DALTONIANA

NEWSLETTER
OF THE INTERNATIONAL RESEARCH GROUP ON COLOUR VISION DEFICIENCIES

President: **Prof A ROTH (Switzerland)**

General Secretary & Newsletter Editor
Prof J D MORELAND
Department of Communication & Neuroscience
University of Keele
KEELE Staffs. ST5 5BG UK

Treasurer
Mrs J BIRCH
The City University
Northampton Square
LONDON ECW 0HB UK

Secretary-Treasurer for the Americas
Dr B DRUM
Wilmer Institute, B-27, Johns Hopkins Hospital
601 N Broadway
BALTIMORE MD 21205 USA

Secretary-Treasurer for the Socialist Countries
Prof M MARRÉ
Universitäts-Augenklinik
Fetscherstraße 74
8019 DRESDEN DDR

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IRGCVD News

The Directorial Committee met on 26 March during the Regional Symposium in Tokyo.

Present:	Dain, Marré, Moreland, Ohta, Pokorny, Roth, Serra.
Written Contributions:	Birch, Drum, Mollon, Zrenner.

1) 1991 IRGCVD Symposium, Sydney, Australia: Planning by the local organizer Stephen Dain is well advanced. The meeting dates are 20-23 June. Arrangements are being made for a joint one-day meeting with the International Association for Colour (AIC) on 24 June just before its own meeting in Sydney 26-28 June. Positive steps will be taken to encourage student attendance. It may be possible to announce details in the next issue of Daltoniana.

2) Proceedings review: Our Editor, Bruce Drum, has worked very hard to improve the standard of papers published in the Symposium Proceedings. The Cagliari papers have been processed by a system of limited peer review. In addition to the usual editing for good English, reviewers (IRGCVD members selected for their special expertise) made suggestions for improvement and, indeed, this review procedure has produced a substantial improvement in many papers. However, there still remain some with inconsistent or uninterpretable data and others whose authors did not respond to suggestions or to requests for crucial information.

This uneven quality was much more pronounced in the past and it has led some contributors to withhold their manuscripts from the Proceedings in favour of submission to a refereed journal. Your Committee proposes extending the present supportive review process by publishing basic standard requirements for authors and adding, to the existing Directorial right of rejection, one based on unanimous agreement of the Editor and a minimum of two reviewers. It should be emphasized that a reviewer's primary role will be supportive and, where changes in a manuscript are required to meet the acceptance standard, specific positive guidance will be offered to the author.

This extension of the review process would not exclude clinically oriented papers but it would ensure a uniform minimum standard which would help to win back authors who prefer to publish in "respectable" journals.

3) Membership fees: The membership fee has remained at UK£10 since 1979. Increased operating costs have obliged us to revise the fees. Your committee has used this opportunity to review membership policy positively. Two important decisions emerged from its discussions: a) Symposium Proceedings would be made available to all members (the resultant increased bulk order produces a significant reduction in the unit price from the publishers) and b) Student membership will be instituted.

The new fees which take effect this year are as follows:

Full member:	UK£30 (receives Daltoniana + proceedings)
Student member:	UK£10 (receives Daltoniana)
Honorary member:	no fee (receives Daltoniana)

Members, who are retired, can opt to receive only Daltoniana at a fee of UK£10 by writing to the treasurer. Student status should be established by a supervisor's supporting letter addressed to the treasurer.

Of course, student, honorary and retired members would be able to purchase individual current Proceedings at the appropriate bulk price.

Honorary Member

At a General Meeting of members at the Tokyo Symposium on 27 March, in recognition of his outstanding achievements in the field of colour vision and of his services to the IRGCVD, Prof Dr-Ing habil Manfred Richter was elected an honorary member.

Congratulations

On behalf of all IRGCVD members, Daltoniana offers its congratulations and best wishes to Kenji Kitahara on his election to the chair in Ophthalmology at the Jikei University School of Medicine.

New Members

Dr D A Atchison
Department of Optometry
Queensland Institute of Technology
2 George Street
PO Box 2434
Brisbane Q4001
Australia

Prof Pascual Capilla
Escuela Universitaria de Optica
Universidad de Alicante
Alicante
Spain

Correction

Daltoniana apologizes to Dr. Shi-zhou HUANG whose name in the membership list (Daltoniana 65) is abbreviated incorrectly as Dr. H. Shi-Zhou.

Cagliari Symposium Proceedings

These are expected to be published later this year. There is still a shortfall in meeting the publisher's minimum order (of 140 on which the volume price was fixed). An advertisment which appeared in Daltoniana No. 65 netted 33 extra orders. Another 20 or more orders are needed. There is an order form on the last page, so be sure to send it if you need a copy for yourself or your institution.

Regional Symposium: Tokyo

The Regional IRGCVD Symposium, March 26-28, 1990 Tokyo, Japan was held at the Tokyo Medical College. The meeting was recognized as a satellite Symposium of the 26th International Congress of Ophthalmology. Daltoniana extends its congratulations to Professor Yasuo Ohta and his organizing committee on a splendid Symposium.

The Symposium, which included an exhibition, was divided into 7 sessions with 7 invited and 29 contributed papers. Unfortunately, two papers from China and one from Finland could not be presented. The Proceedings are to be published by Kugler and Ghedini.

The edited abstracts of presented papers are printed below.

SESSION A

Color appearance and the cone mosaic in trichromacy and dichromacy. C M Cicerone, University of California, Irvine, USA. **(Invited Paper)**

The relative numbers of the different cone types in the living human eye have been estimated by means of a detection model and its application to measurements of the detection of small spots of light under conditions of chromatic adaptation. For our sample of 9 color normal trichromats, measurements in the fovea centralis yield a range in the ratio of numbers of L to M cones which spans 1.51 to 2.47 with a mean value of 2.05 (0.12 SEM). In addition to the well-known decline in density of cones with eccentricity, our results indicate that the relative numbers of L to M cones remain constant up to 4 deg in the temporal retina. We have investigated the relationship between the relative numbers of the different cone types and the red/green opponent site by comparing measured values of unique yellow and unique blue to predictions based on our measured ratios of the different cone types. The predictions match the measured unique hues for our individual observers and the range of L to M cones that we

measure predicts the 20nm range in unique yellow as reported in the literature. Using these methods, we have also estimated the density of cones in the fovea centralis of 3 deuteranopes and 3 protanopes and have concluded that the density of cones in the dichromat equals that in the trichromat. The extent to which a reduced form of red/green discrimination is preserved in the protanope will be discussed. (Supported by BNS-8819874/EY08649.)

A relation on brightness/luminance ratio between illuminant and object colors. Y Nayatani, Osaka Electro-Communication University, Neyagawa, Japan.

In a heterochromatic brightness match between a chromatic and a white light stimulus kept at the same luminance, it is generally confirmed that the former is brighter than the latter (the Helmholtz-Kohlrausch Effect). Specially, for the spectral colors, the luminosity function for the heterochromatic brightness match was recommended by CIE TC 1.02 (Luminous Efficiency Function). On the other hand, the results of the heterochromatic brightness match for object colors or color stimuli with object color mode were reported by Wyszecki and Sanders-Wyszecki. However, Ware and Cowan reported in the study of CIE TC 1.03 (Models for Heterochromatic Brightness Matching) that the brightness/luminance (B/L) ratio characteristics for chromatic colors were different between chromatic-light stimuli and chromatic object colors. To confirm this, the present author made the following analyses by using his existing model of chromatic object colors already proposed: (1) Confirmation of the effectiveness of the model to predict the experimental results of object colors, and (2) prediction of the luminosity function spectral colors for the heterochromatic brightness match by extrapolating the model. It was found that the predicted luminosity function was very close to that recommended by CIE TC 1.03. The following conclusions were derived. (1) The same relation holds for the brightness/luminance ratio between chromatic light stimuli and chromatic object colors. (2) The author's model is effective for predicting the brightness of various chromatic colors.

Color appearance in mesopic vision. H Yaguchi, C Monma, K Tokunaga and Y Miyake, Faculty of Engineering, Chiba University, Chiba, Japan.

Color appearances for 17 color chips under 9 illuminance levels from 0.03 lux to 316 lux were estimated by the color naming method based on the Natural Color System (NCS). In the NCS, colors are described in terms of the relative amount of the basic colors that are perceived to be present; these amounts are expressed as percentages. Six basic perceived colors are used in the NCS; they are whiteness, blackness, redness, greenness, yellowness and blueness. The sum of the hue components is called chromaticness. The experimental results show that chromaticness decreased and the whiteness and blackness increased with decreasing illuminance. This property was particularly enhanced for red color chips but whiteness did not change with illuminance. For bluish color, whiteness increases at the illuminance level lower than 0.1 lux. No apparent hue shift caused by changing illuminance was observed except for bluish green color chips. Bluish green was perceived more bluish at the low illuminance level. The perceived color at the various illuminance levels were reproduced on a color CRT monitor by the computer simulation.

Color appearance at extra-fovea studied by color naming method. M Takase and M Ikeda, National Defence Academy, Yokosuka and Tokyo Institute of Technology, Yokohama, Japan.

It is said that the red-green opponent color system deteriorates faster than the yellow-blue opponent color system towards the periphery of the retina showing a shift of color vision towards deuteranopic vision. In this paper the color vision of a normal subject was tested foveally and parafoveally by using 195 different colored lights of 120 Td covering the entire area of the chromaticity diagram and by using restricted sets of 35 and 34 colored lights, from the 195, at 10° and 30° nasal retina on the 0° meridian. The color naming method was employed where a subject rated each stimulus in terms of chromatic and achromatic components, and then the chromatic component in terms of red, yellow, green and blue hues.
All lights appeared less saturated when they were viewed extra-foveally confirming earlier work. As for the chromatic components, however, red and green decreased rapidly and blue more rapidly extra-foveally but yellow only slowly. It was concluded, therefore, that extra-foveal color vision does not necessarily follow deuteranopic vision.

Effects of color memory on color appearance. K Uchikawa and H Shinoda, Tokyo Institute of Technology Graduate School, Yokohama, Japan

Color appearance change of colored stimuli in memory was studied by a successive comparison method between memory and test stimuli. The stimuli were generated on a color CRT monitor. Two memory stimuli were successively presented for 1s each with 1s ISI and then, 2s later, two test stimuli, one of which was the same color as either of the two memory stimuli, were presented in the same way as the memory stimuli. The observer identified which test stimulus appeared the same as one of the memory stimuli by the forced-choice method. Two observers with normal color vision were employed. The results show that when memory and test stimuli were varied along a red-green direction a yellow-green stimulus was never influenced by an orange stimulus, but strongly influenced by a green-yellow stimuli in color memory, although the orange and the green-yellow stimuli were separated by the same discrimination steps in opposite directions from the yellow-green stimulus. This indicates that proximity of color appearance of two colors might be different in memory from that simultaneously observed, suggesting a categorical nature of color memory.

SESSION B

Aspects of anomalous trichromatic opponent-colour vision. H Scheibner, Physiologisches Institut II, Universität Düsseldorf, D-4000 Düsseldorf, FRG. **(Invited Paper)**

Starting with the fundamental colour triangle PDT (="red", "green", "blue" fundamental tristimulus values), it is shown how an opponent-colour triangle MSL can be constructed (M=blue-yellow chrominance, S=green-red chrominance, L=luminance). Taking advantage of the typical "alterations" (von Kries), by which protanomaly and deuteranomaly are characterised, it is shown how the fundamental colour triangle and the colour-opponent triangle have to be modified in order to reproduce the protanomalous and deuteranomalous alterations. Experimental results derived from a) protanomalous spectral colour matching and b) direct deuteranomalous determination of an opponent-colour triangle (including some Abney Effect) demonstrate the statements.

Temporal integration properties of color-defective vision measured by the critical durations for bichromatically mixed lights. Y Kawabata and T S Aiba, Hokkaido University, Sapporo, Japan.

The critical durations for temporal integration were examined in 3 protanopes and 2 deuteranopes as well as 2 protanomalous and 1 deuteranomalous subjects by means of incremental thresholds that were measured for a bichromatically mixed red/green or blue/yellow test light of various durations superimposed upon an achromatic background of different intensities. Our previous study with color normals (Color Research & Application 15, No 1, 1990) showed that the critical durations were markedly shortened when the red and green components in the test light were balanced in intensity. No such dependence on the red-green mixing ratio was manifested in the present study. Moreover, those for the monochromatic red or green test light under the 1000 td background were shorter for color defectives than for normals, although, for the bi-chromatic test light, they were more or less equivalent in the two groups. These results were interpreted as being due to the absence in the color defectives of the R/G opponent color system. With respect to the results for the blue/yellow bi-chromatic test light the color defectives (protanopes) did not appear to be much different from normals.

ERG recording with high speed scanning of monochromatic stimuli. M Sugimoto, N Miyamura and Y Uju, Department of Ophthalmology, Mie University School of Medicine, Mie, Japan.

Sixteen monochromatic lights, with peak wavelength in the range 400 to 700 nm at 20 nm intervals, were adjusted to equal energy. These stimuli were provided in a dark room successively in ascending or descending series and were modulated sinusoidally. The modulation frequency was changed from 3 to 40 Hz. Spectral ERG responses obtained could be evaluated as a pattern on the oscilloscope rectangular CRT. In scans using more than 20 Hz stimulus frequency, a spectral pattern with maximal response at middle wavelengths was obtained in normal subjects, reflecting cone system activity. On the other hand, protans showed a different balance of responses from that of normal subjects at long wavelengths. This method provides the possibility of objectively diagnosing colour blind subjects.

Electroretinographic findings in congenital red-green color deficiency. H Hidetoshi[1], T Johji[2] and K Kazuo[3]. 1: Fukui Prefecture Saiseikai Hospital, Fukui, Japan. 2,3: Kanazawa University, Kanazawa, Japan.

Among the components of human electroretinogram (ERG), the rapid off-response is composed mainly of cone potential. The authors deal with the ERG rapid off-response in congenital red-green color deficiency. Compared with normal color subjects, the mean spectral sensitivity of the rapid off-response is higher at short wavelength and lower at longer wavelength in protan subjects, and lower at short wavelength and higher at longer wavelength in deutan subjects. The ratio of the sensitivity at short wavelength (λ_1) to the sensitivity at long wavelength (λ_2) {sensitivity quotient, SQ (λ_1, λ_2)} was larger in every protan subject and smaller in every deutan subject compared with normal subjects. Protan and deutan subjects were divided into four grades (very mild, mild, moderate, strong). The SQ (λ_1, λ_2) did not differ significantly among the four grades but it must be emphasized that it was definitely abnormal even in the very mild grade who reads almost all pseudoisochromatic plates correctly. The SQ (λ_1, λ_2) was also studied in genetic carrier and typical congenital red-green color deficiency, ie, pigment test anomaly and spectral test anomaly. The SQ (λ_1, λ_2) was abnormal in some genetic carriers, in all cases of spectral test anomaly and in some cases of pigment test anomaly. These findings reveal abnormality at cone level. The SQ (λ_1, λ_2) is valuable for the objective diagnosis of congenital red-green color deficiency and understanding its pathogenesis.

Color vision estimated color reversal VECPs in patients with intraocular lens implant. M Tsukamoto, E Adachi-Usami, N Fujimoto, Department of Ophthalmology, School of Medicine, Chiba University, Chiba, Japan.

Using an equi-energy color pattern reversal stimulator, VECPs were recorded in 12 phakic and 27 pseudophakic eyes. Two complementary color checks along the confusion axis for protan, deutan and tritan where energies were equal, reversed 3/second, were displayed on a TV monitor.
The peak latency of the P 100 component for the three test stimuli was significantly prolonged in the elderly subjects and it was most obvious for tritan stimuli suggesting a more prominent blue-yellow defect. To exclude the effect of the lens, the same recordings were done on eyes with a posterior chamber lens, divided into two groups, those with PMMA and those with UV400. Age-matched normal phakic eyes were tested as control. No significant difference was found between phakic and pseudophakic eyes. Subjective tests for eyes with a UV400 intraocular lens showed slight decrease of misreading rate of Standard Pseudoisochromatic Plates Part 2, total error score of Farnsworth-Munsell 100-Hue Test and difference score (Smith) indicating better color vision but the differences were not significant.

SESSION C

Multiplexing and demultiplexing chromatic and achromatic contrast in visual cortex. P Gouras, Department of Ophthalmology, Columbia University, New York, USA. **(Invited Paper)**

Primates have five sets of on and off channels subserving the same arrays of L, M and S cones. Four subserve the L and M cones, one serves the S cones. The S set and three of the L and M sets go to the parvocellular layers of the geniculate. Two of these L and M sets multiplex chromatic with achromatic signals. In the fovea these channels serve only one cone, transmitting the highest spatial resolution. In striate cortex, an achromatic circuit (interblobs) demultiplexes the high spatial resolution signal by forming large numbers of orientation selective channels using each L and/or M cone indiscriminately as unit areas of achromatic space. A separate system (blobs) uses the same L and M cone channels discriminately for chromatic contrast. In order to eliminate ambiguity from achromatic contrast, high spatial resolution must be sacrificed. For this reason a unit area of chromatic space is larger than a unit area of achromatic space and the number of chromatic orientation channels reduced. Within each unit area of chromatic space the four sets of parvo-channels may be organized into single opponent detectors, each member excited by a selected quality; red, green, yellow, blue, white and black. Double opponency occurs across areas of chromatic space. Therefore separate achromatic and chromatic contrast detecting systems are established with retinotopic order in visual cortex.

Color vision and pattern reversal VECPs in a family of dominantly inherited juvenile optic atrophy E Adachi-Usami, E Kato, M Tsukamoto, Department of Ophthalmology, School of Medicine, Chiba University, Chiba, Japan.

Three patients in a family with autosomal dominant juvenile optic atrophy were studied. Subjective color tests showed tritan deficiencies and the amplitudes of pattern reversal VECPs (visually evoked cortical potentials) for the transient and steady-state stimuli reduced remarkably. Both color vision and VECP abnormalities were found to progress with increasing age. It was, thus, suggested that the visual disfunction of the disease is progressive heredodegenerative as Jaeger pointed out.

Analysis of feature extraction processing in the red-green system. Y Ejima, S Takahashi and T Kaihara, Kyoto University, Kyoto, Japan.

This paper presents a logical rationale for color-coding in the human visual system. The intermediate neural structures of the red-green system, involving the opponent color and the double-opponent processes, are analyzed within the context of known physiologic limitations. The high signal correlation between L and M cones resulting from the overlap of their spectral sensitivity curves is beneficial to encode spatial and spectral information simultaneously and efficiently. The red-green opponent-color neurons make up a map and represent an array of preset processes or filters, each tuned slightly differently, that operate in parallel on the afferent signal. This functional parallelism makes it possible that lateral inhibition serves a dynamic readjustment of a neuron's operating range necessary to meet criterion of efficiency as energy compression or minimization of information capacity. Further processing at the double-opponent stage forms three independent sets of features of hue and brightness contrast, which provide the visual cues to the recognition of objects. The development of stimulus selectivities or the formation of features at this stage is influenced extensively by the patterns of correlated neuronal activity generated by visual experience.

Studies on SWS cone mechanism by measures of the probe-flash threshold. H Terasaki[1], Y Okada[1] and H Hirose[2]. 1: Nagoya University School of Medicine, Nagoya, Japan. 2: National Nagoya Hospital, Nagoya, Japan.

Selective sensitivity loss of SWS cone mechanism has been reported in many retinal disorders with various psychophysical examinations. We have studied blue cone mechanism in normals and patients suffering from some retinal disease by the modified method of the probe-flash threshold reported by D. Hood in 1982. That is, increment thresholds were measured using a three channel Maxwellian viewing system in which a 1° spot was flashed for 50msec on a 2° spot flashing for 500msec on steady background field of 13° . This technique has some advantage compared with no flashing steady background. The result revealed that normals demonstrated a threshold sharply rising with flash intensity, which showed no significant difference between the reattached retina with good visual acuity and normals. However, a significant sensitivity loss and slow rising intensity curve were found in diabetic retinopathy with good visual acuity and with almost normal response in clinical color tests. These results suggest that neural response in inner layer rather than photoreceptor response in outer layer will contribute to the response function obtained by this approach and suggest the possibility of application in layer by layer diagnosis in retinal diseases.

Spectral sensitivity of cone mechanism in the cynomolgus monkey studied with local macular electroretinogram. H Ozaki, J Yanase, T Kasuga, A Ogura, and H Joho, Product Development Laboratories, Yamanouchi Pharmaceutical Co Ltd, Tokyo, Japan.

Spectral sensitivity of cone mechanism in the cynomolgus monkey was studied with local macular electroretinogram recorded at the cornea, in response to flickering stimuli from 1.5 Hz to 40 Hz, by response averaging and synchronous detection.
The amplitude criteria derived from increment threshold response of b-wave elicited by the low frequency test light superimposed on a white back-ground revealed spectral sensitivity function with three peaks that occurred at about 450, 540 and 610 nm. The results, reflecting colour opponent interaction, resembled psychophysical spectral sensitivity function of human subject measured with similar conditions. Whereas, at higher frequency test light the spectral sensitivity function could be described by three different functions which depended on stimulus frequency and stimulus size.

SESSION D

The clinical utility of anomaloscopy. J D Moreland, University of Keele, Keele, UK. **(Invited Paper)**

An anomaloscope match, designed to assess cone function, is achieved ideally by comparing a variable mixture of two spectral stimuli on a dichromatic confusion line with an intermediate test stimulus. The match has 3 parameters: matching range, mid-match point and test luminance. These provide, respectively, measures of colour discrimination, normal or anomalous photopigment spectra (if range is acceptably small) and spectral sensitivity. These measures have diagnostic significance for congenital and for acquired colour vision deficiencies.
The Rayleigh match (Red + Green = Yellow) is used to assess long-wave and middle-wave cone function. Its utility in studies of congenital and acquired deficiencies is well established.
A blue-green match (Blue + Green = Cyan) can be used to assess short-wave cone function: highly relevant in ophthalmic disease diagnosis and follow-up but its use is beset with problems. At short wavelengths conventional light sources have low luminosity. In addition, normal variability in macular and in lens spectral absorbance is higher than for the primaries of Rayleigh's match. Macular pigment variance, in particular, causes a significant loss of diagnostic precision in Engelking's (1925) blue-green match and in the modifications which were introduced by Trendelenburg in 1941 and by Jaeger in 1981. This paper traces the development of blue-green equations from Engelking's match through to the highly sensitive Moreland (1978, 1984) match of the present time.

A computer simulation of anomalous colour vision. S Kondo, Faculty of Engineering, Shinshu University, Japan.

Phenomena associated with congenital colour vision defects are simulated. Panel D-15 Test result shows very good agreement with that obtained by real observers.
Simulation on the colour appearance of the defective observers will be presented using colour slides. A model of defective colour vision, which is proposed by the author for applying to the simulation, is derived by taking account of factors such as confusion lines and copunctal points, luminosity curves, neutral points, unique hues observed by unilaterally defective observers, etc . .

The F-M 100 hue test as a tool in a visual laboratory. L R Ronchi, Instituto Nazionale di Ottica, Florence, Italy.

Recent visual research has demonstrated that color discrimination is linked to contrast detection rather than to spatial resolution. This is in line with the limited "capacity" of the visual system, as well as with the coming into play of tritanopia under "difficult" viewing conditions.
An experiment is here described, where the caps of the 100 Hue Test are used as test-objects. Instead of "arranging" them, the observer is requested to estimate the perceptual difference of paired caps, according to a subjective five point scale.
The evaluation of the defect or anomaly is thus quantified and compared on the one hand to the "color difference" in a Fechnerian framework, and on the other hand to the traditional error score.

Cases of deuteranomaly displaying atypical Rayleigh matches. S Yamade and M Kono, Department of Ophthalmology, Shiga University of Medical Science, Ohtsu, Japan.

This study presents 9 cases of deuteranomaly which showed atypical Rayleigh matches. Two are pigment color defects, displaying errors on plate tests, Panel D-15 and lantern test but which show normal Rayleigh matches on the anomaloscope; 5 are cases whose matches are distributed around the normal; and 2 are cases whose Rayleigh matches lie on the red side (mixture scale 55). The authors discuss the interpretation of the Rayleigh matches in these cases, stressing that what is important is not the mixture scale alone, but their location in the anomaloscope coordinate system represented by the mixture and test scales. Attention should be payed to whether the point lies on the protanopic matching line or on the deuteranopic matching line. Brightness matching was performed on the anomaloscope with the direct comparison method for the 2 cases of pigment color defect and several of the other cases. Since the brightness matches were on the deuteranopic line, these cases were suspected of being a kind of deuteranomaly.

Transient tritanopia effect and focal macular ERG in central serous retinopathy. Y Miyake, K Ichikawa, N Shiroyama and H Ichikawa, Department of Ophthalmology, Nagoya University School of Medicine, Nagoya, Japan.

A blue sensation in the presence of a bright yellow adapting field remains invisible for several seconds after the yellow field has been turned off. This transient tritanopia effect (TTE) is considered to be due to inhibition of B cones by L cones through the horizontal cell (Zrenner and Gouras, 1980). Our comparable evaluation of the TTE and B cone sensitivity in clinical diseases indicated that receptor disease (such as retinitis pigmentosa) shows the reduction of TTE and B cone sensitivity, while inner retinal disease (such as glaucoma) shows reduced B cone sensitivity with normal TTE. In the convalescent stage of central serous retinopathy (CSR), we found the condition in focal macular ERG where only the oscillatory potentials (OPs) remain affected despite a- and b-wave recovery to near normal level. This result suggests some subclinical abnormality in the inner retinal layer where OPs are generated.
We evaluated TTE and B cone sensitivity in two CSR patients with selectively reduced macular OPs. In both patients, the B cone sensitivity was significantly reduced but the TTE was normal. Thus, in the convalescent state of CSR, abnormal function in the inner retina was suggested by the comparative evaluation of TTE and B cone sensitivity, as well as by focal macular ERG.

SESSION E

The power of metameric color equations in testing color vision. A Roth, Clinique Universitaire d'Ophtalmologie, Geneva, Switzerland. **(Invited Paper)**

Metameric color equations provide two kinds of information: (i) The position of the match-midpoint (MMP), which defines the color mixture at the match, (ii) the width of the matching range (MR), which gives the hue discrimination around the match.
Each of these parameters can be normal or abnormal. An abnormal MMP is related to shifted spectral sensitivities, ie, scotopisation. An abnormal MR is related to a reduced hue discrimination.
Recent neurophysiological experience demonstrates that only two metameric equations, a red-green equation (Rayleigh) and a blue-green equation (Moreland), are needed to test accurately the three color vision mechanisms from the photopigments of the receptors to the color opponent pathways of the visual system. This procedure, "the two equation method", is used in Geneva as a reliable and precise test for the clinical diagnosis of all color vision defects. In our experience, no clinically relevant information is missed by this simple test. More specific color vision tests like measurements of spectral sensitivity, measurements of hue or saturation discrimination, measurements of the three color mechanisms, etc might bring, at the cost of time consuming testing, interesting complementary information that is, however, not needed for the clinical diagnosis.

Analysis of tritan detection thresholds and discrimination errors. J Pokorny, V C Smith and T Yeh, Eye Research Laboratories, University of Chicago, Chicago, USA.

The type III acquired blue-yellow color vision defect is characterized by failure of screening plates (e.g. the Standard Pseudo-isochromatic Plates, Part II) and an accumulation of errors on the Farnsworth-Munsell 100-hue test. Recent studies of acquired color vision defects have included specialized tests of increment detection for the isolated S (Short Wavelength Sensitive) cone system. A puzzling aspect in at least one such study was the lack of correlation between evidence of S cone loss on increment detection and evidence of S cone loss on the FM-100-hue test. The purpose of this paper is to attempt to reconcile these findings and to provide a unified framework for analyzing detection and discrimination data. Our starting point is Boynton and Kambe's (Color Res Appl.5: 13-23, 1980) analysis of color discrimination data. They introduced the concept of the S-cone troland, defining it as the amount of S-cone excitation produced by an equal energy spectrum of 1 troland retinal illuminance. We calculate the S-cone troland levels for a variety of increment threshold stimulus conditions and for FM 100-hue caps at various illumination levels. Once the S-cone trolands are known, a TVI (threshold vs illuminance) curve can be constructed. There are two regions of the function which are of interest. At low background levels, the incremental threshold is independent of background luminance and represents a measure of the absolute threshold for the S cone system. At high luminances the incremental threshold is proportional to the background and represents the radiance region within which Weber's law is operative. We describe two hypothetical changes in S cone function with disease. First, a sensitivity loss mechanism in which the receptors are less sensitive to light (neutral density hypothesis). Second, we consider a disease process in which the functional consequence is a decrease in the ability to see differences between lights. These mechanisms change TVI functions in distinct ways. We describe expected performance on increment threshold and FM 100-hue tests based on these two physiologically plausible mechanisms.

Congenital deuteranomaly in one of monozygotic triplets. A Yokota[1], Y Shin[1], J Kimura[1], T Senoo[1], R Seki[1] and K Tsubota[2]. 1: Department of Ophthalmology, Dokkyo University School of Medicine, Tochigi, Japan. 2: Department of Ophthalmology, National Tochigi Hospital, Tochigi, Japan.

Deuteranomaly-like abnormalities were noted in just one triplet. Blood type and salivary type examinations, etc. showed that these triplets were monozygotic at a probability of 99.99%. As a result of pseudoisochromatic plate, panel D-15, FM 100-hue and anomaloscopic examinations, the symptom was diagnosed as typical congenital deuteranomaly without any differences between the right and left eyes. General ophthalmological examination, including visual acuity, visual field, critical fusion frequency, and fundus examination, revealed no abnormalities. Chromosome examination proved normal as 46XX. Upon investigation of the family background of the triplets, neither of the other two triplets, their brother or their parents had color anomaly, but their maternal grandfather was found to have deuteranopia. From these findings, the triplet was considered to have congenital deuteranomaly. It is not known, however, what mechanism led to the onset of the congenital color anomaly in just one of these monozygotic triplets.

SESSION F

Color matching as a clinical tool. J Pokorny, Eye Research Laboratories, University of Chicago, Chicago, USA. **(Invited Paper)**

Color matching is the definitive technique for documenting normal color vision and for diagnosing congenital color vision defects. The efficacy of the technique lies in the widely accepted supposition that color matching reflects directly the number and spectral sensitivities of the active receptor types. Color matching behavior may be modified by systemic or ophthalmic disease. There are two major ways in which disease alters color matching; the match-midpoint may be shifted (an alteration of normal color vision) and/or the match-width may be enlarged (a reduction of normal color vision). The nature of the change often allows precise interpretation of the etiology of the functional change. Simplified procedures which we use for clinical evaluation include a match of a "yellow" to a mixture of "red" and "green" (the Rayleigh equation) and a match of "blue-green" to a mixture of "blue" and "green" (the Moreland equation). To evaluate reduced forms of color vision we use a match of "green" to a mixture of "red" and "blue" (a dichromatic coefficient). Examples will be given of alterations systems (both prereceptoral and retinal) and reduction systems (both receptoral and neural).

The effect of colour vision test design on the tritan defect observed with short duration stimuli. S Dain, J Riley and A Steer, University of New South Wales, Kensington, Australia.

A number of studies have shown that tritan errors are made with tests like the City University Test (CUT), with short duration presentations. The tritan errors may be a function of test bias in that the normal colour difference involved in a tritan response may be smaller than for protan and deutan responses. This difference can be as high as one half in the CUT. This study assesses the significance of the colorimetric bias in the construction of the CUT to the short duration tritan errors. In order to assess whether the tritan responses remained when an unbiassed test design is used, we constructed a test with the same physical construction as the CUT but with equal (as far as possible) colour differences for tritan, protan and deutan responses. The CUT and new test were administered to ten subjects with normal colour vision at durations ranging from 4ms to 1s using conditions and procedures which otherwise complied with the CUT instructions. Comparing the two tests, the frequencies of total number of errors and tritan

errors as a function of viewing duration were not significantly different and were highly correlated. It was also noted that the frequencies of errors differed significantly between the two series within the CUT indicating that, unlike congenital red-green deficiencies, for tritan deficiencies the two series do represent different levels of difficulty. We conclude that short duration tritan responses remain even when test bias is eliminated and that the CUT provides a valid two level extent diagnosis of tritan deficiencies.

The different action of anticonvulsant drugs on colour vision. A Bayer[1,2], E Zrenner[1], W Paulus[2] S Reid[3] and D Schmidt[3]. 1: Department of Ophthalmology, University of Tübingen, FRG. 2: Department of Neurology, Ludwig-Maximilians-University, Munich, FRG. 3: Department of Neurology, Freie Universität, Berlin, FRG.

Psychophysical and electrophysiological data obtained in 57 patients suffering from epileptic seizures indicate that Diphenylhydantoin, Carbamazepine, Valproic Acid and gamma-vinyl-GABA affect colour vision in different ways probably related to the different mechanisms of drug action.
The Farnsworth-Munsell 100-Hue and the Panel D-15 tests as well as measurements of transient tritanopia, spectral sensitivity and blue cone ERG in patients treated with Diphenylhydantoin or Carbamazepine in therapeutic dosages revealed a defect in the short wavelength sensitive cone function and a loss of postreceptoral interaction between long- and short-wavelength sensitive cones.
Fourteen patients treated with Diphenylhydantoin or Carbamazepine received additionally the experimental anticonvulsant drug gamma-vinyl-GABA, an irreversible inhibitor of GABA-Transaminase, the enzyme catalyzing the catabolism of the neurotransmitter GABA and thereby highly increases postsynaptic GABA concentration.
Interestingly the decreased blue cone's sensitivity improved in most of these patients. Thresholds as determined in experiments of transient tritanopia returned back to normal approximately within 10 days after the beginning of treatment with gamma-vinyl-GABA.
Nine epileptic patients treated with Valproic Acid, which enhances slightly GABAergic synaptic transmission by a presynaptic mechanism, had normal colour vision as well as four untreated patients.
The data of our study suggest that GABA is involved in the control of the blue sensitive cone mechanism by longer wavelength sensitive cones. If, as hypothesized, Diphenylhydantoin and Carbamazepine affect the calcium and sodium metabolism, their effects on the phototransduction process, especially in the outer segments of the photoreceptor cells, may play a role in the colour vision deficiencies induced by these drugs.

Some remarks on colour discrimination in multiple sclerosis. A Serra, S Mulas, I Zucca, Cattedra di Ottica Fisiopatologica, Università di Cagliari, Cagliari, Italy.

We tested a number of patients suffering from multiple sclerosis, some of which had a monolateral attack of optic neuritis. We examined central vision (visual acuity, colour discrimination), peripheral vision (visual field, both isopter profile and perimetry) and ocular motility (fusional amplitude and accommodative astigmatism).
The colour discrimination responses are tentatively correlated with some responses resulting from the other tests.
We found that the monocular previous attack of optic neuritis left a particular trace in terms of an interocular difference in colour discrimination and in other visual function.

SESSION G

Acquired color vision defects in dependence on depth localization and eccentrization of fixation. M Marré, A Pinckers, Augenklinik der Medizinische Akademie, Dresden, GDR. **(Invited Paper)**

Lesions of the complex "choriocapillaris, Bruch's membrane and pigment epithelium" show exclusively blue-yellow (BY) defects in foveolar fixation and anarchic color vision, BY defects or, more seldom, type I red-green (RG) defects in eccentric fixation.
Diseases of the receptor cell layer develop BY defects in peripheral forms with central fixation but type I RG defects in central forms with eccentric fixation. In optic nerve diseases BY defects are found in cases with central fixation and type II RG defects in cases with eccentric fixation. Being signs of receptor damage, pathologic scotopization of color vision and pseudoprotanomaly indicate retinal processes and are important criteria for differential diagnosis between retinal and optic nerve diseases.

Colour threshold of the macula within 3° from the fovea in congenital colour deficiencies and normal subjects. M Tomonaga, Y Ohta, K Hamano, K Shimizu and T Motohashi, Department of Ophthalmology, Tokyo Medical College, Tokyo, Japan.

We have made an investigation regarding the changes occurring in colour thresholds at the central 0° and visual angles at 1°, 2° and 3° in the retina in congenital colour deficiencies by measuring the thresholds within 3° from the fovea by the use of a fundus photo-perimeter. As the result, remarkable increases in the thresholds were observed in protanopia with red stimulus (620 nm), compared with the thresholds in normal subjects and cases with deuteranomaly and deuteranopia.
With a green stimulus (560 nm), cases with protanopia, deuteranopia and deuteranomaly exhibited increases in the thresholds almost to the same degree, compared with normal subjects.

Characteristics of the panel D-15 test in optic nerve diseases with congenital red-green color defects. J Noki, A Kandatsu, R Tamaki and K Kitahara, Department of Ophthalmology, Jikei University School of Medicine, Tokyo, Japan.

The characteristics of the panel D-15 test (PD-15) were studied in five cases of congenital red-green color vision defects with some optic nerve involvement. In three of the cases, the spectral sensitivities for 1°, 200ms test flashes on a 1000 photopic troland white background were measured using a two channel Maxwellian view optical system. The spectral sensitivities on a white background for all the cases showed a reduction in sensitivity for all wavelengths but mainly in the short wavelength regions. On the other hand, PD-15 showed a typical pattern of red-green defects in four cases, while the other case showed no errors. None of them showed blue-yellow confusions. That is to say, the reduction in sensitivity for blue cones could not be detected on PD-15.
As a result, it was suggested that PD-15 has a limited usefulness in the classification of acquired color vision defects in optic nerve diseases with congenital color vision defects. Also, it was felt that acquired color vision defects could not be classified using only PD-15.

Rayleigh match and visual sensitivity in central serous choroidopathy. M Isashiki, Y Nakashima and N Ohba, Department of Ophthalmology, Kagoshima University Faculty of Medicine, Kagoshima, Japan.

We performed a prospective study of the Rayleigh match and visual sensitivity in 25 patients (27 eyes) with central serous retinochoroidopathy. Measurements with a modified Nagel anomaloscope showed a pseudoprotanomalous Rayleigh match when the disease was active; the abnormality was invariably observed with all sizes of the match field (0.5°, 1.5°, 2.5°) with no size-correlated alteration as observed in the normal. Visual sensitivity of the fovea with Octopus automated perimetry was abnormal when the disease was active and returned to normal with resolution of the macular edema. Recovery of the pseudoprotanomalous defect was statistically significantly slower than that of the foveal visual sensitivity and visual acuity. The results indicate that the disease process involves the foveal cone pigment density more markedly than the visual discrimination.

The color sense of pseudophakic eyes: chromatopsia. K Ichikawa, Department of Ophthalmology, Chukyo Hospital, Nagoya, Japan.

Chromatopsia is a common clinical symptom in pseudophakic eyes, but it is not necessarily so well understood. We report here an investigation of chromatopsia in a total of 336 eyes from 302 patients with pseudophakic eyes which were in the early stage, i.e., one or two days after operation. Under a fluorescent lamp of 1,000 lux (3SP-10K, NEC), patients were shown a white paper, set at 45cm from their eyes. If they could see color on the paper they were chromatopsia positive and those who could not see a color were chromatopsia negative. The chromatopsia-positive patients then chose the cap number in FM 100-hue test for the color that was most similar to the color which a white paper appeared to be, and thus the color of the chromatopsia was determined. Twenty-nine patients suffering from chromatopsia had color filters made by simulating the coloring due to ageing of the crystalline lines. On using the filters, chromatopsia disappeared.
Chromatopsia occurred without relation to age, sex or vision before operation. The colors observed in 52 cases (17.2%) were almost all in the range of 13 to 18 (yellow), and 54 (blue) to 77 (red-purple) in the cap numbers of the FM 100-hue test.
Colors in the range of 54 to 77 accounted for 79.3% (46/58). It was possible to cure or alleviate chromatopsia by using a colored lens which imitated the coloring of the ageing crystalline lens.

Studies on colour compensation tinted spectacle lenses for pseudophakic patients. Y Ohta, H Kudo, H Hagiwara, K Hamano, A Hanabusa and K Saiki, Department of Ophthalmology, Tokyo Medical College, Tokyo, Japan.

It is considered so desirable for intraocular lenses to filter hazardous radiation to the retina as well as to minimize photophobia and cyanopsia, that we have conducted a preliminary experiment to produce new intraocular lenses by adding UV absorbant and yellow-dye to PMMA. To find the optimal amount of the yellow-dye to be added, we prepared 3 types of plastic spectacle lenses for simulative tests each of which differs respectively in terms of shade. At or below 500 nm of wavelength, each one of the absorption effects resembled that of the human lens.
For the experiment, (1) for the convenience of standardization, we firstly prepared standard spectacle lenses with additive of 0.01% monomethene system yellow-dye. Additionally, 2 different types of test spectacle lenses were prepared: one was 2 times densified, another 4 times. Each pair of the spectacles glazed with those 3 differently densified lenses was worn by patients for comparison. (2) Under the light of EDL-D65 fluorescent -lamp, the patients were tested with Panel D-15 and FM 100-Hue tests and also with the Tritanomalosope.
Result and Conclusion: From the colour vision tests, it has been proved that the colour vision of pseudophakic eye with the aid of the standard spectacle lens resembles that of the normal eye as compared with that of pseudophakic eye without the aid of the standard spectacle lens.

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