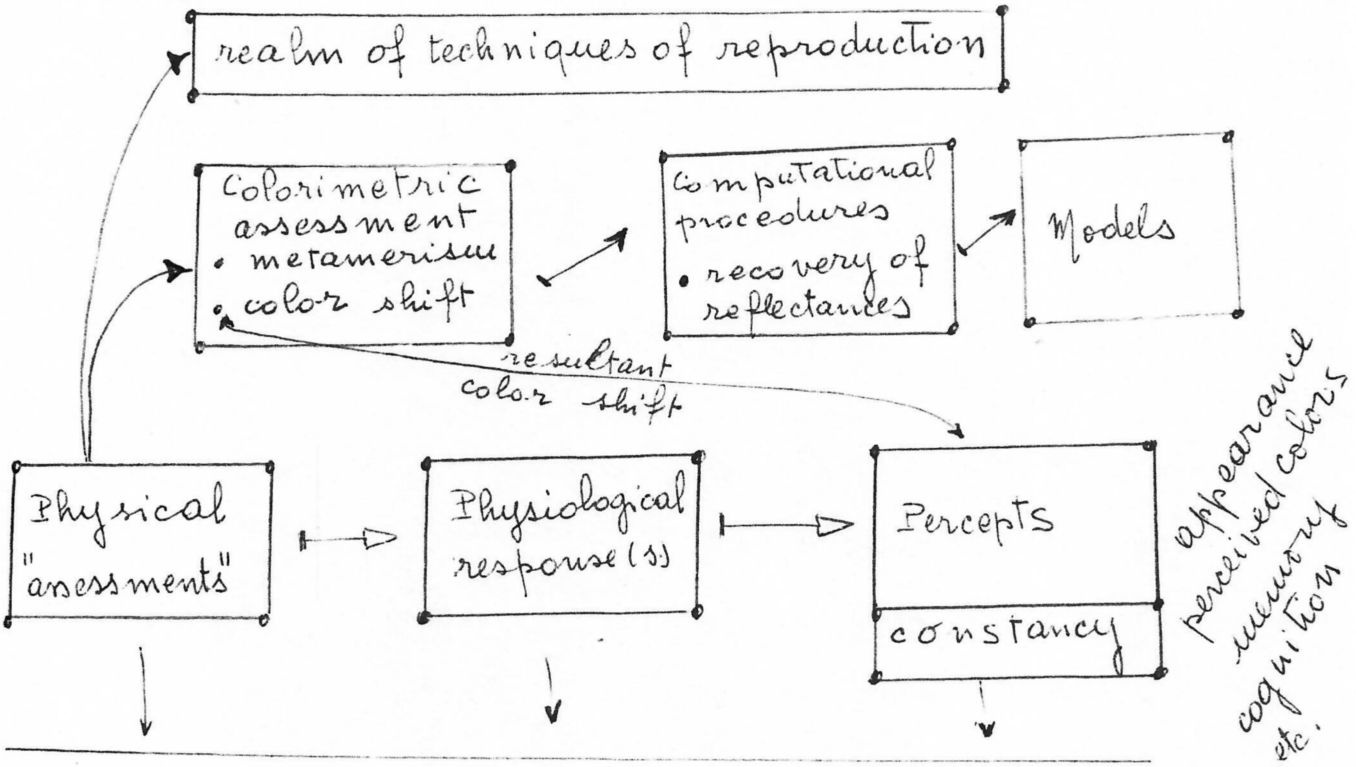
Reproduction of fine art paintings is similarly problematical, because a significant number of the pigments used in paints have colours that lie outside the gamut of printing inks, particularly in recent times as the range of paint colours has expanded greatly with the introduction of synthetic pigments. This is one aspect of the Esprit III research project "Methodology for Art Reproduction in Colour" (MARC).

The objective of the MARC project, to achieve the highest possible fidelity of colour reproduction, has led us to develop methods for using more than four printing inks in order to expand the colour gamut, yielding a wider range of colours and higher colour fidelity of reproduction than hitherto achievable. Software was designed to transform CIELAB encoded images into ink amounts, using any given set of primary coloured inks plus black. Initially the algorithms were tested using the seven inks proposed by Kuppers, but were extended to other ink sets, including those in which the standard cyan, magenta, yellow and black inks are supplemented by red, green and violet inks to increase the gamut of the process in these regions of colour space.

L. Ronchi - March 1994 !

early proposal: Bartleson / Breneman (1967)

The "marriage" of quality / fidelity (and) (perceptual) color constancy through the "equivalence"



possible situations met when comparing two images

equal	equal	equal	
different	different	different	
very different	slightly different	equal	fidelity within tolerances constancy never complete
	if equal	also equal	Mach (1896)
different (beyond the spatio-temporal cutoffs)		equal (within the equivalence classes)	Ratliff / Sirovich (1978)

from "steady" to "transient"

SYNOPSIS

ASSESSMENTS OF QUALITY (absolute ?) vs FIDELITY (comparatively ?) OF REPRODUCTIONS

I)- Steady reproductions

white-and-black

- instrumental assess.
  - .densitometry
  - .preservation of ratios
  - . ratios referred to white

- visual assess.
  - . qualitative (acceptable, 1st excellent)
  - . quantitative contrast sensitivity
  - . power law (brightness/Lumin. relation)
  - . appearance
    - -simple scenes
    - - complex scenes (influence of the surround, induction)
  - . constancy

** colored images**

- instrumental assess.
  - . spectrophotometry
  - . reproduction colorimetry
  - . principal component analysis
  - . evaluation of distortions and deviations

- visual assess.
  - . is the color a luxury, a surplus?
  - . the advent of multichannel color modelling abolished the priviliges of achromatic vision
  - . but color assessment cannot be disentangled from photometric assessm.
  - . color appearance

** advent of new techniques**

- automatic reproduction of a picture color is, itself, color measurement on a grand scale
- new problems arise; e.g., the use of a camera and digitizer imposes the match in quality of the digitized display image and of the image obtained with the spectroradiometer.

II) From steady to dynamic situations

(continuity of motion, reduction of noise, dissociations of various visual functions)

III)- Some experimental data obtained by us

BLACK-and-WHITE REPRODUCTION. The historical development of the concept of "quality and its evaluation

1876- Hurter and Driffield:quantitative evaluation

1885- Bloch's law

1890- Hurter/Drieffield:J.Chem.Ind.9,455,(1890). D-logE curve (physical transduction characteristic)

1920- W.B.Ferguson- The Photographic Research (Phot.Roy.Soc. Lond.(1920)- A review paper

1920- L.A.Jones- J.Frankl.Inst.190,30,(1920) Definition of QUALITY =exact reproduction of tones

1922- E.Goldberg- Der Aufbau des Photographisches Bild,W.Knapp, Halle (1922): the gradient of the characteristic curve in the various zones, from highlights to shadows.

1923- G.Labussière- Bull.Soc.Franc.Phot.10, 45,(1923). The concept of speed of emulsions is developed.

1923-R.Luther-Trans.Faraday Soc.19, 340,(1925). It is imperative to make reference to the human observer. Hence, a normal observer, a normal negative a normal positive are to be defined.

1926-G.E.Sheppard-Phot.J.50,190,(1926), the minimum gradient, the gamma (maximum gradient) and their practical role

1926-1927-L.A.Jones- J.Franklin Inst.202,589,(1926);203,111,(1927); 204,41,(1927): the gradient and the compression and expansion of the contrast in the reproduction.

1928- L.A.Jones, M.E.Russel- Proc.7th Intern.Congr. on Photography- (1928). Definition of the shadow compression facto and of effective speed of an emulsion

1932- Hess, Maxime, Mannheim- La Photographie, Colin, Paris,p.128, (1932). The gamma of the emulsion is to be faced with that controlled by the development.

1935- L.A.Jones, M.E.Russel- J.Opt.Soc.Am.25,401,(1935)- For amateur material, speed is defined as the exposure needed t obtain a satisfactory negative. Three crietria used for evaluating the speed are compared

1941- Kodak Reference Handbook, Eastman Kodak Ko.,Rochester,(1941). The concept of contrast rendered is discussed in relation to the gamma, the variability of gradient, the speed, the under-exposure, etc.

VISUAL EVALUATIONS OF QUALITY

qualitative: 1923: it is necessary to define the normal observer
1935: a satisfactory negative
1942: the 1st acceptable, the 1st excellent

based on jnd (differential sensitivity), based on subjective scaling techniques ,the power law, its dependencies on the background, surround, from simple to moderately complex to complex field

1860- G.F.Fechner- Elemente der Psychophysik, Breitkopf und Hartel Leipzig,(1860)
1872- J.A.F.Plateau- Bull.Acad.Roy.Belg. 33, 376,(1872)
1876- E.Hering- Sitzber. Ak.Wiss. Wien Math. naturwiss. Kl.Abt. 172, 310,(1876)

1957- S.S.Steves, E.H.Galanter-J.Exptl.Psychol. 54,337,(1957)
1958- S.S.Stevens- Science, 127,383,(1958)
1959- D.Jameson, L.M.Hurvich-J.Opt.Soc.Am. 49,890,(1959)
1961- D.Jameson, L.M.Hurvich- Science, 133,174,(1961)
1962- G. van den Brink- Vision Res. 2, 495,(1962)
1962- E.J.Breneman-Phot.Sci.Eng. 6,172,(1962)
1964- D.Jameson, L.M.Hurvich-Vision Res. 4,172,(1964)
1979- H.W.Bodmann et al.-Proc.20th CIE Session, Kyoto,(1979)

C.N.Nelson- IN: The Theory of Photographic Process, NcMillan, New York, Ch.22,(1966) ←

* Jones' criterion of 1:1 relative luminance reproduction is rejected, in favour of an operational definition of optimum quality, derived from psychological scaling experiments. Next, the D-logE curve of the reproduction, resulting from the best quality assessment, is considered.

1967- C.J.Bartleson, E.J.Breneman-J.Opt.Soc.Am.57,953,(1967)- Tone reproduction of COMPLEX fields is analyzed in terms of perceptual requirements for optimum quality. Optimization is met when the brightnesses proportional to WHITE are reproduced. The memory referred to daylight illuminations is of basic importance.

1967- L.D.Clark-Phot.Sci.Eng. 11,306,(1967)- Stevens' brightness predictions may be used to analyze tone reproduction with essentially the same results as Bartleson and Breneman criterion.

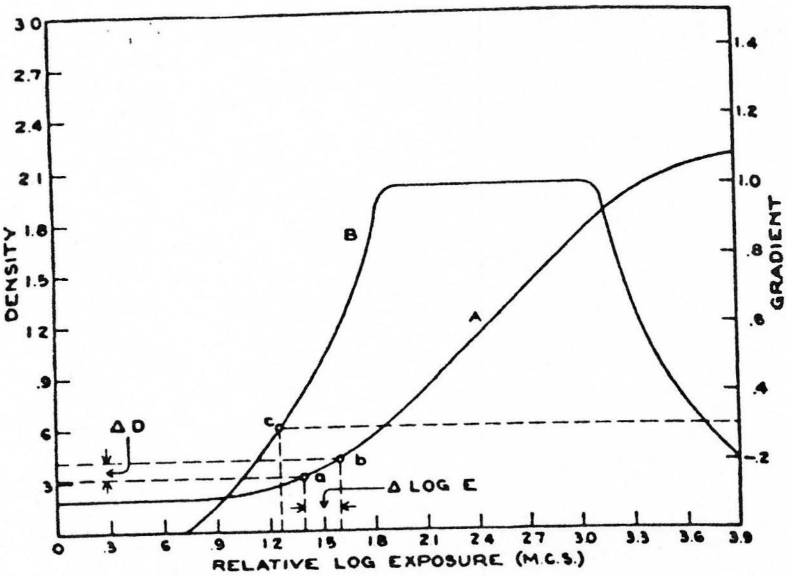
1968- C.J.Bartleson- J.Opt.Soc.Am. 58,992,(1968)- The departure from the optimal quality is assumed as a measurement of degradation. This holds for transparencies, photographic prints, photomechanical prints, monochrome TV.

The vector (principal component analysis) is applied to evaluate the tone reproduction of natural scenes (J.L.Simons,J.Opt.Soc.Am.53,968,(1963)).

1941- L.A.Jones, H.R.Condit- J.Opt.Soc.Am.31,651,(1941): a reasonable evaluation of the quality of the reproduced image needs the classification of the contrast scales in the outdoor scenes

1942-L.A.Jones,C.N.Nelson- J.Opt.Soc.Am. 32,558,(1942)- The requirements for standardization are specified:
- normal observer (for visual acuity, contrast sens
- normal contrast range in the scene(say,32:1)
- psychophysical method of evaluation:
  * the first acceptable reproduction,
  * the first excellent reproduction
- densitometric measurements and their corralations

1943- L.A.Jones, J.W. McNair- J.Opt.Soc.Am. 33,479,(1943)- The evaluation of ASA, a sensitometric method for the description of a reproduced gray scale.



Typical *D*−log *E* and gradient curves of negative material.

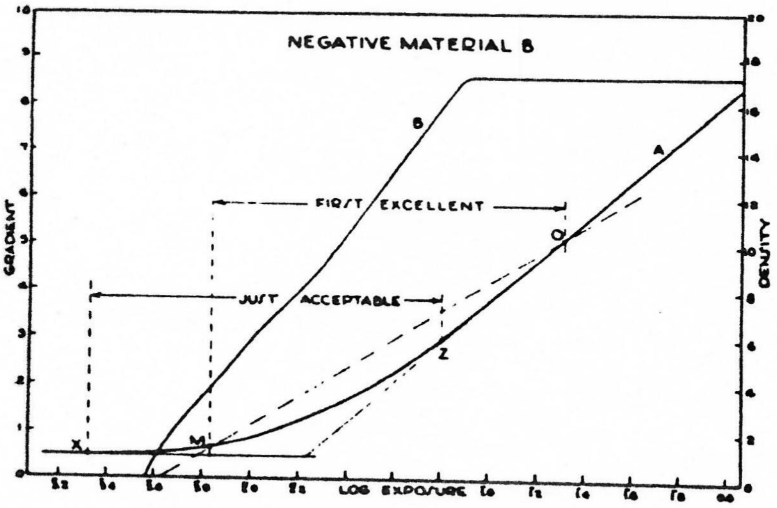
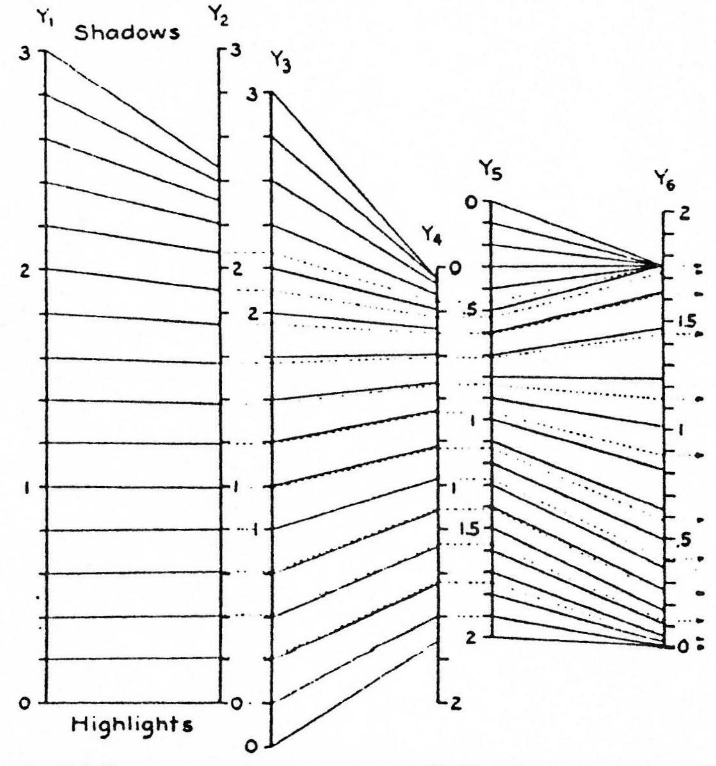


FIG. 1. Curve *A*, the *D*-log *E* characteristic with points indicating the portions used for making the first excellent print. Curve *B*, the first derivative of Curve *A*.



EVALUATION OF THE QUALITY OF IMAGES IN COLOR

1940-1950- Why color photography ?(philosophical aspects)

some current views: * once obtained a good black-and-white reproduction, few additional details are enough to get a good color reproduction

or:

* the color reproduction does not poses "additional" problems, compared to the black-and-white one: simply, the one channel procedure is to be extended to three channels.

A QUESTION: does the specification of white come first, and then that of color, or viceversa ?

One of the first laboratory (visual) approaches:

* Influence of spectral composition on the "power function" brightness versus luminance: controversial findings (dependencies versus independencies)

D.Jameson, L.M.Hurvich-J.Opt.Soc.Am. 44, 213,(1954)
G.E.Ekman, H.Eisler, T.Künnapas- Scand. J.Psychol. 1, 41,(1960)
S.S.Stevens- IN: Sensory Communication, W.A.Rosenblith Ed.,MIT Press, New York, p.1,(1961)
D.H.Krantz- IN: Handbook of Sensory Physiology, Vol.VII/1, Springer, Berlin, (1972)

1951- D.L.MacAdam-Quality of Color Reproduction
J. of the SMPTE, Vol.56,p.487,(1951)

* no blind reliance on measurements!
* the concept of adaptation, as referred to balance (towards perceptual CONSTANCY)
* ..... however, if the surroundings are prominently illuminated, fluctuations of balance and even the standard white adopted for the production of the picture can be very objectionable
* the concept of "1st excellent print", deduced from the D-logE curve cannot be directly be applied to evaluate the quality of color reproduction.It is mainly of academic interest.
* the departures from the observer's ever-changing criterion of WHITE distort the perception of ALL COLORS

1993- The Hunt- Berns effect. A proposal by G.B.Beretta-
CIS-N-93-743-Sept.(1993)

> Sometimes the cognitive factor fails and an observer is not able to decide on a set; thus the observer cannot decide on the appearance of colors. We propose to call this the *Hunt-Berns effect* because of the following anecdote: Professor Roy S. Berns had invited Dr. Hunt for dinner to a restaurant in Rochester. The lighting in the restaurant was pink and the brightest object in their field of view was the tablecloth. Being knowledgeable of the Helson-Judd effect, it would have been perfectly plausible to use the tablecloth as the reference white and chromatically adapt correspondingly. However, to their discomfort the two scientists contemplated that the tablecloth might as well be pink. It was impossible for them to decide on the color of the tablecloth until they had an object they knew *a priori* it was white.

THE "QUALITY" FROM THE (steady) COLORIMETRIC POINT OF VIEW

from: Color in Science and Industry, D.B; D.B.Judd, G.Wyszecki, Wiley,
New York, (1975)

These authors define as "an idea" ...that ... reproduction of pictures in color is simply tristimulus colorimetry repeated, say 100,000 times for each picture point... It solves the problems, whether the medium is: printink ink, the transparent dyed layers of color-film slides, the motion-picture film the flying spot of light on TV rec. screen

Optimization: to duplicate exactly the CIE standard observer color-matching functions

--> historical refs. Maxwell-Ives' criterion(1915); Bingley's spec.(1915

- * in theory: three cameras, with spectral sensitivities conforming to the three curves of the trstimulus values of the spectrum
- * in practice: TV, six cameras, three for positive lobes, three for negative lobes, next, combination by eletronic means; photography: six separation negatives, next correction poisitves, etc. Masking, matrixing, etc.
- * in reality: TV, practical taking sensitivities and transformation of electrical signals.

A caveat : telecasting in color is beset by many other impediments to color fidelity than failure to duplicate exactly the CIE standard observer color-matching functions.

The limitations:

- * much depends on chosen primaries (restriction of the gamut)
- * within the gamut, when negative lobes are neglected, the colors near the boundary are rendered less saturated than the colors in the original.

Reference to color vision:

to use primaries matching the spectral sensitivities of human photoreceptors as close as possible (tuned filters) Standards are proposed

alternately, to apply the black-art approach to a camera with arbitrary sensors, by post-processing the sensors response and by checking visually the outcome. Various computational procedures have been proposed

DEFINITIONS OF "QUALITY " OF COLOR REPRODUCTION AFTER Hunt (Objectives in
color reproduction,
J.Photogr.Sci 18,205,(1970)

SPECTRAL COLOR REPRODUCTION **1)- SPECTRAL COLOR REPRODUCTION** A reproduction which has a precise match of the spectral reflection curve of the original,or precisely matches it	It results in t[illegible]ful color appearance for any kind of lighting, avoiding difficulties due to metamerism. It does not apply to Television. It may be useful for catalogues.
2)- COLORIMETRIC COLOR REPRODUCTION Original and reproduction have the same coordinates u',v' and luminance Y with respect to white	It applies to Television if the original and television have the same white point
3)- EXACT COLOR REPRODUCTION Not only the u',v' coordinates of the original and reproduction are the same, but also the absolute luminance value is the same.	Recall that, in general, color TV does not exceed 100 cd/sq.m.
4)- EQUIVALENT COLOR REPRODUCTION a)- there is a change in white point b)- there are differences in luminance levels c)- there are differences in the surround	The type of reproduction should make allowance for it !
5)- CORRESPONDING COLOR REPRODUCTION Takes 4 a) and 4 c), eliminates 4 b)	This is the case of color TV
6)- PREFERRED COLOR REPRODUCTION Some colors (skin, sky, grass) appear more colorful in the reproduction than in the real life	It depends on personal decision. The chrominance gain control, in some TV sets, should permit to do it.

R. W. G. Hunt
Research Division, Kodak Limited
Headstone Drive, Harrow, Middlesex
England HA1 4TY

Color Res.Appl. 7, 46,(1982)

Chromatic Adaptation in Image Reproduction*

an "encyclopedia" of vitally important findings. In particular:

REFLECTION PRINTS	the picture in itself being assesses as a collection of objects	CORRESPONDING COLOR REPRODUCTION	(which ignores any effect of absolute luminance)	colors in the reproduction would have the same appearance as the originals if they had been illuminated at the same level
TV Displays TRANSPARENCIES FILMS	illusion of seeing the actual scene (not the single objects)	EQUIVALENT COLOR REPRODUCTION	(the absolute luminance is important)	colors in the reproduction have the same appearance as those in the original scene

EVALUATION OF QUALITY OF REPRODUCED IMAGES IN COLOR FROM THE ERGONOMICAL POINT OF VIEW

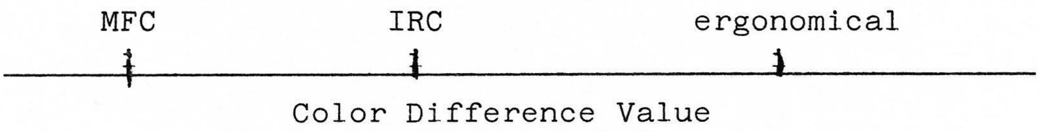
The reproduced image may be evaluated:

* instrumentally (the use of **advanced sophisticated tools** is
[illegible] recommendable, by avoiding typical color measuring instrumentation)

** visually - color differences evaluated with psychophysical methods

- the "tolerable" color difference depends on the use of display or goal of the experiment

IRC = image reproduction colorimetry
MFC = matching and formulation colorimetry



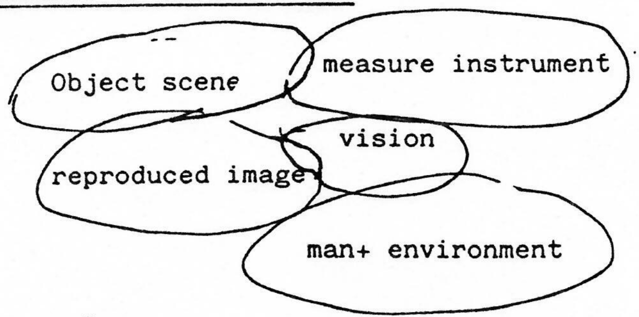
1992-D.Travis, T.F.M.Stewart, C. Mac Kay- Evaluation of image quality on Displays Screen Equipments

Displays, 13, 139, (1992)

Various possibilities:

Only qualitative assessment	assessment mediated by physical measurement of the device	performance-based tests (by assessing the usability of the components

QUALITY VS FIDELITY OF REPRODUCTION



{ an inestricable vicious circle!

- Quality of the external scene
- Quality of reproduction
- Quality of color
- Quality of the display
- Quality of vision (testing procedures)
- Spatial fidelity (imposed by digital quantization)
- Quality of measure instrument

THE MULTIFACET ASPECTS OF THE TERM "QUALITY"

CUSTOMERS

* base purchasing decisions on the relevance of a product for their activities ("How much does it improve my work ? "
* perform analysis of hardware specifications of a peripheral device, which is looked as a component of an application

MASS MARKET (ref. computer applications for)

* image quality : a term having a general meaning
* color, referred to:
    - aesthetics
    - FIDELITY of reproduction. To achieve it, it is necessary to be able to predict and control color reproduction in a closed system (the available tools being: densitometry, colorimetry, spectrophotometry)
    - preservation of color appearance (especially important for the WYSIWYG color system).

CASUAL USERS

* want what they ask for, but they do not know what to ask for (their usual claim is: this color does not look right)

SKILLED USERS

* identify correctly the appearance of colors (an acquired skill)
* the color is given the correct name
* cognition of color names is an important indicator of color identification capability

GENERAL CONSIDERATIONS

"...we know too little about what makes us see objects and people from the mosaic of colored patches presented to the eye from real scenes, to state with confidence that a completely faithful reproduction would always look good"..."adding art to science"....
..."perfect color fidelity usually leads to poor pictures and should be avoided on purpose. Intentional systematic deviations from fidelity can make the picture better than the original..."
(from: D.B.Judd, G.Wyszecki- Color In Business, Science and Industry, Wyley, New York,(1975)

FROM HANDBOOKS CONSULTED BY ENGINEERS (Ligting eng.Electronic eng.

VISUAL CLARITY* term used to indicate a preferential appearance of scenes containing colored objects when illuminated by certain sources.

* a combination of various factors

-based on visual observ.	-measured, calculated
perceived contrast	color rendering
perceived color	
color discrimination	
color preference	
border sharpness	

S.M.Aston, H.E.Bellchambers- Light.Res.Technol.Vol.1(4),259,(1969)
H.E.Bellchambers,A.C.Godby- Light.Res. Technol.Vol.4(2),104,(1972)
T.M.Lemons,A.V.Robinson- Lg Light.Des.Appl. Vol.6,p.24,Nov.(1976)

**** **** ****

CRITERIA FOR PICTURE REPRODUCTION

* qualitative: the reproduced images shall be acceptable to the human eye

* quantitative: the techical details of the system shall not obtrusively evident to the viewe

QUALITIES OF A PICTURE JUDGED BY EYE

spatial realm
- sharpness (or pictorial quality), well focussed eye
- contrast between light-and-dark areas (background lighting affecects the observed contrast and can introduce contrast changes not present in the original scene
- available gray scale (influenced by surrounding light)

temporal realm
- flicker (a function of frequency and brightness,tolerance to flicker being needed over an extended period of viewin
- continuity of motion

chromatic realm

- color values (if present, must be acceptable and realistic, as results from qualitative observations)

- color reproduction needs not to be accurate when compared to the original scene, because observed colors are greatly influences by surroundings, illumination,etc. and the eye compensates for such variations

Fink's Electronic Engineering Handbook, McGraw-Hill Co., New York,(1075), Section 20

THE TRANSFER OF THE ASSESSMENT OF QUALITY FROM TRADITIONAL TO THE NEW ELECTRONIC IMAGES

1940- RCA Receiving Tube Manual Technical Series RC-14,(1940)
RCA Manuf. Co. Inc. Harrison, New Jersey,p.10,(1940)

1944- P.W.Dorst -J.Opt.Soc.Am. 34,597,(1944)- Comparison of the quality of electronic image and of photographic image.

subsequent developments

FACTORS AFFECTING THE QUALITY OF THE REPRODUCED IMAGE (film, video, etc)

ILLUMINATION of the ambient viewed by the camera

quality
quantity

interaction of light with the surfaces in the environment (textures, etc.)

SPECTRORADIOMETRIC IMAGE — **DIGITIZED IMAGE** — **IMAGE ON THE DISPLAY**

* non-linearities (gammas) of videocameras and phosphor guns (a field to be yet fully explored)

* predictive models (light outputs vs DAC, for every gun) of reproduced colors

seven models have been up to now proposes,

none yields satisfactory predictive accuracy

* gain adjustement of the receiver

* color compression (the optimal algorithm is yet matter of discussion)

AMBIENT ILLUMINATION AT THE RECEIVER

quality
quantity
spatial distributi

---

* basic statement *

the pattern of stimulation at the moment of recording } —> IDEALLY SHOULD BE THE SAME AS —> { patterning of stimulation at the receiver

(to avoid the so-called mismatches "outside the camera)

THE OTHER FACET OF THE PROBLEM

characteristics of quality of a color display

ENVIRONMENT

component analysis
main-component analysis of spectral surface reflectances

RADIOMETRIC ASSESSMENT

elaborated spectroradiometers and sophisticated illumination standards

CALIBRATION OF MONITOR

- of electronics
- of the digitizing system

non-linear input-output relation (is power law the best ?)

IMPERATIVE: to fix the white on the monitor

calibration/ color specification

IDEAL MONITOR :
- temporal stability
- spatial uniformity
- gun independence (additivity chromatic mixtures)
- phosphor constancy (independenc of chromaticity coordinates on input voltabe

REAL MONITORs: several violate the assumptions above

OPTICAL CHARACTERISTICS:

- resolution,- edge sharpness
- contrast
- color quality
- perception modes
- spatio-temporal characteristics (flicker, jaggies, moiré patterns-
- brightness-luminance discrepancy

INFORMATION HANDLING CAPACITY

- display size
- pixel density
- number of colors
- interactivity

tele-cine technique: converting information on the film into a video-signal

CINE CAMERA: capable of dealing with a wide range of spectral reflectances (multiplicity of materials,fabrics, natural colors)

RECORD ON THE FILM: has already analysed the scene in the red,green,blue sensitivities which,in the negative, are converted into cyan,magenta, yellow

PROJECTION IN A CINEMA
(with chosen illuminant)

two options:

I)- to analyse the projected image as 'another' color (by forgetting its special properties on the film
(OPTICAL PRO JECTED MODE)

- hence, the colors on the display monitor are to be made as close as possible to those on the projected film

II)- To make use of the properties of the film
(NARROW BAND ANALYSIS AND LOG PROCESSING)

- hence: analysis by three relatively narrow spectral bands conversion of the linear signals from the photo-multiplier into density and then, by 3 x 3 matrixing, to overcome some of the inherent defects of any film system
  The exponents of the output signals from the matrix convert them back into the $E^{-1/\mathrm{gamma}}$ form

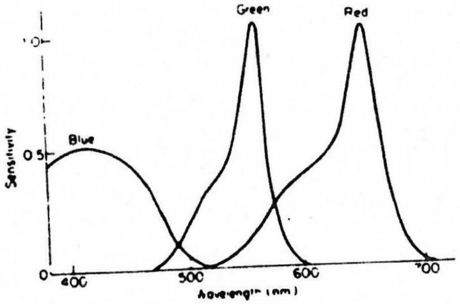


Figure 2.11 Typical sensitivity curves for a colour film

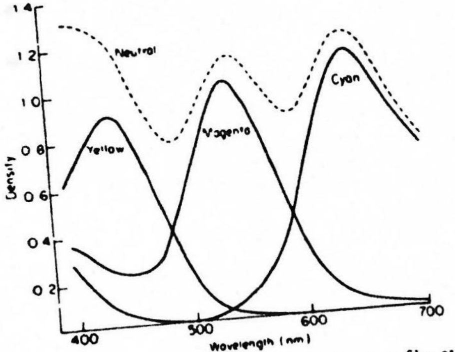


Figure 2.7 Spectral density curves of a typical colour film at unit end

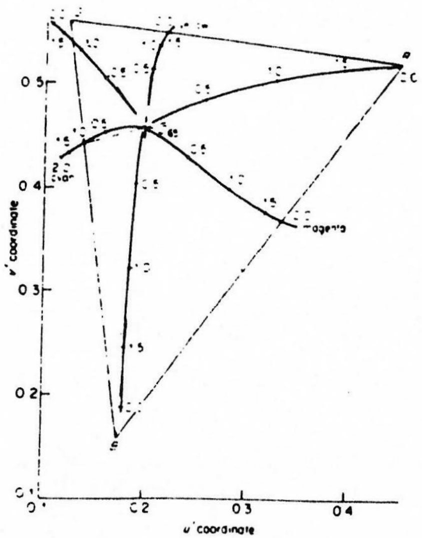


Figure 2.12 Chromaticities of typical film dyes at 0.5, 1.0, 1.5 and 2.0 ENDS. The gamut of the PAL System I television primaries is also shown, triangle *RGB*.

CAUSES OF LOSS IN COLOR FIDELITY

- spectral sensitivities of the negative stock
- dye characteristics of the final print

(note: as the left figure ahows, at the end 2.0 the chromaticities are not very dissimilar to the television primaries

END (for one dye) is defined as the density achieved when sufficient of the other two are added to make the three layers together give a neutral in a stated illuminant

---

THE FILM ACHIEVES HIGHER CHROMA BUT LOWER BRIGHTNESS COMPARED TO TELEVISION IN? SOME SPECTRAL REGIONS BUT NOT IN OTHERS

Colour telecine machines

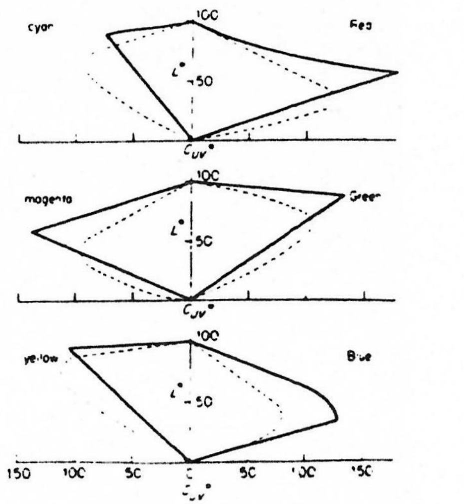


Figure 2.13 $L^*C^*_{uv}$ sections of the colour solid showing television (solid lines) and film (broken lines) The television sections are plane. the film sections are curved as shown in figure 2.12

Studies on tone reproduction in photography have shown that for a dim or dark SURROUND an increase in contrast (gamma > 1) is required to give a monochrome reproduction the semblance of reality . Bartleson's equations are:

$L^{**} = 11.5\,(100Y \times Y_0^{-1} + 1.0)^{0.50} - 16$ for a light surround (e.g. print with white border)

$L^{**} = 17.5\,(100\,Y \times Y_0^{-1} + 0.6)^{0.41} - 16$ for a dim surround (e.g. television)

$L^{**} = 25.4\,(100Y \times Y_{\bullet 1} + 0.1)^{0.33} - 16$ for a dark surround (e.g. slide or cine projection)

$\gamma = 1.25$ dim surr.
$\gamma = 1.50$ dark surr.

C.J.Bartleson-J.Opt.Soc.Am. 58,992,(1968); J.Soc. Mot.Pict. and TV Engns. 184, 613,(1975)
R.W.G.Hunt- J.Photogr.Sci. 17,198,(1969)

QUALITY OF THE REPRODUCED COLOR IMAGE after Sproson (Colour Science in Television and Display Systems, Hilger, Bristol, (1983)

Perfect or ideal analysis- The chromaticity coordinates and the luminance are the same in the scene and in the reproduction (Modifying factors are ignored)

Practical color analysis-

- negative lobes in the primaries are needed

* are essential for accurate reproduction within the primaries (to avoid loss in saturation and change in hue)

In photography, this is achieved by involving dye chemistry. In color television, once abandoned the best fitting method, electrical matrixing is used It is inserted in signal processing, and is based on the addition and subtraction of electrical signals, starting from the total color error, and small changes are made to each of the six independent variables (instead of 9, being the displayed white fixed)

- the problem of white

The TV reproduction is usually adjusted to D_{65}

* in general, a change in white point is introduced between the scene and the reproduction
The color temperature of scenes is highly variable: 3000K in studio, 4000 K in sport stadia, 5000 to 10,000K is daylight

- The effect of absolute luminance, L

* on colorfulness (proportional to $L^{1/6}$ or to $L^{1/10}$)

* on perceived brightness

orienting calculations of colorfulness, for TV reproduction of:

a typical studio scene $(65/308)^{1/6} = 18\%$; of a typical outdoor scene $(65/3495)^{1/6} = 52\%$

- effect of dark surround

* complex desaturation effects are caused by dim or dark surrounds

they may be compensated by properly choosing the gamma   gamma = 1.2-1.3 necessary for acceptable luminance and color rendition

- effect of gamma $L = k\,V^{gamma}$ being L, luminous output; V= drive voltage-cutoff voltage   k=constant

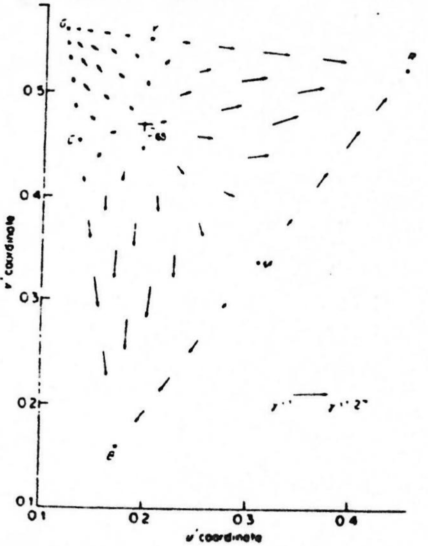


Figure 7.1 Effect of an overall gamma of 1.27: six chromaticities are unchanged, namely *RGB* and *YMC* in addition to white D_{65}.

* In the ideal case is gamma =1 . In practical cases (because of noise), gamma ranges from 1.27 to 2.8
The effect of gamma on chromaticity and luminance (not on color appearance) can be calculated (see left)

The difference from the "gamma" in the scene and the gamma in the reproduction (which is greater than 1) is one of the reasons why the displayed picture would not correspond to the displayed picture

- effect of chromatic adaptation- In natural environments, the eye adapts to color temperature ranging from 2,000 to 20,000 K. In color television, this natural compensating process is simulated by changes of gain in red, green, blue channels.

* effect of chrominance gain (optional)

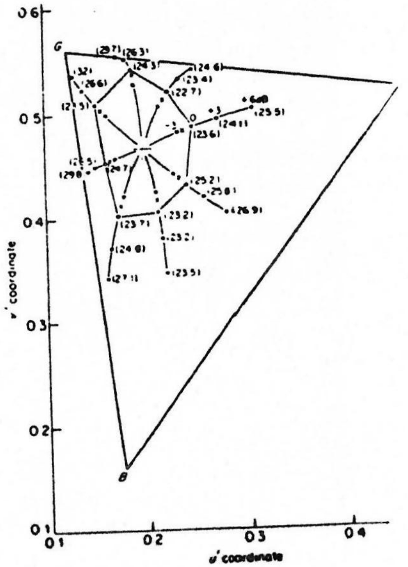


Figure 7.15 Effect of chrominance gain on displayed chromaticities—signal gamma = 0.4; display tube gamma = 3, overall gamma = 1.2. Chromaticities corresponding to gains of −3, 0, +3 and +6 dB are shown. The chromaticities corresponding to 0 dB gain are joined in an octagon. x, original chromaticities. Numbers in brackets are the luminances of the displayed colours.

BEYOND THE CRITERION BASED ON TRISTIMULUS COLORIMETRY

* an important question in reproduction of pictures is

COLOR FIDELITY

telling us how faithfully the colors of the original scene are reproduced.

e.g. B/ Wandell- The high fidelity color reproduction
Color Res.Appl. 11 Suppl.,30,(1986)

a)- to predict the responses of the "biological camera" (eye photorec.)

b)- to use image data to generate a rendering that APPEARS as the original image at the time of acquisition (by involving mental estimations also)

* Often it is discussed "why the reproduction still fails to create the same EMOTION as the original art pieces"?

ACCORDINGLY, TIMES SEEM TO BE RIPE TO SHIFT OUR CONCERN FROM THE DISTAL STRUCTURES, ALONG THE VISUAL PATH, TO PROXIMAL AND CENTRAL MECHANISMS.

* Post-receptoral stages imply neural mechanisms, hence transient responses. It means that the definitions of quality, fidelity, and similar, should be transferred from the steady realm (dominated by the essentially steady tristimulus colorimetry), to the transient, dynamic realm.

* In this same framework, also the definition of perceptual constancy requires a careful analysis. The question arises whether it is simply referred to steady state conditions or it is applied to both steady and transient conditions. In this latter case, the question arises whether the relation between quality/fidelity and constancy mediated through visual adaptation can be reconciled with the difference in time response characteristics of sensory and adaptive responses, respectively.

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SIMPLE VERSUS COMPLEX STIMULI

QUALITY/FIDELITY	PERCEPTUAL CONSTANCY	EQUIVALENCE
In matter of picture assessment, from seeing a collection of objects to seeing an actual scece(Hunt,1982) In matter of assessment of appearance: influence of surround induction effects in complex scenes (Krauskopf/ Zaidi,1986) The power law, relating brightness to luminance, depends on field complexity	The relative brightness constancy criterion, for complex field, differs from that for simple ones (Bartleson/Breneman ,1967)	Simple stimuli Uniform and constant during their exposure time Complex stimuli With internal spatial or temporal structure

SHARPNESS

QUALITY/FIDELITY	PERCEPTUAL CONSTANCY	EQUIVALENCE
sharpness is one of the items of pictorial quality	Worthey (1985) ascribes the lack of constancy to the failure in allowing sharp vision of some spectral compositions	After Ratliff and Sirovich (1978) border sharpness is an ingredient of equivalence

MULTIVARIATE STATISTICAL ANALYSIS, PRINCIPAL COMPONENTS ANALYSIS, VECTOR ANALYSIS

A mathematical tool widely used, in the assessment of quality/fidelity, after Bartleson and Breneman (1967), in modelling of perceptual constancy as well as in studies on equivalence

QUALITY/FIDELITY

- The image reproduced by the use of a video-camera should be observed under conditions identical to those of the real object

- Hunt (1982): lighting is of vital importance for the evaluation of reflection print

- Visual clarity is a term used to indicate a preferential appearance of scenes containing colored objects

-Color reproduction needs not to be accurate when compared to the original scene, because observed colors are greatly influenced by ... illumination, and the eye compensates for such variations (Fink's Handbook,1975)

ILLUMINATING ENGINEERING VIEWPOINTS

PERCEPTUAL CONSTANCY

* The "ratio principle" holds over a range of illumination of a million-to-one (Jacobsen/Gilchrist,1988)

*The brightness of objects does not vary directly with the light they reflect and the objects may appear the same under different illuminants

* Object colors are perceived more-or-less constant despite considerable variations in the color of the ambient light

* When the change in illuminant spectral composition is discounted, the related changes in object luminance are also discounted (Worthey, 1985)

* Certain illuminant effects are not corrected by von Kries adaptation (e.g. light of good color rendering be replaced by a metameric one,providing lower red-green contrast (Helson etal.1982 Worthey, 1982)

* Color constancy is never complete; "simpler" color constancy is ideal. The visual system never totally corrects for

the physical changes in light reflected by the objects (Worthey,1985;Lucassen/Walraven Buchsbaum,1988; Valberg et al.1990)

* An image-processing system, assigning onl colors despite the changes in lighting (Maloney/Wandell,1986)

* Computational models, dierctly estimatin the illuminant, and recovering spectral reflectances, d'espite the environmental changes

* Discounting the illuminant and assigning stable colors, in spite of changes in lighting (essential to exact color rendering)

CONTRAST AS A FACTOR

QUALITY/FIDELITY

- * perceived contrast is one of the ingredients of visual clarity
- * the eye can introduce contrast changes not present in the original scene
- * <u>in white-and-black reproductions</u>
  - instrumental assessment of the preservation of contrast ratios, ios referred to white
  - contrast rendering (compression, expansion) as related to the gamma
  - contrast scales in outdoor scenes (Jones et al.1941)

PERCEPTUAL CONSTANCY

- Lightness constancy: the ratio principle (Jacobsen/Gilchrist, 1988; Lucassen/Walraven,1990)
- object brightness and reference brightness relation(Graham/ Brown, 1965)
- Preservation of relative brightnesses in complex fields (Bartleson/Breneman,1967)
- Contrast perception subserves the perceptual constancy of familiar objects (Hering, 1877)
- The eye does <u>not</u> discount those features of the illuminant that govern color contrast (Worthey, 1985)
- Color constancy is related to color contrast (Helmholtz,1866; Haak,1921; Jaensch,1921;Koffka, 1932)
- Contrast at the borders is one of the ingredients of Retinex Theory
- An increasing tendency to constancy of matching is tested when the luminance of the comparison field is reduced and that of the test-field is increased (Hennemann, 1935)

EQUIVALENCE

- * Determination of "equivalent contrast pulses"
- * quantification of decay time of simultaneous contrast contribution (one of the components of adaptation (Hunt, 1952)

EFFECTS AND INVOLVEMENT OF CHROMATIC ADAPTATION

QUALITY/FIDELITY

The effects of the surround (on differential sensitivity, on the power law, on psychophysical scaling,etc.) are included in the framework ofadaptive effects

Adaptation is referred to balance,as a first step towards constancy (Mac Adam, 1951)

Adaptation mediates the compensation of the effects of some environmental changes

The photographer's error

PERCEPTUAL CONSTANCY

Certain illuminant effects are not corrected by von Kries adaptation

Adaptation subserves the subject's resistance to environmental modifications

There is a connection between crhomatic adaptation and the three independeent mechanisms of Young's theory (Helmholtz,1966)

Constancy is accounted by a single stage receptor adaptation theory(von Kries, 1905)

The adaptive color shift partially compensates the resultant color shift under changing illumination

The single-stage model by von Kries does not always comform to the prediction of adaptation theories,nor represents a solution for complete color constancy (Worthey, 1985;Worthey/Brill 1986; Brill/West,1986)

Chromatic adaptation is also to be related to the equilibrium of post-receptoral color-opponent mechanisms (Shevellell, 1982)

The photographer's error

EQUIVALENCE

-A practical problem:"on first loc ing at the bipartite field, the cc or appearance may not be the same as after continued viewing, and a regular observational routine has to be stipulated

- Hunt's procedure (1953): a cycli presentation of conditioning and test stimuli. The results refer tc a constant adaptation at a particu ar time fo the cycle

- To reduce and control the Troxle effect,presentations of 0.5 sec every 2 sec are recommendable (More= and and Cruz, 1972)

- Possible interdependencies bewtw among the response to a given stimulus and that to the preceding sti ulus introduce a bias to be elimin ated.

-In a display, the total situation is changed if additional conditioning stimuli are either pre-exposed or steadily presented

-If the retina is not fully adapte to the conditioning stimulus, when the test stimulus is applied, the time of application must be invariartr

QUALITY/FIDELITY

- → Color preference is one of the ingredients of visual clarity
- → Acceptable reprodutions
- → Color values must be realistic
- → Cognition of color
- → "to look good "
- → pictorial quality visual evaluation
- → mental estimation
- → creating emotions

Biological Camera (eye photoreceptors)

- → Reference to appearance
- → psychophysical scaling experiments
- → perceptuaL requirements
- → effects of changing criterion
- → the picture as a collection of objects or as an actual scene (Hunt,1982)
- → aesthetical evaluation
- → cognition of color names, identification

Double-opponent cells in the visual cortex mediate color constancy (Rubin/Richards, 1982)

Mechanisms located in the V 4 area subserve color constancy (Zeki,1994)

FROM THE PHOTORECEPTORS TO THE HIGHER CENTERS

PERCEPTUAL CONSTANCY

✱ Absolute lightness is of little meaning for brightness constancy (Hurvich/Jameson,1961)

✱ The object-color is a mental phenomenon

✱ A particular sample may not exhibit color constancy, as judged by a color match, but may be correctly identified through cognitive cues (Arend,1991)

✱ Two stimuli, very different physically, may be slightly different at the site of sensation, but appear the same at the site of the perception of a scene (MacCann/Houston, 1983)

✱ Matching on the basis of perception is to be compared to matching based on recognition

✱ Color constancy is due to mechanisms partly retinal, partly cortical (Judd, 1993)

✱ Constancy implies a stage of separate chromatic coding, disconnected from luminance and contrast (Lucassen/Walraven,1993)

✱ Constancy, being related to chromatic adaptation, needs a tw-process theory, the first, receptoral the second related to color-opponent mechanisms (Shevell,1982; Werner/Walraven, 1982)

EQUIVALENCE

→ Stages in the visual system needed for the assessment of equivalence:

- . stage where Talbot equivalence holds
- . color-opponent stages (being neural, onl transient responses are expected; they may be thrown out-of-balance by silent hue substitution

→ Higher stages, seat of mechanisms capable to sense the direction of temporal change of color per sé (Zaidy/Halevy,1993)

→ Simultaneous presentation implies a com arative judgement

→ Substitution relates specifically to the appearance of the stimulus, even by requesting absolute judgements (e.g. color-naming)

✱ A model of constancy including both sensory zone and the cognitive zone is proposed (Fairchild,1993)

✱ Retinex model

✱ Constancy is due to "unconscious inferences" (Helmholtz)

EFFECTS OF TIME AS A VARIABLE

QUALITY/FIDELITY

* Treatment basically referred to the steady state (e.g. tristimulus reproduction colorimetry)
* Basic movie requirement: continuity of motion
* Frame replication reduces noise
* Avoidance of flicker

PERCEPTUAL CONSTANCY

- Objects do not markedly change their apparent color as they move across the visual field, in spite of changing response characteristics
- The evaluation of color constancy depends on the presentation mode (immediate or delayed) (Helmholtz,1966;Haak 1921; Jaensch,1921; Koffka, 1932)
- To cope with the time changes due to transient adaptation, instantaneous constancy is defined and assessed by considering the non-adaptive models of color constancy(Brill/West,1986)
- Computer methods to simulate dynamically the effects of illuminants on color constancy may be proposed (Troost/de Weert,1992)
- A generalized concept of constancy in a dynamic context (Petrov, 1993)
- Light cannot be separated from the matter when these two variables are spatially and temporally inseparable, e.g. in the case of an homogeneous surface illuminated in a dark void (Lucassen/Walraven,1993)

EQUIVALENCE

* In visual match by strict substitution, if the stimuli are not constant in time, their duration must be specified
* With certain complex stimuli, the light patches may have internal spatial or temporal structures tha are perceived, but it is sufficien to make mental average and to app the uniform match criteria
* When two patches are presented in rapid succession, flicker extinction may be recorded
* The exposure durations of the tes and comparison stimuli may range from steadily exposures to brief flashes that are not simultaneous
* Conditioning stimuli may be presen ed in intervals between the actual presentation and matching of the te
* K.Ruddock- Control of the time pat ern of the stimulus. IN: Techn. of Photostim. in Biology, B.H.Crawford et al. Eds., Elsevier,(1978),N.Y.
* The content of higher frequencies may differ in a pair, but it is eliminated by attenuation beyond the cut off; lower frequency excitation may be suppressed by antagonistic inhibi ion (Ratliff/Sirovich,1978)
* Non-zero events merging into the no se may be termed "null"

CONTRADICTIONS

* Associations of visual functions in the steady state are established by various authors (e.g. Mansfield,(1973), Threshold vs suprathreshold brightness percepts; Krauskopf (1980), detection vs discrimination.

* Dissociation (disarrangement, breakdown of accosiation) in the transient state (see examples below):

at ON-

in the locally adapted state

at OFF-

AT THE ONSET OF AN ADAPTIG FIELD

- Disarrangement of the relation between brightness and differential sensitivity (Crawford, 1947; Shevell 1977 ; Hood et al. 1978 ; Finkelstein/Hood,1981; Hayhoe et al.1987)

  Differences in the above effect, when passing from homochr. to heterochr. combinations (Bush, 1955; Baker, 1963;Boynton,1965

- Photopic saturation (conc. differential sensitivity and its deviation from Weber law, flash-on-flash technique) occurs specifically in a transient state (King-Smith 1974; Geisler, 1978), bur the brightness enhancement (re: Broca-Sulzer effect) is not tested for co-terminating test and probe (Raab/Osman, 1962; Alpern,1968; Geisler, 1978)

- Response to a flickering stimulus: temporal discrimination gradually increases after the onset of an adapting field (build-up-time) (Granit/Hammond, 1931; Drum et al. 1978; Harris et al,1990; for S-cones: Stockman et al.1991)

LOCAL ADAPTATION AND STABILIZED VISION

(a limiting case of light-adaptation)

. brightness attenuation (even total fading-out), bur differential sensitivity to brief flashes remains unaltered(SparroK ,196

- casual association of chromatic and achromatic responses
  - totally dissolved (Troland, 1919; Stainton, 1922;Gur,1968)
  - unaltered (Vimal et al.1987)
- brightness-luminance discrepancy (brightness enhancement occurring when a narrow-band stimulus is compared to a broad band one) is much larger in the transient than in the steady state (when the color-opponent systems, thrown out-of--balance, reach their equilibrium).
- flicker adaptation (e.g. Pantle, 1971)(J.P.Harris et al. (1990)

AT THE OFFSET OF AN ADAPTING FIELD

* the blurring of the details in the after-image is not correlated with the fading of brightness (Brindley, 1962)

* in the achromatic case, detection threshold decreases,flicker threshold increases, as the time in the darkness elapses (Eisner, 1989; Coletta/Adams (1984)

* blue brightness is enhanced (Stiles, 1949) but differential sensitivity is transiently reduced (Mollon/Polden, 1977)

APPLICATIONS

-Yellow-tinted glasses, compared to luminance-matched neutral glasses, enhance brightness (even of 40%)(S.A.Kelly, 1990) but visual acuity does not seem to take profit of it.

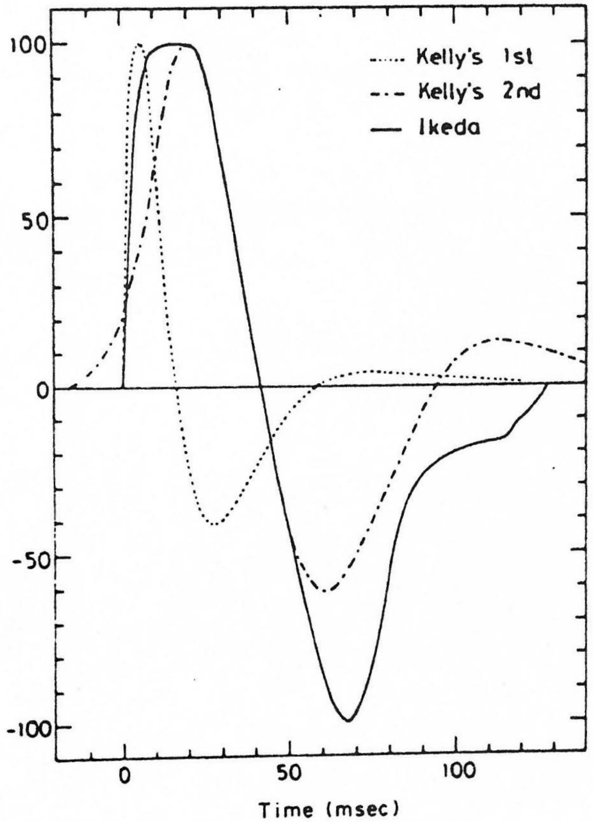
GENERAL

- Relation between threshold and appearance , in complex scenes : altered by the presence of a time variable surround (Krauskopf/Zaidi,1986; Guth, 1973; de Valois et al.1986)

M.Ikeda

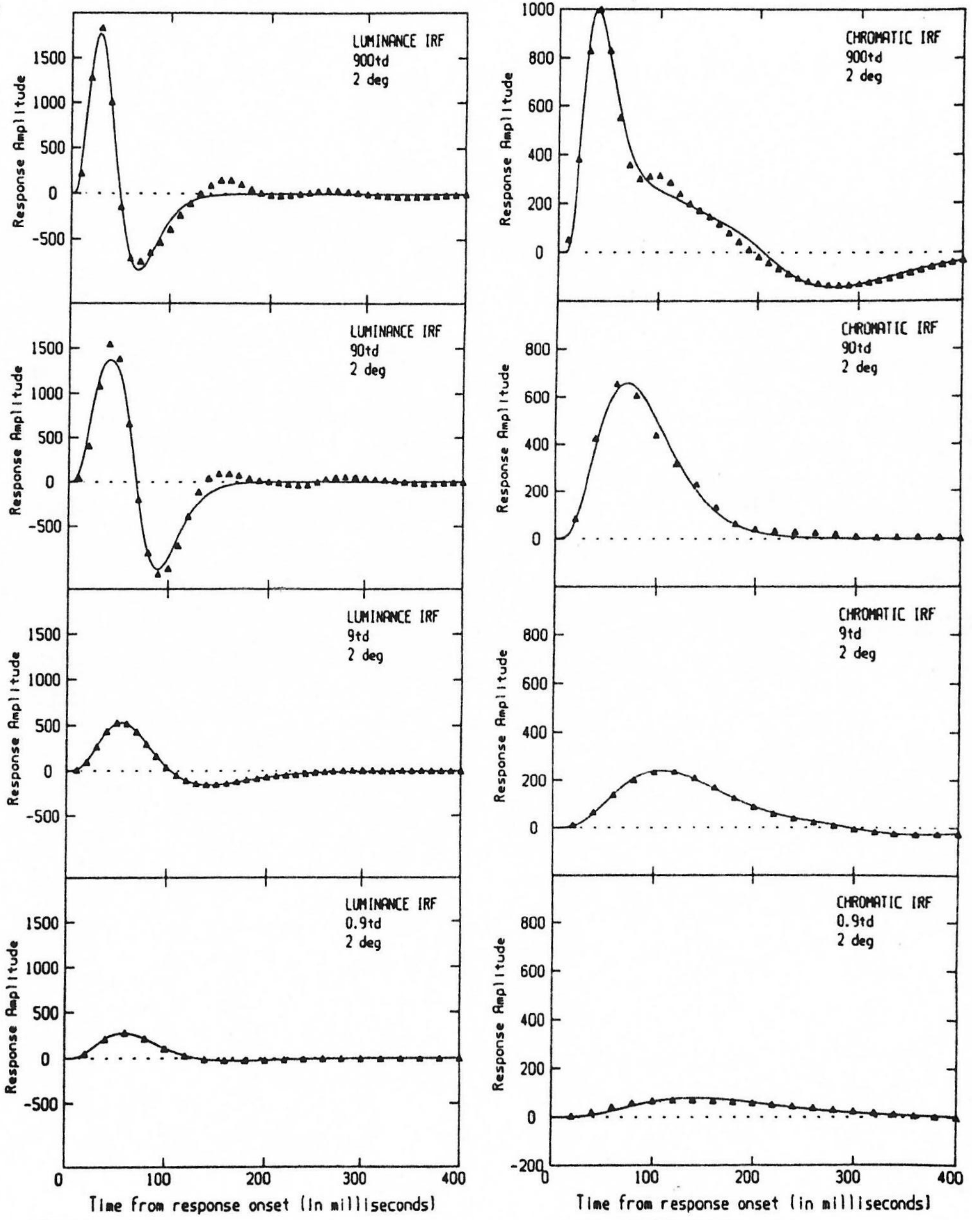
TEMPORAL IMPULSE RESPONSE

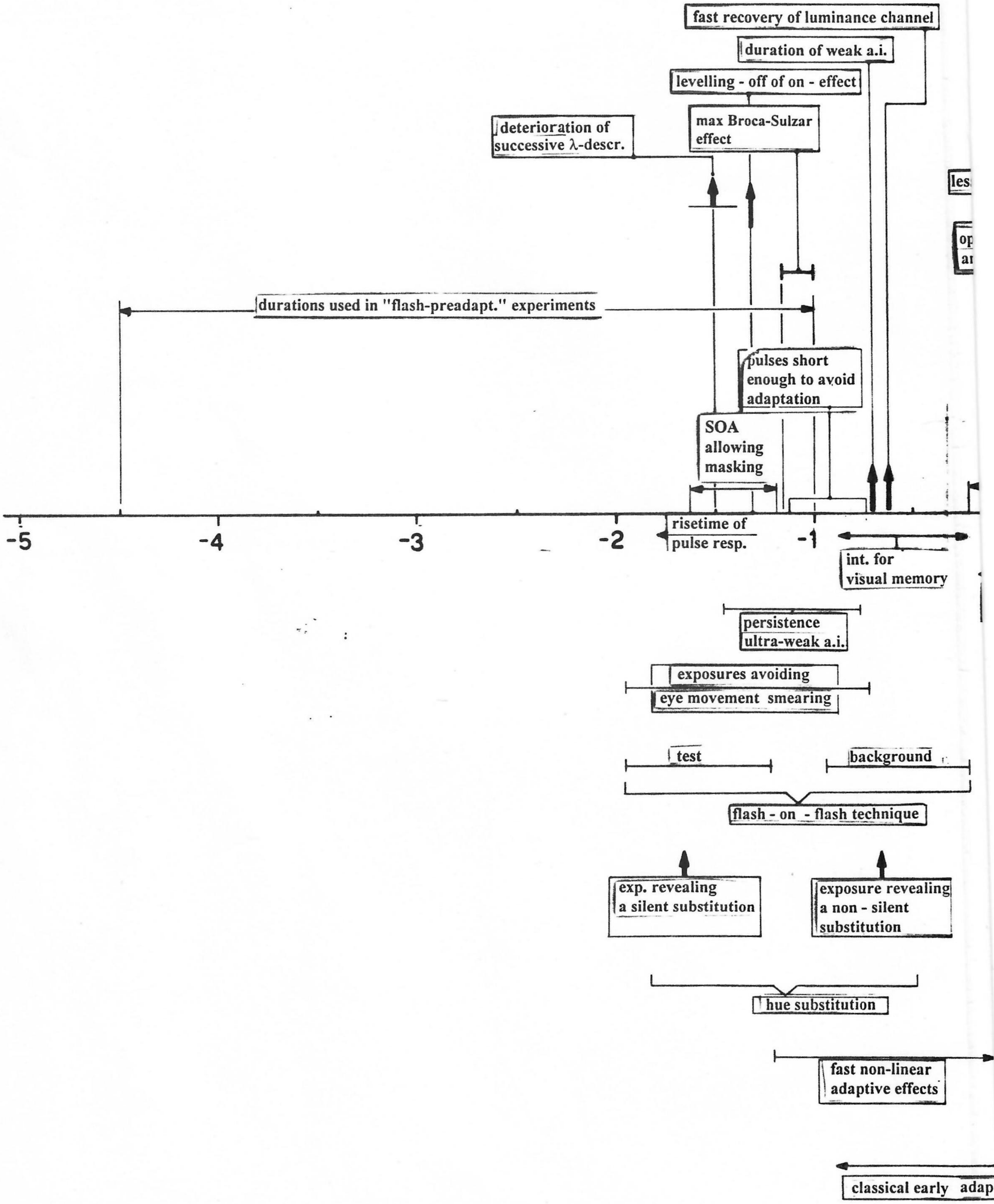
Vision Res. 9, 1431,(1986)



from:W.H.Swanson,T.Ueno, V.C.Smith and J.Pokorny

J.Opt.Soc.Am. A4 , 1992, (1987)




fast recovery of luminance channel
duration of weak a.i.
levelling - off of on - effect
max Broca-Sulzar effect
deterioration of successive λ-descr.
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durations used in "flash-preadapt." experiments
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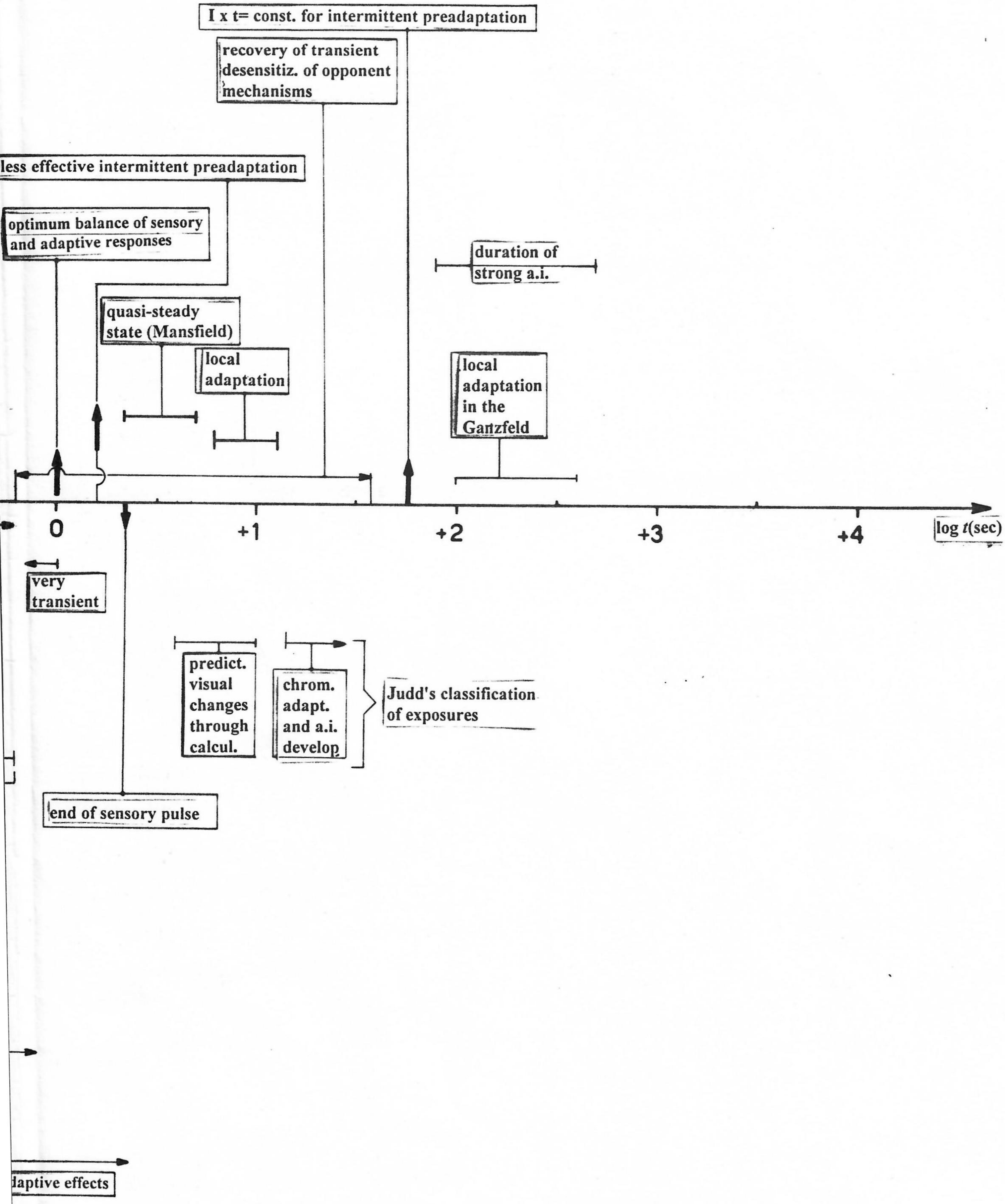
risetime of pulse resp.
int. for visual memory
persistence ultra-weak a.i.
exposures avoiding eye movement smearing
test
background
flash - on - flash technique
exp. revealing a silent substitution
exposure revealing a non - silent substitution
hue substitution
fast non-linear adaptive effects
classical early adap

Components of sensory (photic) and adaptive pulse responses



AIC 1994 INTERIM MEETING

IMAGES IN COLOUR

Programme

Sunday 10 April

16.00 Registration

18.00 Invited Lecture: Recent Advances in Colorimetry–Based Digital Imaging
R S Berns, Centre for Imaging Science, Rochester Institute of Technology USA

19.30 Dinner

Monday 11 April

8.00 Breakfast

9.00 Day Registration

9.15 Introduction and Welcome
Dr P M Forsyth

9.20 On the Definition of 'Quality' of Colour Images
Lucia R Ronchi, INO, Florence, Italy

9.55 A Name–Based Algorithm for Generating maximally Discriminable Colour Sets
Darren Van Laar and Richard Flavell, University of Portsmouth

10.30 Coffee

11.00 Uniform Colour Space for Colour Displays
Claudio Oleari, University of Parma, Italy

11.35 DSP Algorithms for Colouring Black and White Still Images
Hussian Al–Ahmad, University of Bradford

12.30 Lunch

13.30 Evaluation of a Colour Reproduction Index of Images on a Soft Display
R E Jacobson, GG Attridge, P Parmar and M R Pointer, University Westminster

14.05 Improving Estimates of Gamma when Calibrating Visual Displays
Darren Van Laar and Richard Flavell, University of Portsmouth

14.40 Spatial and Tonal Resolution in Desk–Top Publishing
R W G Hunt, City University, London

15.15 Tea

16.15 Bartleson Introduction

16.45 Bartleson Lecture: Magnitude Estimation Technique for Colour Appearance Research
M R Luo, University of Derby

19.00 Dinner

Tuesday 12 April

8.00 Breakfast

9.00 Day Registration

9.15 Introduction

9.20 Invited Lecture: Colour Science in Photography
G G Attridge, University of Westminster, London

10.05 Coffee

10.30 Testing Colour Appearance Models in Cross–Media Image Reproduction
Mark D Fairchild and Karen Rybarczyk, Centre for Imaging Science RIT, USA

11.05 Learning Colour Constancy
A C Hurlbert and W Wen, Medical school, Newcastle–Upon–Tyne

11.40 Paul Klee: Imagery and Imagination
Roy Osborne

12.30 Lunch

13.30 Colour Images Direct from Painting: Applications in Conservation
David Saunders, The National Gallery, London

14.05 Models for Characterising Four–Primary Imaging Devices
M C Lo and M R Luo, University of Derby

14.40 Extending the colour gamut of printed images
L W MacDonald and J M Deane, Crosfield Electronics Ltd

15.15 Close
Lucia Ronchi

15.30 Tea

AIC Symposium - Images in Colour - Delegate List - 25 March 1994

Werner Adrian	University of Waterloo, Ontario, Canada
Paula Alessi	Eastman Kodak Company, Rochester, U.S.A.
Geoffrey Attridge	University of Westminster, London
Mike Austin	The Royal Photographic Society, Bath
Lionel Baker	SPIE
Mrs Trudi Bartleson	Pittsford, U.S.A.
Roy Berns	Rochester Institute of Technology U.S.A.
Peter Bodrogi	University of Veszprem, Hungary
Dr C Conboy	Xaar Limited, Cambridge
Richard Crocker	Manchester Metropolitan University
Osvaldo Da Pos	Department of Psychology, Padua
Mark Fairchild	Rochester Institute of Technology U.S.A.
Adrian Ford	University of Westminster, London
Patrick Forsyth	The Colour Group (Great Britain)
Dr M C A Griffin	Xaar Limited, Cambridge
Margaret Halstead	The Colour Group (Great Britain)
Andrew Hanson	National Physical Laboratory, Teddington
Chris Hawkyard	UMIST, Manchester
Paul Hoffenberg	Datacolor International, Lawrenceville, New Jersey
Robert Hunt	Northwood, Middlesex
Ralph Jacobson	University of Westminster, London
Norbert Johnson	3M Center, St Paul, U.S.A.
Ian Kelly	Brighton
Wen-Guey Kuo	Loughborough University, Loughborough
Mei-chun Lo	Loughborough University, Loughborough
Dr A Logvinenko	Queens University, Belfast
Reinhard Lorenz	Ettlingen, Germany
Ronnier Luo	University of Derby, Derby
Tony Mortimer	PIRA International, Leatherhead
Roma Nath	The Colour Group (Great Britain)
Anders Nilsson	Scandinavian Colour Institute, Stockholm, Sweden
Claudio Oleari	University of Parma, Italy
Roy Osborne	London
Jake Palmer	University of Westminster, London
Paresh Parmar	University of Westminster, London
Danny Rich	Datacolor International, Lawrenceville, New Jersey
Alan Robertson	National Research Council, Canada
Frank Rochow	LMT Lichtmesstechnik, Berlin, Germany
Lucia Ronchi	Institute of Optics, Florence, Italy
Ms M V Ryckevorsel	Amsterdam, The Netherlands
Arthur Saunders	Kodak Limited, Harrow
Marcus Scott-Taggart	PIRA International, Leatherhead
Lars Sivik	University of Goteburg, Sweden
Flt Lt P J Smith	RSDC Jaric, RAF Brampton
Mr D Spitzer	AKZO Coatings, Sassenheim,The Netherlands
Ingeburg Tastl	Technical University of Vienna, Austria
Heinz Tersteige	BAM, Berlin, Germany
Gunnar Tonnquist	Scandinavian Colour Institute, Stockholm, Sweden
C van Trigt	Heeze, The Netherlands
Darren Van Laar	University of Portsmouth
John Verrill	National Physical Laboratory, Teddington
Dr S Westland	Keele University, Staffs
David Wright	Radlett, Herts