DALTONIANA

NEWSLETTER
OF THE INTERNATIONAL RESEARCH GROUP ON COLOUR VISION DEFICIENCIES

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IRGCVD News

XIth IRGCVD Symposium and joint IRGCVD-AIC meeting 20-25 June, Sydney

With 63 registrants for the XIth IRGCVD Symposium and 40 for the IRGCVD-AIC meeting the contributors of 52 papers and posters were distributed almost evenly between the American, Asian (including Australia) and European (including the UK) continents. Abstracts are reproduced in this issue. Professor Sperling was presented with a commemorative medal prior to his delivery of the Verriest Memorial Lecture. Participants engaged in lively debate during the paper and poster sessions, during the breaks and even during the social programme. We spent an unforgettable evening dining in the bay and another with Australian musical entertainment, including an evocative performance on a didgeridoo and a sheep shearing demonstration. The Group owes a particular debt of gratitude to local organiser Associate Professor Steven Dain for the enormous amount of work which he undertook to ensure the smooth running of the Symposium and of our joint meeting with the AIC.

GENERAL MEETING OF MEMBERS

The General Secretary reported on the revitalisation of Daltoniana following the Cagliari Symposium. Professor Wolfgang Jaeger and Professor Marion Marré were elected Honorary Members.

Invitations for the 1993 Symposium had been received from Alicante and Tübingen. The representatives from both venues were unable to present their case in person and the Directorial Committee, after long deliberations, recommended Tübingen to the meeting. Members accepted this recommendation after some discussion.

Elections

Apart from the President and General Secretary all members of the Directorial Committee are at the end of their term in office. Election to the 10 vacancies will be by postal ballot. The list of nominees is given on the voting paper on page 19.

By-Law Revisions

The new Directorial Committee will examine how the By-Laws could be changed to more closely reflect current practice and to provide for overlapping terms of office to enable changes in Committee composition while maintaining a suitable level of continuity. Draft amendments, approved in Committee, will be published in Daltoniana.

Finance

The Treasurer presented an interim statement of account. However, a number of major commitments await resolution. The final figures, which would more accurately reflect the position of the Group, will be published in a future issue of Daltoniana.

Proceedings

Cagliari Symposium (1989): proceedings have been printed and mailing the bulk order should have begun by mid-July. A small number of copies are still available for sale to members (see Announcement below) at a discount to IRGCVD members of more than 50% on the retail price.

Sydney Symposium (1991): In moving to our present system, where membership fees cover the cost of the Proceedings, the increased sales attract a better than 70% discount on the retail price. All Honorary members and full members in good-standing should receive a copy of the Proceedings as well as others who have paid separately at the Symposium. Their names (according to information at the time of printing) are noted in the following list.

Aarnisalo, Abraham, Abramov, Adams, Akita, Alexander, Alvarez, Applegate, Atchison, Bailey, Barker, Bayer, Biersdorf, Billock, Birch, Bolle, Bowman, Bresnick, Bronte-Stewart, Buck, Burns, Capilla, Cavonius, Chan, Chisholm, Cicerone, Cobb, Cohen, B Cole, G Cole, Comerford, Crognale, Dain, Deeb, Derefeldt, Dessy, Dickinson, Dodt, Drum, Eisner, Elsner, Enoch, Flanagan, Fletcher, Foster, Fry, Fukuda, Fusco, Gonella, Gouras, Grall, Greenstein, Grigsby, Guffani, Haegerstrom-Portnoy, Hagiwara, Hahn, Hamano, Hansen, Hart, Hedin, Heilner, Hermès, Heron, Higgins, Hill, Hine, Hood, Honson, Hovis, Huang, Hukami, H Ichikawa, K Ichikawa, Illueca, Ishihara, Jacobs, Jaeger, Jameson, Kaiser, Kandatsu, King-Smith, Kinnear, Kitahara, Knoblauch, Knox-Laird, Kudo, Kulikowski, Lachenmayr, Lagerlöf, Lakowski, Lanthony, Larimer, Leid, Lindsey, Littlewood, MacLeod, Majima, Mäntyjärvi, M Marré, Massof, Mattiello, Mollon, Moreland, Motohashi, Murakami, Nagy, Nathans, Negrete, Neitz, Nichols, Obara, Ohhama, Ohta, Orquin, Ourgaud, Paulus, Pease, Pelizzone, Perez, Perez-Carpinell, Piantanida, Pidgeon, Pinckers, Pokorny, Pollack, Rawlins, Reeves, Regan, Robbins, Robertson, Ronchi, Roth, Rovamo, Roy, Rubin, Ruddock, Saiki, Sample, Scase, Scheibner, Schneck, Serra, Shevell, Shimizu, Skoog, Smith, Sperling, Sternheim, Stockman, Stone, Swanson, Takahashi, Tamaki, Tanabe, Teller, Toyoguchi, Travis, Vaegan, Valberg, Verdon, Viénot, Vingrys, Voke, Weitz, Werner, Wolf, Wright, Yeh, Yorke, Young, Zisman, Zrenner, Zwas, Zwick.

Others, wishing to order a volume, should contact the Proceedings Editor, Dr Bruce Drum. Members in arrears should bring their membership up-to-date without delay.

DALTONIANA

At present Daltoniana has a mailing list of some 300 although current records show only 192 members in good standing. The excess cost cannot be sustained indefinitely and, after this issue, Daltoniana will be mailed only to members in good standing. Other members should have received final reminders from the Treasurer.

CONGRATULATIONS

To Hermann Krastel on his appointment as Professor in the University of Heidelberg.

To Hans Vos and Pieter Walraven on their AIC Deane B Judd award at the AIC Congress in Sydney.

LITERATURE SURVEY

Members are requested to send material to the Editor for inclusion in the Literature Survey. This could be abstracts from their own publications or short summaries of papers which may interest other members of the Group. Recent issues of Daltoniana show the preferred format of contributions.

ANNOUNCEMENT

Last chance to buy discounted Cagliari Proceedings!

A small number of copies of the Cagliari Proceedings are still available for the discounted price of US$100 per copy: LESS THAN HALF of the expected retail price. This offer is limited to IRGCVD members who did not participate in the original bulk order or who want an additional copy. Contact the Proceedings Editor, Bruce Drum, by telephone (int. + 1 301 955 9653) or by fax (int. + 1 301 955 1829) to reserve your copy.

XIth Symposium of the IRGCVD

Session 1 *Poster Defence*

Selective loss of S-pathway sensitivity in central serous choroidopathy revealed by spatio-chromatic visual evoked cortical potentials (VECP). M A CROGNALE[1], J RABIN[1], G SWITKES[2] and A J ADAMS[1]. 1: University of California, Berkeley. 2: University of California, Santa Cruz, California, USA.

Many ocular diseases are reported to produce a selective loss of specific achromatic or chromatic pathways, particularly S-cone pathways. To study these losses we have employed spatio-chromatic stimuli which can vary along arbitrary directions in the color space proposed by MacLeod, Boynton, Krauskopf and Lennie. Such stimuli, by keeping the same time-averaged luminance and chrominance, avoid the complications of chromatic adaptation while allowing selective activation of various pathways. We report how responses to these stimuli, as measured by VECPs, can be used to analyze selective sensitivity loss in retinal disease. Specifically, we study losses in a subject with a history of central serous choroidopathy. Visual acuity, D-15, Adams DSAT D-15 and F-M 100 hue scores are now normal. VECPs elicited from stimulation of the affected eye are compared with those elicited from the unaffected eye and with responses from normal subjects. For the affected eye we find that response amplitudes for 1 c/deg gratings modulated along the S-cone axis are greatly reduced compared to those from the unaffected eye and for normals. No interocular response difference is observed for chromatic stimuli along the L-M axis or for luminance modulated stimuli. A 3 to 4-fold increase in S-cone contrast was required to equate response amplitudes from the affected eye to those from the normal eye. VECP measures of response latency also showed significant differences. The results of electrophysiological measurements of sensitivity are compared with those obtained psychophysically. This application of an objective technique for clinical assessment of a variety of acquired color vision losses is discussed.

Phase selectivity in chromatic and luminance flicker fusion. M L F DE MATTIELLO, A GONELLA and M DEL VALLE BRIZUELA.

In a previous work we have observed that the phase influences on the time of fusion of chromatic stimuli red and green, and that can result a relevant parameter of diagnosis in optic neuropathy. The fact that the phase may act independently, would show the existence of a new independent channel similar to the tuned to spatial and temporal frequency and color. Having this idea in mind, the behaviour of patients who present glaucoma, multiple sclerosis and optic neuropathy is analysed employing the threshold of chromatic and temporal fusion technique. The variability in the times of fusion of the patients as regard the normal population considered as pattern, reveals the variable under study. A statistical treatment of the data informs about the reliability of the diagnostic differentiation, that can be obtained by means of the application of this non-invasive test.

Orientation selectivity in equiluminant gratings. P FLANAGAN, Department of Psychology, Deakin University, Victoria, Australia.

Two sinusoidally modulated gratings that are defined by different pairs of equiluminant colours (e.g., Magenta/Cyan and Light-purple/Greenish-yellow) and that differ in orientation appear to alternate when superimposed: First one orientation dominates, then the other, while part of the time both orientations are seen. The rate of alternation for these equiluminant gratings varies with orientation difference between them: for orientations differing by about 15 deg the alternation rate is low and both gratings are perceived at the same time; the rate of alternation then increases with increase in orientation difference and becomes a maximum for orientation differences of between 60 and 75 deg. When both gratings are composed of different pairs of equiluminant colours (Magenta/Cyan and Light-purple/Greenish-yellow), or one grating is equiluminant and the other is achromatic (Magenta/Cyan or Light-purple/Greenish-yellow) or when both gratings are achromatic (Light-grey/Dark-grey), the alternation rates are higher than those that occur when both gratings are defined by the same pair of of equiluminant colours (Magenta/Cyan or Light-purple/Greenish-yellow) or when both gratings are achromatic (Light-grey/Dark-grey). If this pattern alternation, or monocular rivalry, reflects the orientation selectivity of visual mechanisms these data indicate that mechanisms that respond to equiluminant oriented contours are independent of those that respond to luminance-defined contours and that colour selective mechanisms respond independently to

the orientation of contours defined by different pairs of equiluminant colours, indicating that mechanisms responding to equiluminant colours are selective for orientation.

Proposals to test and compensate (some) color vision deficiencies of VDT operators. L R RONCHI, C CASTELLINI, C CIAMBERLINI and E PAMPALONI, Istituto Nazionale di Ottica, 6 Largo Fermi, 50125 Florence, Italy.

One of the ingredients of the "quality of a color vision monitor (CVM) coupled to a pattern generating computer is the "range" of available luminance, for each of the three primaries. The predictions of the utilizations are (tacitly) based on the average normal eye, however color vision defectives make large use of CVM in their occupations. In the case where one is faced with reduced sensitivity in one or more photoreceptors, the consequences of the handicap might be minimized by properly increasing the luminance range of one or more primaries of the CVM. This cannot be accomplished by acting on the knob controlling the "brightness" at the display, because it operates by modifying the three primaries in a fixed manner. Rather, the possibility should be given to act on the guns, separately. Two tests are described, one based on the method of limits, the other on the method of constant stimuli, which allow, through a proper software, to assess, on the DVM itself used at the site of occupation, the proper increase in gun output for each primary. Some data, recorded from normals and from subjects classified as defectives by the use of pigmentary tests, are displayed.

A simulator for color and spatial vision of the elderly eye. M E SCHNECK, K HUIE, A J ADAMS and K ADAMS, School of Optometry, University of California at Berkeley, California, USA.

Clinicians, architects, planners of public areas, industry and community officials all need guidance to take into account the visual needs of the growing population of older individuals. Studies of vision in the elderly have shown that several pre-retinal elements undergo changes that are likely to be significant for vision. In terms of pre-retinal factors, the elderly eye has three distinct differences when compared to the young eye. 1) The yellow filtering effect of the crystalline lens increases with age, which is likely to reduce the vividness of some colors. 2) The smaller pupil allows less light into the older eye. This is critical for indoor environments and for night driving. 3) There is more scatter in the aging lens and cornea, which is regarded as the cause of reduced low contrast acuity in the presence of a veiling glare. Little is known about how these factors COMBINE to affect vision in older eyes. We considered these three factors in the development of a device to allow a younger eye to mimic an aging eye (separate from the changes in neural function) and constructed a filter sandwich to mimic these 3 factors. The "sandwich" filter was used with young eyes (under age 30) to mimic the effects of aging on 1) low contrast visual acuity, 2) color discrimination on the FM 100 Hue and desaturated D-15 test, 3) glare sensitivity (Berkeley glare test) and 4) spatial contrast sensitivity. The results, when compared to the vision of a group of normal eyes (mean age 66, range 60 to 74 years), suggest that the sandwich is a practical simulator for use by clinicians and others (eg architects and planners) as they assess the visual world of the elderly. The simulator appears to have its most appropriate application for interior environments and their entryways.

Session 2: *Genetics*

Invited Paper

Studies on the molecular genetics of tritanopia. C J WEITZ, Y MIYAKE, K SHINZATO, E MONTAG and J NATHANS, Department of Molecular Biology and Genetics, Johns Hopkins University School of Medicine.

Tritanopia differs fundamentally from other inherited anomalies of colour vision. Its autosomal dominant transmission[1] implies a mechanism unlike that of protanopia and deuteranopia. Since tritanopes lack a measureable blue cone electroretinographic response[2], the defect is likely to be localised within blue cone photoreceptors. These findings suggest that a mutant gene product actively interferes with blue cone function or viability. Could a mutation in the gene encoding the blue sensitive visual pigment[3] be responsible for tritanopia? To test this hypothesis we have used the polymerase chain reaction and denaturing gradient gel electrophoresis to screen for sequence variation in this gene in members of five families in which tritan individuals appear in more than one generation. We have found three different single-nucleotide changes in affected members of four families that were not detected in control subjects of appropriate ancestry ($p < 0.001$, < 0.003, < 0.003 respectively). Two of the changes encode different single-amino acid substitutions (Gly^{79}-to-Arg and Ser^{214}-to-Pro, respectively) and the third, a single

nucleotide deletion, disrupts a splicing consensus sequence likely to be important for proper maturation of messenger RNA. In the two families segregating the Gly^{79}-to-Arg substitution, the pattern of transmission is consistent with autosomal dominant with low penetrance; in the family segregating the Ser^{214}-to-Pro substitution, the transmission is consistent with autosomal dominant with high or complete penetrance. In the family segregating the splice donor consensus site deletion, one affected subject does not detectably carry the variant allele, raising the possibility that this change is only coincidentally present in the proband, despite its not being detected in a large control group; the possibility of misdiagnosis of the discrepant subject has not yet been tested. No sequence changes were detected in this gene in the proband of the fifth family, but the studies do not as yet allow exclusion of the blue-sensitive opsin locus as the site of an undetected mutation. In four additional tritans for whom no affected relatives are known (and who could therefore represent cases of acquired tritanopia or as-yet-unrecognised recessive forms), no sequence changes were detected in three, and the fourth proved to be an additional example of the Ser^{214}-to-Pro change. Expression studies of visual pigment DNA bearing these sequence alterations are in progress.

1 *Kalmus, H. Ann. Hum. genet.* **20**: *39 (1955)*
2 *Miyake, Y. et al Arch Ophthalmol.* **103**: *1496 (1985)*
3 *Nathans, J. et al Science* **232**: *193 (1986)*

Session 3: *Genetics and Congenital Deficiencies*

Molecular studies on genotype-phenotype relationships in human X-linked red/green color defects. S S DEEB, D T LINDSEY, Y HIBIYA, E SANOCKI, J WINDERICKX, D T TELLER and A G MOTULSKY, Departments of Medicine and Psychology, University of Washington, Seattle, WA, USA.

The molecular structure of visual pigment genes was determined in 66 red-green color defective Caucasian males ascertained by anomaloscopy. The point of fusion in hybrid genes (either 5' red-3' green or 5' green-3' red) was determined. Both red and green pigment genes have six exons but exons 1 and 6 are identical. Four amino acid polymorphisms were found in 19 normal red pigment genes and one in 16 normal green pigment genes. A single red pigment gene in the absence of any green genes was found in 10 deuteranopes. However, three others with such gene pattern tested as deuteranomalous trichromats. Two deuteranopes had one normal red gene and an additional green-red fusion gene that effectively was a red pigment gene since the fusion point was in intron 1. In 25 deuteranomalous trichromats, green-red hybrid genes were found with fusion in introns 2, 3 or 4. All 25 had a normal red pigment gene and most (19) had one or more additional normal green pigment genes. A green-red-green fusion gene caused by a double cross-over event was discovered in two deuteranomalous individuals. The absence of any red pigment gene material in red-green hybrid genes with intron 1 fusion was associated with protanopia in 6 cases, as expected. However, another six protanopes as well as 12 protanomalous trichromats had fusion in introns 2, 3 or 4. Anomalous trichromacy is usually associated with hybrid genes that result from recombination between the red and green genes. However, hybrid genes may not always be associated with color vision defects as shown in our earlier work. Individuals with a single normal pigment gene (e.g., red) and/or hybrid genes with intron 1 fusions are usually but not always dichromats. Using current methodology, dichromacy and trichromacy cannot always be predicted from the molecular patterns, particularly among protans. The newly found polymorphisms may partially explain the unaccounted variation in color vision phenotypes.

Classification of anomalous trichromatism with the Nagel anomaloscope. J BIRCH, Department of Optometry and Visual Science, The City University, London, UK.

The colour matches obtained with the Nagel anomaloscope by 127 consecutive, unrelated, male anomalous trichromats are reviewed. One hundred subjects were deuteranomalous trichromats, twenty were protanomalous trichromats and seven were extreme anomalous trichromats having combined protan and deutan characteristics. Although some subjects have identical matching ranges in each of these three classifications, the data shows a continuous range of severity rather than discrete subgroups. The matching ranges of the deuteranomalous observers are clearly separated from the normal matching range, whereas the matching ranges of some protanomalous observers overlap with it. The Nagel anomaloscope is the standard reference test for red-green colour deficiency and new colour vision theories derived from molecular genetics must be able to explain the individual variations demonstrated by the test.

Spectral sensitivity of protanopes and protanomalous trichromats. G H JACOBS and J NEITZ, Department of Psychology, University of California, Santa Barbara, California, USA.

Comparisons of the spectral sensitivities of protanopic and protanomalous individuals have been reported on a number of occasions. As judged both by psychophysical and electrophysiological indices that are designed to obviate contributions from neural interactions, the differences in spectra for representatives of these two phenotypic classes are either very small or absent entirely. ERG flicker photometry has proven useful as an objective means for obtaining spectra that seem to provide more reliable and sensitive estimates of the underlying cone pigments than many of the earlier techniques. We recorded spectra from both protanopic and protanomalous subjects using ERG flicker photometry. The results were: (1) variations in spectra between subjects within a phenotypic group are extremely small; (2) the average spectra obtained from anomalous and dichromatic subjects are indiscriminable; (3) the same condition of chromatic adaptation yields small effects in the protanomalous, but no effects in protanopic subjects. The results have implications both for the question of what pigments underlie protan defects, and for models that seek to explain the genetic regulation of the proportions of different cone types.

Session 4: *Poster Defence*

Abnormalities in chromatic and luminance flicker fusion in glaucoma. M L F DE MATTIELLO, A GONELLA, P CAPILLA and C ILLUECA, Alicante, Spain.

Brightness relations for two chromatic stimuli (red and green) were studied using two light-emitting diodes (LEDs). The stimuli could be varied in amplitude for the analysis of brightness, and in frequency and symmetry for the study of the critical frequency of temporal and chromatic fusion. A range of visual functions was assessed in a group of 15 patients with glaucoma and in a group of matched normal controls. Overall results for the glaucoma group showed a statistically significant impairment relative to the control group. More detailed analysis was performed after division of the patient group according to history of visual involvement: subgroup A, primary open-angle; B juvenile open-angle; C, congenital glaucoma.

The characteristics of monochromatic VEP in normal subjects. S-z HUANG, L WU and D WU, Zhongshan Ophthalmic Center, Sun Yat-sen University of Medical Sciences, Guangzhou, China.

Thirteen normal subjects (25 eyes) were tested with monochromatic pattern reversal visual evoked potential and black-white pattern reversal visual potential. The monochromatic light was got with the colour filters. Their wavelength was 440, 460, 480, 500, 520, 530, 540, 550, 560, 570, 580, 590, 600, 610, 620 nm with 5-10 nm of the half-bandwidth. It was found that the amplitude was the greatest in 560-570 nm and the latency was the shortest in 560 nm. The latency was longer and most of the amplitudes were greater under the monochromatic stimuli than under the black-white pattern reversal stimulus, which may suggest that the color coding was more complex than the luminous sense

Evaluation of an apparatus for measuring wavelength discrimination: the differenciateur de tonalité. F VIÉNOT and C FONTVIEILLE, CNRS UPR 257, Museum National d'Histoire Naturelle, Paris, France.

The Differenciateur de Tonalité (Viénot et al, Colour Vision Deficiencies VIII, 1987) is an apparatus for measuring the wavelength discrimination curve across the spectrum. It consists of a single projector in which a bi-prism and a single interference wedge are combined. We report two studies where the Differenciateur has been used either as a technique to supplement classical procedures for screening color deficiencies or as an original device to measure a wavelength discrimination curve across the spectrum. To test the performance of a portable prototype of the Differenciateur in a screening situation, a study was conducted with 26 male school students, aged 19 to 33. A laboratory was set up at the school and each student was examined for his/her differential threshold at 490 and 590 nm with the Differenciateur, and with the Ishihara plates, the Panel D-15, the desaturated D-15 and the Nagel anomaloscope. In the version used in this part of the study, a wavelength difference up to 19 nm could be presented. The correlation between threshold at 590 nm and the range of the anomaloscope matches is highly significant for all observers but one. The worst wavelength discrimination at 590 nm was 7 nm, for one protanomal and one deuteranomal observer who were separated by their luminance match. No Nagel dichromat was found among the students. The second study consisted of measuring the wavelength discrimination curve over the whole spectrum, every 20 nm, for a few normal and

color-defective observers. The two minima at 490 nm and 590 nm (or one, in the case of dichromats) were clearly identified. Methodological practice seems to be easily acquired by an operator.

Visual mechanisms associated with rhesus visual motor performance. H ZWICK, J CALABRESE, M COOK, J MOLCHANY and K R BLOOM, Letterman Army Institute of Research, San Francisco, California, USA.

While numerous investigations of visual function and visual performance exist, the relationship between these measures is largely unexplored. In this study, we present such data for the rhesus monkey. Two rhesus monkeys were trained on a pursuit tracking task requiring continuous racking of a horizontally moving annulus by maintaining a small spot from a HeNe laser pointer in the center of this annulus. The role of central and paracentral mechanisms was evaluated through manipulation of the size, intensity and wavelength of this annulus. Spectral sensitivity functions were derived from intensity vs time on target functions. The spectral sensitivity functions for both animals appeared more photopic for high performance resolution criteria, taking between 540 and 580 nm; for lower resolution performance criteria, spectral sensitivity functions appeared more scotopic, peaking between 500 and 520 nm. These data suggest that selectivity of photopic and scotopic receptor mechanism in simple visual pursuit performance depends upon target size and performance fidelity.

Session 5: *Spatial Aspects of Colour Vision*

The Verriest Memorial Lecture

Spatial and other influences on red-green opponency. H G SPERLING, Sensory Sciences Center, University of Texas Health Science Center at Houston.

Different techniques were used to manipulate the inhibitory interaction between the red and green photoreceptors (R and G cones) of rhesus and human primates. The response techniques which were used were the corneal electroretinogram (ERG) and psychophysical increment-threshold spectral sensitivity functions. Red-green opponency, as measured by the depth of the notch at 580 nm, was removed by intravitreal injection of bicuculline but not by strychnine. Therefore, red-green opponency is mediated by GABA and not glycine. The depth of the notch is dependent upon stimulus size. Between 30' and 15' test light diameters, this sign of red-green opponency disappeared. Psychophysical increment-thresholds were shown to produce the notch while decrement thresholds did not, and intravitreal APB was shown to reduce the notch, evidence that red-green opponency is carried by the "on" and not the "off" bipolar pathways of the retina. Red and green annuli selectively reduced red and green inhibition, as though there were selective reduction of the inhibitory surround response in center-surround organized red-green receptive fields.

Relative contributions of luminance and chromaticity to the Craik-Cornsweet effect. G R COLE, T HINE and J SCOTT, Centre for Visual Sciences and Optical Sciences Centre, Australian National University, Canberra ACT 2601, Australia.

A Craik-Cornsweet (CC) edge resembles the double derivative of a smoothed step edge. Traditionally, such stimuli are presented as black-white profiles and a difference in brightness is observed on either side of the edge which does not directly correspond to the luminance profile. In addition, for a range of contrasts of the CC edge, the regions on either side look relatively uniform but of different brightness. All stimuli were generated on a fully calibrated (spectrally and radiometrically) Tektronix 690SR colour monitor optically incorporated within a Maxwellian view system. We used a radially symmetric version of the CC stimulus transiently presented for 200 ms on a uniform steady "white" background field (1080td). The profile constituted a step edge, blurred with a 0.25 deg gaussian, which was then differenced with the original step edge. The contrast of the stimulus could have any direction in L, M, S cone contrast space. Complete detection thresholds were obtained in three theoretically important planes in L, M, S cone contrast space. The CC effect was measured by determining the contrast of a step added to the stimulus required to cancel the effect. These cancellation results were obtained in the three planes at 3x and 6x threshold for each of three observers. In agreement with the passive filtering properties of the M and P cell systems supposedly driving the luminance and chromatic systems respectively, we found the CC effect to be almost solely driven by the luminance signal.

Opponent-colour responses generated by spatially tuned mechanisms in human vision. A B MORLAND and K H RUDDOCK, Biophysics Section, Physics Department, Imperial College, London, SW7 2BZ.

It has been shown experimentally that threshold luminance for detection of a target is influenced by spatial or temporal modulation of the background field, and the results of such experiments characterize two spatio-temporal response mechanisms (J L Barbur and K H Ruddock, 1980, Biol. Cybernet. **37***: 77-92; I E Holliday and K H Ruddock, 1983, Biol. Cybernet.* **47***: 173-190). Using a modification of this method, in which the modulation depth of the background field is controlled by the addition of a spatially uniform, monochromatic field, the spectral characteristics of this response can be determined (P J Brent and K H Ruddock, 1990, J Physiol. 430: 108P). We present data which show that under appropriate conditions, spectral responses recorded by this method are narrow-band functions, with red-green opponent response characteristics. Measurements have also been made on subjects with congenital and acquired deficiencies of colour vision. Data for red-green dichromats yield broad-band responses, which lack the narrow bandwidth tuning observed in normal responses. Similar data were obtained with a patient who has normal colour-matching and spectral sensitivity, but exhibits gross loss of visual capacity in the recognition of coloured images, e.g. failing to read any of the Ishihara pseudo-isochromatic plates. This patient has a fifteen year history of visual problems following a bout of glandular fever.*

Entoptic visualization of foveal area capillaries. R A APPLEGATE[1] and A BRADLEY[2]. 1: Department of Ophthalmology, University of Texas Health Science Center San Antonio, San Antonio, TX 78284. 2: Department of Visual Science, School of Optometry, Indiana University, Bloomington, IN 47405.

In this paper we will present theoretical and practical considerations which demonstrate that entoptic visualization of the smallest capillaries near the fovea is optimized by a small short-wavelength source (1mm or less) rotating at 3.5 Hz in a circular path imaged in the plane of the eye's entrance pupil. Data from use of these techniques will be presented. They suggest that the locus of fixation is generally not centered within the foveal avascular zone significantly increasing the probability of foveola damage during foveal area photocoagulation therapy.

Session 6: *Test Methods*

Developing an optimised clinical test of colour vision. A S Cheng and A J Vingrys, Department of Optometry, University of Melbourne, Parkville, Victoria 3052, Australia.

Although new tests of colour vision have been designed, some involve complex figure/ground judgements or need a substantial motor component for their completion. Furthermore, these tests may fail to assess both luminance and colour processing. We describe a test of colour and luminance thresholds using motor free methods and a simple discriminatory task that can be used for the clinical assessment of both acquired and congenital colour defects. Our design is based on Munsell papers and comprises 37 test plates. Thirty two plates test saturation thresholds on a neutral background using spots of four hues located along the protan, deutan and tritan axes. The other five plates test luminance thresholds by varying the value of the test spot relative to its background. Each plate has four 1° spots, one being the test spot and the other three being controls. Results using a prototype of this test on 10 young (aged 19-39) and 8 older normal controls (aged 64-78), 12 congenital colour defectives (10 deutans and 2 protans, aged 22-73) and 11 patients with age-related maculopathy (aged 65-83) show promise and are reported in this study. Some improvements in test design and presentation are suggested.

Pfluegertrident plate for clinical evaluation of the sense of colour. R ISHIHARA, K SHIMIZU, K HAMANO, F OBARA and Y OHTA, Tokyo Medical College, Tokyo, Japan.

Pfluegertrident-plate in which Pflueger-Trident "E" is used as an object was prepared in 1980 as an adjunct of Velhagen Chart. For testing infants, a subject is asked to answer the direction of the object by showing a sample of Pflueger-Trident "E" in the same direction as the object stands. For the sense of colour, we tested 86 colour defects of 10 years old and older, 11 colour defects ranging from 5 to 9 years old, and 11 normal ranging from 3 to 5 years old. When testing the 86 colour defects of 10 and older age, high error percentage was recorded with No. 3, No. 4, No. 9 and No. 12 plate. To No. 4, however, the error score by deutan was low. Of the error score by protan and deutan, they both were exactly the same

by percentage. Screening efficiency by Pfluegertrident-Plate was 84.0%. By type, screening efficiency by deuteranomaly was fairly low as 67.6%. Of colour defects ranging from 5 to 9 years old, they were all marked "not passed". Of those subjects ranging from 3 to 5 years old with normal colour vision, all the subjects of 4 and 5 years old were marked "passed", but none of those 8 years old.

Sensitivity of five screening tests for tritan discrimination as evaluated in normals at reduced levels of illumination. H KUDO, V C SMITH and J POKORNY, Visual Sciences Center, University of Chicago, Chicago, Illinois, USA.

We evaluated five tritan screening tests under reduced illumination as a way of producing a tritan-like condition in color normals. The Tokyo Medical College plates, the Rabkin plates, the Velhagen plates, the Standard Pseudoisochromatic Plates Part 2 and the Minimalist test were evaluated at six light levels which ranged from 0.1 to 63 Lux. Fifteen observers with normal color vision served in the experiment; five older observers (median age 49) and ten younger observers (median age 28). All performed all tests correctly at 63 Lux. For the Minimalist test, the scores increased with decreasing illumination level. The scores of the tritan series were always greater than that of the protan and the deutan series. For pseudoisochromatic plates, the Rabkin plates were the least sensitive to reduced illumination, the Tokyo Medical College plates and the Standard Pseudoisochromatic Plates Part 2 showed relatively high sensitivity. For the Velhagen plates, four of the individual plates showed differing sensitivity. There were statistically significant differences between younger and older groups on all tests.

Screening of red-green defectives with Hahn Colour Vision Test. M MÄNTYJÄRVI, Department of Ophthalmology, University of Kuopio, Kuopio, Finland.

The Hahn Colour Vision Test (1986) consists of 12 pseudoisochromatic screening plates (10 with number figures, 2 with winding lines), and 9 diagnostic plates (6 with number figures, 3 with winding lines). The Hahn Test was studied in a group of 425 male trade school students in a real screening situation. After screening, the students were examined with the Nagel anomaloscope. In the study group, the anomaloscope found 31 red-green defectives (7.3%). Of these 31, the Hahn screening plates found 23 (sensitivity 74.2%). None of the normals were suspected as defectives (specificity 100%). With the diagnostic plates, the quality of the defect (deutan, protan) was correctly diagnosed in 21 of the 23 defectives (91.3%). The quantity of the defect (strong, medium, mild) was correctly defined in 10 of the 23 defectives (43.5%) with the number figures, and in 9 (39.1%) with the winding lines.

Evaluation of the tritan album. S TANABE, Department of Ophthalmology, Japanese Red Cross, Nagoya First Hospital, Nagoya, Japan.

Lanthony's Tritan Album was applied to colour vision test together with Panel D-15 Test and SPP-2 (Standard Pseudoisochromatic Plates Part 2 for Acquired Color Vision Defects) for 100 normal eyes and 295 affected eyes. All of the normal eyes showed no abnormalities in this test. The blue-yellow defect was detected in 33% of the affected eyes and in 43% of the eyes of the central serous retinopathy with this test alone, so that its detecting ability was not satisfactorily good. The inconsistent results, for example, making correct answer in plate No. 2 and/or No. 3 and failing No. 1, were often met. Nevertheless, the failures in the Tritan Album properly imply the blue-yellow defect and it has an advantage of being simple and easy to administer that deserves to be included in the test battery. As to the design of the plates, if the squares consist of more dots, that is, 12 or 13 for one side of the background and 5 for that of the figure respectively, the figure would claim more established perception resulting in less inadvertant errors.

Session 7: *Occupational Aspects of Colour Vision*

Invited Paper

Does defective colour vision really matter? B L COLE, Department of Optometry, University of Melbourne, Australia.

It has been accepted that defective colour vision is an occupational handicap since Wilson observed the high prevalence of defective colour vision among his students and wrote, in 1855, about the dangers "attending the present system of railway and marine coloured signals". Standards for colour vision were introduced for the marine and railroad industries in the 1870s and for aviation in 1919. Colour vision

standards for drivers of motor vehicles have not been widely adopted and never effectively, and there is no accepted system of standards for that wide gamut of occupations that involve colour recognition, colour discrimination or aesthetic judgement of colour. The recent emergence of the concept of equal employment opportunity to prevent unjustified exclusion of the handicapped from employment and the advocacy of an articulate group of people with defective colour vision who do not wish to be excluded from their choice of occupation has weakened some existing standards. In several countries there is no effective barrier to dichromats flying aircraft, and the colour vision standards of the police, firemen and the defence forces have been liberalised. Yet there is an impressive body of evidence to show that colour figures importantly in many occupations and that some of those with defective colour vision will perform less effectively in those occupations because of their defect.. There is also evidence that those with defective colour vision have a range of difficulties in everyday life, although this has been studied surprisingly little in the last 125 years. There is accident data to suggest that defective colour vision is a risk factor but accident data is always uncertain and more credence has to be given to the uncertainty than to the indications of risk. There is a need for better definition of colour vision standards and of test protocols and for international advocacy and acceptance of the standards. A schema of standards and test procedures is proposed.

The ability of colour defective observers to recognise an optimised set of red, green and white signal lights. A J VINGRYS and B L COLE, Department of Optometry, University of Melbourne, Parkville, Victoria 3052, Australia.

Restricted red and green colour domains have been recommended by the CIE (Pub 2.2, 1975) in order to assist colour defective observers identify coloured signal lights. However, the benefits, if any, of using such a restricted domain with point source signals have never been demonstrated. Sloan and Habel (1955) showed that if the colours were relatively large and bright then only protanopes will have difficulty in their recognition although studies exist to indicate that other congenital colour defective groups cannot reliably recognise colour signal lights even if their colours lie within the CIE restricted domains (Kinney et al, 1979). The purpose of this study is to compare the ability of 20 congenitally colour defect observers and 4 normal controls in identifying an optimised and well practised set of point-source coloured signal lights with the recognition of a more variable set of colours chosen from the CIE restricted boundaries. If substantial improvements in performance are found then these may allow an ergonomic alternative to existing colour vision standards. Our results indicate that optimising signal colours does not afford reliable recognition by colour defectives although deuteranopes and protanomals show some improvements in performance. We note that the present yellow limit for red signals may be too liberal and that longer wavelength reds afford more reliable recognition by all observers. We also found that the lantern test adequately separated those observers who were able to perform the task from those who could not.

Session 8: *Occupational Aspects of Colour Vision*

The clinical use of the Holmes-Wright lantern. J BIRCH, Department of Optometry and Visual Science, The City University, London.

The Holmes-Wright colour perception lantern is an occupational colour vision test given to recruits in the Royal Navy, RAF and civil aviation. A standardised examination procedure is used which involves the presentation of 27 paired red, green or white "signal" lights, subtending approximately one minute of arc at a distance of 20 feet (6 metres). The examination is first performed in daylight and then in the dark following fifteen minutes dark adaption. Examination results will be presented for colour deficient observers having different types of congenital red-green colour deficiency, previously classified with the Nagel anomaloscope, and for a group of young normal trichromats.

Mistakes and difficulties in colour discrimination in daily life of colour vision defectives. A MAJIMA, Department of Ophthalmology, Nagoya City University Medical School.

Since strong colour vision defectives encounter difficulties and make mistakes in colour discrimination, the occupational consequences of colour vision defectives have been discussed for a long time. By questioning, the author investigated the faulty colour vision experienced in daily life by 296 colour vision defectives. They consisted of 46 protanomals, 35 protanopes, 93 deuteranomals and 122 deuteranopes. The answers were obtained from them and/or their parents. One hundred and seventeen of the 175 subjects diagnosed as having moderate or strong R-G defect with H-R-R Plates experienced difficulties and/or made mistakes in colour discrimination. The results of Panel D-15 Test were divided into three

categories: passing group, atypical failing group (2 or more cross line errors without parallel or lacing pattern) and failing group. In passing, atypical failing and failing groups, 33%, 54% and 76% of subjects had trouble in colour discrimination, respectively. The most indistinct materials for colour vision defectives in daily life were as follows: 1) colour pencils and ball-point pens; 2) crayons and paints; 3) trees, flowers, plants and animals; 4) textiles and dress materials; 5) traffic signals; 6) coloured topographic charts and papers; etc.

Session 9: *Basic Aspects*

Individuals showing extreme variation in the L:M cone ratio. G H JACOBS and J NEITZ, Department of Psychology, University of California, Santa Barbara, California, USA.

Several different psychophysical procedures have been used to estimate the ratio of cones containing the two types of middle to long wavelength cone pigment in normal trichromats. The L:M cone ratios reported span a range from about 0.33 to 10 with a mean value of about 2. ERG flicker photometry provides a method to reliably measure spectral sensitivity under conditions that appear (a) to obviate contributions from receptors other than M and L cones, and (b) to avoid contamination from postreceptoral interactions. These functions are well fit by summative combinations of the spectra for standard M and L cone pigments. The proportions required for such fits may provide a reasonable estimate of the L:M cone ratio. In a sample of 20 normal trichromatic males the derived L:M ratio varied from 9 to 0.67 with a mean value of 1.99. We have recently discovered two subjects who are extreme relative to this picture - although both make normal color matches (and thus presumably have spectrally normal M and L pigments), one requires an unmeasurably small M-cone contribution; the other is similarly displaced in the opposite direction.

The visual characteristics of a deutan type of pigmentfarbenanomaly. A KANDATSU and K KITAHARA, Department of Ophthalmology, The Jikei University School of Medicine, Tokyo, Japan.

Observers with normal Rayleigh color matches who make errors on pigment tests have been classified as having pigmentfarbenanomaly (PFA). We studied the visual characteristics of a deutan type of PFA by measuring the spectral sensitivities under various conditions. The spectral sensitivities on a white background showed three peaks although the peaks for the red and green cone systems were not prominent. The patterns of the sensitivity on a 430nm background coincided with the sensitivity curve for red cones. The patterns of the sensitivity on a 700nm background showed two peaks in the middle and long wavelength areas, one of which showed the pattern of the sensitivity for red cones and the other showed the pattern of the sensitivity for green cones. The Fechner fraction of the green cone system showed significantly higher values than that of the red cone system. As a result, it was felt that deutan type of PFA has an abnormal pigment which has similar pattern of the sensitivity to green cone pigment besides the normal red cone pigment.

Chromaticities of the Farnsworth-Munsell 100-Hue test in cone excitation space. V C SMITH, J POKORNY and T YEH, Visual Sciences Center, University of Chicago, Chicago, Illinois, USA.

The Farnsworth-Munsell 100-Hue Test (FM 100-hue) has been subject to a variety of sophisticated analyses in recent years including conversion to uniform color space and Fourier analysis of error patterns. The majority of acquired color defects seen by clinicians arise from retinal or optic nerve disorders. Chromatic discrimination at these levels is well described within cone excitation space. We therefore calculated cap locations in the MacLeod-Boynton space, where S cone excitation is plotted vs relative L cone excitation in a constant luminance plane. The cap locations form an ellipse tilted from the S and L/L+M axes similar to chromatic discrimination ellipses presented by Nagy, Eskew and Boynton. Discrimination loss in one or other axis does give an approximately sinusoidal error pattern as a function of cap number, but the separation is not 90 degrees. Normal error scores are consistent with chromatic discrimination data as a function of test illuminance. Error patterns for congenital and acquired defects can be predicted and compared with data.

S-cone discrimination sensitivity and the performance on arrangement tests. T YEH, J POKORNY and V C SMITH, Visual Sciences Center, University of Chicago, Illinois, USA.

We examined tritan discrimination data at different luminance levels. Two types of psychophysical measurements on S-cones were reviewed: increment thresholds and discrimination thresholds. Data collected under diverse conditions were related by a theoretical template which used Boynton and Kambe's definition of S-cone trolands. Our analysis showed that threshold sensitivity for S-cones is controlled by more than one gain control mechanism. A single TVR type of template cannot describe both chromaticity change and luminance change for S-cones. We took the above results to evaluate performance on four arrangement tests: the Farnsworth Munsell 100-hue test, the Farnsworth Panel D-15, the Lanthony Desaturated Panel D-15 and the Lanthony New Color test. We calculated the S-cone excitation for the caps of the tests. As confirmed with other studies, the results show that tritan errors are expected in color normal observers at low light levels. The calculation also revealed that tritan errors would develop in the desaturated panel D-15 at higher light levels than of the panel D-15. Finally, we applied this analysis to discuss the performance of tritanopes on the FM 100-Hue test and the Lanthony New Color Test.

Sessions10 and 11: *Test Methods*

A ROC analysis of some colour vision tests. A R HILL, Oxford Eye Hospital, Radcliffe Infirmary, Oxford, England.

There are three principal clinical applications of colour vision tests for the investigation of inherited colour vision deficiencies: (1) to detect the presence of colour vision deficiencies, (2) to classify the type of deficiency and (3) to determine the magnitude of any colour vision loss. To these can be added two further uses in the investigation of acquired colour vision deficiencies: (1) as an indicator or predictor of clinical status and (2) to assist clinical management by monitoring change over time in the colour vision deficiency as the pathology progresses or regresses. For various reasons, there is imprecision in the ability of all colour vision tests to perform one or other of the above functions. Where the test outcome is categorical and there is a range of performance measures on the test, this imprecision can be represented by means of a receiver operator characteristic (ROC) curve which displays the trade-off between test sensitivity and specificity. ROC curves have been produced for a number of colour vision tests. From these ROC analyses it is possible not only to compare the efficiency of different tests (or test combinations) but also to optimise the cut-off criteria on a single test. The practical value to clinical decision making from different aspects of ROC analysis will be discussed.

Using panel tests in screening for congenital colour vision defects. A J VINGRYS[1], D A ATCHISON[2] and K J BOWMAN[2]. 1: Department of Optometry, University of Melbourne. 2: School of Optometry, Queensland University of Technology.

The sensitivity and specificity of the D15, Lanthony's desaturated D15 and FM 100 Hue panels were compared in 99 congenital colour defective (33±13 years) and 128 colour normal (32±11 years) males. Results were analysed using the colour difference vector technique of Vingrys and King-Smith (Invest Ophthalmol Vis Sci, 29: 50-63). Vector analysis yields three indices which can be used to quantify a cap arrangement: the C-index (severity), the S-index (polarity) and the angle (axis).

ROC analysis was performed on test outcomes in order to identify the optimum fail criterion for each test. Our data indicates that the efficiencies of the panel tests (D15 = 1.63, desat D15 and FM100 = 1.71) are much poorer than pseudiosochromatic plate tests (typically = 1.98) for screening defects of colour vision indicating that panels need to be supplemented with plate tests in screening protocols. Bayesian probabilities indicate that panel tests are successful in detecting more advanced cases of colour defective vision (Pr[defective given fail at criterion] ≥ 0.99) when a C-index of 1.9 is used on the D-15 panel, 2.3 on the desaturated D15 panel and 2.2 on the FM100 Hue. We conclude that the desaturated D15 panel test is the best screening test since it has the highest efficiency but is faster in its application.

Normative data and standardized testing conditions for an 83 hue color vision test. E M STONE, B E NICHOLS, M S WOLKEN and P R MONTAGUE, Department of Ophthalmology, University of Iowa Hospitals and Clinics, Iowa City, Iowa 52242, USA.

In 1943, Farnsworth constructed a test of color vision discrimination from Munsell's set of 100 hues. He realized that some of the 100 hue steps were more difficult to discern than others and removed 15 of the hues from his test. Hue 85 was also later removed to allow the test to be divided evenly into four racks

(Verriest, 1963). We administered Farnworth's 84 hue Test to 100 normal individuals (200 tests) and calculated the average error score for each hue. We found that normal subjects made more than twice as many errors in a 5 hue zone centred on hue 46 than in any other portion of the test. Previous studies (Nichols, et al., ARVO 1989) have demonstrated that this difficult region substantially weakens the diagnostic power of the test in patients with optic neuropathies. We removed hues 45 and 47 from Farnsworth's test, returned hue 85, and administered the new 83 hue version to 174 normal individuals (358 tests). This modification dramatically smoothed the error peak around hue 46 in this normal group. We also developed a "reliability rack" based on Munsell's neutral value scale that is otherwise identical to the colour racks. We used the reliability rack error scores as a measure of the subject's comprehension of the test. We excluded data from 6 subjects with poor reliability scores when compiling the normative data for the 83-hue test. Details of our testing conditions and bar code-based computer scoring system will be presented. In addition, we will report normative data for each decade between 5 and 77 years for both the 83-hue test and the reliability rack.

Characteristics of random arrangements of D-15 type tests. S J DAIN, Visual Science Unit, School of Optometry, University of New South Wales, Australia.

The distinction between random arrangements of a D-15 type test which do not reflect the presence of colour vision and the arrangements which are made using by a patient with a marked acquired colour vision deficiency is not easily made. On the other hand, the characteristics of random arrangements of the FM 100 Hue have been reported in the literature and the means provided to confirm the presence of some colour vision exists. This paper sets out the characteristics of random arrangements of the FM D-15 test in terms of the Vingrys and King-Smith analysis method. Random arrangements will have low specificity indices coupled with high confusion indices and the limits of random arrangements are identified in terms of those indices for the Standard, Lanthony and Adams D-15 Tests. The data of a group of congenitally colour deficient subjects will be assessed in terms of those limits and it will be seen that they do not fall within the gamut of randomly arranged tests. Finally, some examples of acquired colour vision deficiencies will be shown and interpreted as reflecting the presence of colour vision or as being no more than a random arrangement.

Suitability of fluorescent tube light sources for the Ishihara test as determined by colorimetric methods. S J DAIN, V J HONSON and C T CURTIS, Visual Science Unit, School of Optometry, University of New South Wales, Australia.

This paper represents the next step in an ongoing study intended to produce recommendations on and test methods for the appropriate sources for colour vision examination. At a previous symposium we reported results for the FM 100 Hue Test. In this study the spectral reflectance of the colours of the Ishihara test were measured and the spectral irradiance of the fluorescent tube sources were measured. For each pair of groups of colours intended to be confused by congenital colour deficient subjects the slope of the regresssion line was calculated and compared with the slope of the protan and deutan confusion lines through the mean chromaticity point. The mean deviation from the confusion lines was taken as the inverse measure of the adequacy of the source for that plate. This was carried out for each of the ambiguous, disappearing and diagnostic plate types. The deviation was then compared with the deviation of the data for CIE Standard Illuminant C. A source was considered acceptable for a plate type if the deviation was no greater than that for C. Finally sources which were at least as acceptable as C for all the plate types are listed as being as acceptable as C for the whole test.

Design criteria for a clinical anomaloscope. J D MORELAND, Department of Communication and Neuroscience, Keele University, Keele, England.

The features of an anomaloscope which would optimize its usefulness in clinical work are described and discussed. These include the following. Free viewing. Two equations (Rayleigh and Moreland) with the facility to test fully dichromatic matches (RED = GREEN and BLUE = GREEN); all with simple (fool-proof) interchanges. Two matching variables (essentially hue and brightness) reducing to one (brightness) for dichromatic equations. High field-luminance to test for residual cone activity in advanced stages of cone dystrophy. A choice of field sizes to test for large-field anomalous trichromacy at high luminance in classical dichromats and to test pathologies involving reduction in effective or actual cone pigment concentration. Flicker photometry to establish the relative luminosities of stimuli as a precursor to equiluminant colour matching in which hue is essentially the only variable. Computer control of standardized examination protocolls and data acquisition.

Automated Rayleigh and Moreland matches: optimization of stimulation parameters. M PELIZZONE, J SOMMERHALDER, I HAEFLIGER, D HERMÉS and A ROTH, Ophthalmology Department, Cantonal University Hospital, Geneva, Switzerland.

Our goal is to design a routine automated examination of color vision based on metameric matches. Therefore, we studied the influence of different stimulation parameters on results of automated Rayleigh and Moreland matches. Experiments were conducted on normal subjects with our computer controlled anomaloscope. Results demonstrate that (1) it is important to adjust automatically the luminosity of the reference field as the mixture of primaries is changed in the test field; in doing this color discrimination is not impaired by simultaneous tonality and luminosity changes, (2) the saturation of the reference field can be preset to a fixed value in Moreland match, (3) the duration of presentation of the test fields is one important parameter. Optimal values are 2-3 seconds. With shorter or longer durations the matching range of the metameric matches increases significantly.

Session 12-14: *Acquired Deficiences*

Acute changes in blood glucose and their effects on color vision function in diabetes. M E SCHNECK[1], A J ADAMS[1] and V J VOLBRECHT[2]. 1: School of Optometry, University of California at Berkeley, California, USA. 2: Psychology Department, Colarado State University, Fort Collins, Colarado, USA.

The short wavelength (S) pathway is selectively compromised in diabetes, resulting in a loss of sensitivity to blue light and tritan-like color defects. Perhaps because the degree of S loss increases with the severity of retinopathy and in the presence of macular edema, the loss is often attributed to the long-term changes of diabetes, such as vascular damage and hypoxia. On the other hand, short term, induced hypoxia produces S deficits like those seen in diabetes, and changes in blood glucose are known to produce refractive changes in diabetic eyes. We therefore chose to examine whether acute changes in blood glucose can acutely affect S-sensitivity and color discrimination. We found that increases in blood glucose in diabetics (produced by 24-hour removal of diabetes medication) produced a loss of S sensitivity in 17 diabetics, most of whom had no retinopathy. Rapid reduction of blood glucose by insulin infusion resulted in significant improvements in S sensitivity. At multiple follow-up visits over the next 2 years blood glucose and S-sensitivity as well as several other measures (eg FM 100-Hue and D-15 tests) were assessed. As a group, the diabetics showed a significant relation ($p < 0.001$) between blood glucose at the time of testing (compared to their baseline) and S-cone sensitivity, but not other vision measures. Thus the fluctuations in blood glucose that diabetics exhibit over hours and days can significantly affect measures of S-cone sensitivity without changes in color discrimination tasks.

Longitudinal changes of visual function: eyes whose fellow eye has exudative age-related macular degeneration. A EISNER[1] and R S DOW[2]. 1: Devers Eye Institue. 2: Neurological Sciences Institute, Portland, Oregon, USA.

The eyes of about 30 subjects with unilateral exudative AMD in the fellow eye were tested with a battery of functional tests administered twice, 18 months apart. About 120 subjects without exudative AMD were also tested at 18-month intervals. Longitudinal change was evaluated for a) S cone-mediated sensitivity, b) absolute sensitivity (long wavelength test), c) Rayleigh color-matching, d) dark adaptation, and e) flicker sensitivity (20 Hz 660 nm test, 1000 td 480 nm background). All subjects had 20/25 or better acuity at both testing sessions. All stimuli were foveal or centred on the fovea. Compared to non-AMD subjects, S cone-mediated sensitivity and flicker sensitivity for AMD subjects decreased significantly over time. Changes of dark adaptation rate (summarized by the dark adaptation time constant) were significantly more variable for AMD subjects. Among AMD subjects alone, the proportion of the macula occupied by drusen at baseline was correlated significantly with subsequent reductions of both S-cone sensitivity and color-match-area-effect, and with subsequent widening of large-field color-matching range. The reductions of color-match-area-effect suggest that the quantum catching ability of the foveal cones may have decreased over time. On the basis of previous cross-sectional results, longitudinal changes were compared for particular sets of visual functions for the AMD subjects. Reductions of color-match-area-effect were correlated significantly with reductions of small-field matching range, consistent with two possibilities: 1) wide color-matching ranges may be associated with asymmetric shifts of the color-match midpoint towards deutan, and 2) shrinking small-field color-matching ranges may be associated with increasing pathology.

Matching range and age in a blue-green equation. J D MORELAND, Department of Communication and Neuroscience, Keele University, Keele, England.

In a cross-sectional study of 167 normal eyes (age: 13-83 yr) it was found that both the mid-match point and matching range of the Moreland equation increased with age, showing a marked acceleration beyond about 60 yr. Age changes in log(BLUE/GREEN) of the mid-match point have been accounted for by non-linear changes in the lens absorbance spectrum. Furthermore, the age changes in matching range and log(BLUE/GREEN) of the mid-match point are linearly correlated. This suggests that the loss of blue-green colour discrimination with age is due to increasing lens absorbance. The hypothesis is supported by parallel losses for large and small fields. A calculation which takes into account changes in mid-match point, in the relative luminosities of the stimuli, and in senile miosis, indicates an age-range change in retinal illuminance of about one log unit. The results of a filter simulation experiment will be discussed.

Effect of tinted posterior chamber IOL to colour vision. K OHHAMA, Y OHTA, K SAIKI, T MOTOHASHI and N TAKAHASHI, Tokyo Medical College, Tokyo, Japan.

The human lens turns to yellowish with age, which is said to protect the retina from near-UV light. Transmittance of short-wave light by postoperative cataract eye is found so changed as to affect colour vision. It is reported that cyanopsia is observed after cataract extraction; thus, we made yellow-tinted posterior chamber IOL, hereafter called UVCY-IOL, to rehabilitate normal colour vision postoperatively. Of transmittance, UVCY-IOL is tinted identically to the hue of the 53-year old human lens. All the patients with UVCY-IOL passed in the pseudiosochromatic colour vision plate and Panel D-15 and, with anomaloscope, anomalous quotient was detected to be within normal range. With 100-hue, total error scores with UVCY-IOL decreased significantly as compared with those with clear IOLs. Few subjects complained of photophobia and/or cyanopsia subjectively.

On the assessment of visual impairment by the use of Anandron: colour discrimination versus dark adaptation. A SERRA, I ZUCCA, C M DESSY and M FOSSARELLO, University of Cagliari, Italy.

To ascertain whether the use of Anandron (antiandrogen, RU 23908) in subjects suffering from prostatic carcer affects visual function, 12 patients were examined by a test battery including visual acuity, isopter perimetry, recovery of sensitivity during dark adaptation, colour discrimination besides fundus oculi and fluorescein angiography. The examinations were carried out before therapy and at various intervals: 3, 6, 12, 24 months after. The short term effects show that dark adaptation deteriorates while visual acuity and colour discrimination are unchanged. As a long-term effect recovery of dark adaptation and impairment of colour discrimination were found.

The relationship between spatial contrast sensitivity loss, colour vision loss and aging: implications for a mechanism, VAEGAN[1], A BANKS[2], A GATHY[2] and A HAMER[2]. 1: Department of Ophthalmology, University of New South Wales, Kensington, Australia. 2: Department of Ophthalmology, Sydney University, Australia.

The spatial frequency range most sensitive to initial contrast sensitivity losses in the elderly is uncertain. Global, high, low and mid-range spatial frequency losses have all been reported. We have reinvestigated the pattern of initial loss and its structural basis. We used a rapid reliable printed four alternative forced choice test (Brit J Ophthalmol; 1982, 66: 477-491) to measure contrast sensitivity from 0.15 to 4.8cy/deg in at least 15 normal Australian subjects in each decade to age 80 and compared them to a prior UK sample. The groups did not differ. In both populations the initial losses were at the highest spatial frequencies and were not marked until the 6th decade. We examined the influence of optical factors on this loss. We showed lens yellowing was not an early factor. FM 100 colour vision was tested in a subset (90) of the Australian group. Best scores and lowest variances were in the 3rd decade but a clear pattern of colour loss (a blue yellow defect) did not occur till after 75. We then showed small subpolar cataracts were not responsible since they caused across the board losses similar to those reported for more extensive cataract and well corrected elderly aphakic individuals still had high frequency losses. Some exceptional elderly people had normal contrast sensitivity. Early losses are therefore at high spatial frequencies, are not inevitable and are unlikely to be optical. Degenerative disease processes, at or after the receptors, such as age related macular degeneration or neural depletion in the cortex, may be involved.

Prolonged loss in long wavelength sensitivity after near IR (1064 nm) laser exposure. H ZWICK, S E REYNOLDS, D J LUND, S T SCHUSCHEREBA, B E STUCK and M BELKIN, Letterman Army Institute of Research, San Francisco, USA.

In this investigation, we have examined the effect of near infrared intense macula laser exposure on the non-human primate focal ERG spectral sensitivity function. Seven cynomologous monkeys were exposed to two parafoveal Q-switched Neodymium (1064 nm) laser pulses at approximately 4 millijoules TIE. Focal ERG spectral sensitivity measurements were made in the foveal region using a synchronous detection technique. Immediate suppression in the long wavelength region of the focal ERG spectral sensitivity function was observed in all animals. However, after several months post exposure, selective recovery occurred reflecting a more dominant presence of the long wavelength primate (575 nm) cone system. Such recovery may reflect more long term suppression of other macular receptor systems that normally inhibit the long wavelength cone mechanism. The more rapid long wavelength cone system recovery may occur via such neural receptor disinhibitory processes. Alternatively, the recovery process may reflect alteration in macula photoreceptor alignment induced by post exposure central retinal scarring.

Joint Meeting of the IRGCVD and AIC

Aberrant flicker sensitivity revealed by heterochromatic modulation photometry. J POKORNY[1], J D MORELAND[2] and V C SMITH[1]. 1: Visual Sciences Center, University of Chicago, Chicago, Illinois, USA. 2: Department of Communication and Neuroscience, Keele University, Keele, England.

Heterochromatic modulation photometry is a method in which a series of fixed standard luminance/test luminance ratios are presented, and at each ratio the modulation depth of the pair is reduced in tandem until the observer reports that flicker disappears. The expectation is a distinct minimum modulation threshold at the standard/test ratio representing the luminance match. At other luminance ratios, flicker sensitivity should vary with the luminance difference between standard and test. We have devised theoretical templates to describe modulation sensitivity as a function of standard/test ratio. Based upon knowledge from other flicker studies, flicker sensitivity would be expected to fall within the domain lying between linear visual system response to flicker (sensitivity proportional to the amplitude of modulation) and Weberian visual system response (sensitivity proportional to percent modulation). Using red and green lights, at low photopic luminances this expectation is well realized. At higher luminances when the red light is of higher luminance that the green, observers are much less sensitive to modulation than the models predict. These results may be related to the behaviour of single units in the magnocellular pathway, B.B. Lee (and JP and VCS) observed that these units show increasing second-harmonic response to lights of increasing redness.

Relative loss of chromatic vs achromatic response to monochromatic increments on intense achromatic backgrounds. B DRUM[1] and C E STERNHEIM[2]. 1: Wilmer Institute, Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA. 2: Department of Psychology, University of Maryland, College Park, MD 20742, USA.

The slope of the TVI (log threshold vs log background illuminances) function for monochromatic increments on achromatic backgrounds often exceeds Weber's Law above 4 log trolands (td) (Drum and Sternheim, 1990, OSA Technical Digest **15**, *p. 184). At such illuminances a 2 ° increment presented 0.6 log unit above threshold appears to lose chromatic saturation with increasing background intensity despite increasing excitation purity. We now report further evidence that achromatic backgrounds can produce response saturation in color-opponent pathways. We used a constant stimulus procedure to simultaneously measure increment threshold and assess stimulus color above threshold at background illuminances from 3.5 to 5.3 log td at test illuminances up to 0.8 log unit above threshold. The test stimulus was a foveal, 50 msec, 1° diameter field superposed on a steady, 1° diameter, achromatic (5128 K) background. A concentric, 15° diameter, achromatic surround one log unit dimmer than the background eliminated stray light effects from the test flash. Test chromaticities (450 nm, 550 nm, 650 nm or achromatic), test illuminances (5 levels in 0.2 log unit steps) and blank trials (one-sixth of all trials) were presented in a mixed order from trial to trial. On each trial in which the observer detected a flash he scaled the relative percentages of red, yellow, green, or blue, and the overall percentage of white in the field. Our results show that when background illuminance in increased from 3.5 to 5.3 log td, hue sensations are reduced relative to white. Red hue responses at 450 nm and the entire hue response at 550 nm are almost completely suppressed. Only the yellow hue response component of the 650 nm stimulus appears to be unaffected. These findings confirm that achromatic backgrounds can modify hue signals in chromatic pathways.*

Mechanisms underlying the response time(s) in heterochromatic brightness matching. L R RONCHI and C CASTELLINI, Istituto Nazionale di Ottica, 6 Largo Fermi, 50125 Florence, Italy.

The complexity of visual process has been leading to a number of interlaced paradigms to which experimental data are fitted. In matter of color vision, responses are referred either to receptoral trichromacy or to the post-receptoral opponent organization, or to both. For instance, one of the attributes of color perception, the brightness, is assumed to be the combination of achromatic and opponent (thrown out-of-balance) channels. An experiment is described where an achromatic field, of given luminance, to which the eye is adapted, is followed by a field of variable luminance. The psychometric functions describing the brightness match are steeper when both the fields are achromatic than in the heterochromatic case. Moreover, the response times are less than one sec in the former case, while attain even three or four sec in the latter. Our observers were also requested to act on their decisional criterion, by disentangling the achromatic contribution to brightness from the extra brightness, so that two responses per trial were recorded. The data are tentatively interpreted having in mind de Valois' suggestion, according to which various channels may be simultaneously accessible.

Linear colour mechanisms obtained from detection thresholds in cone contrast space. T Hine, G R Cole and W McIlhagga, Centre for Visual Sciences and Optical Sciences Centre, Australian National University, Canberra, ACT 2601, Australia.

We have obtained thresholds for detection of a 1 deg gaussian blurred (0.25 deg) spot flashed for 200ms on an 8.9 deg diam. white adapting field (1080td). The contrast of the spot was represented in the three dimensional L, M and S cone contrast space. For three specific but theoretically important planes within this space, we obtained complete detection contours for three normal observers. The shapes of the contours were assumed to be determined by the probability summation of three mechanisms, each of which constituted a linear combination of cone contrast inputs. The quantitative weightings of cones inputs into the three best fitting mechanisms revealed the following: a luminance mechanism with little S cone input, a red-green chromatic mechanism driven by L-M, and a blue-yellow chromatic mechanism driven by S-1/2(M+L). The action of these three mechanisms also determined the thresholds obtained for test stimulus directions not contained within the original planes. The red-green chromatic mechanism was an order of magnitude more sensitive than the other two mechanisms.

Dynamic test of colour vision: a comparison of psychophysical and pupillometric data. J L BARBUR, J BIRCH and A J HARLOW.

The development of sensitive tests of colour discrimination is of great interest both for diagnosing colour vision deficiencies and as an aid in the detection of early stage retinal diseases. Colour matching and the use of pseudo-isochromatic plates provide adequate methods for assessing deficiencies of colour vision, but are not always easy to use particularly with infants or other non-communicative subjects. The new test makes use of a high resolution colour monitor, the visual stimulus consisting of small, spatially discrete elements which vary randomly in luminance in both **space** *and* **time**. *The test pattern is generated by introducing a chromaticity difference between selected elements and the remaining background pattern. The threshold for colour discrimination along selected axes in colour space is determined by means of both psychophysical and pupillometric methods. The psychophysical method makes use of a staircase procedure with variable step sizes which provides an estimate of colour discrimination threshold. The pupillometric method involves extraction of transient changes in pupil diameter triggered by the discrimination of a colour difference. This technique is based on recent findings which show that the pupil constricts transiently when the eye is presented with coloured stimuli at isoluminance. The data obtained so far in both normal subjects and in a group of dichromats show that the psychophysical and the pupillometric methods used for assessing colour discrimination thresholds yield consistent results. The new test is insensitive to small luminosity differences introduced by the generation of the chromatic pattern. It is hoped that the use of the pupil response to signal the detection of the chromatic pattern will make it possible to investigate the development of colour discrimination in newborns and other non-verbal subjects.*

Variations in colour matching data: limits on variability in the absorption spectra of cone photoreceptors. A B MORLAND and K H RUDDOCK, Biophysics Section, Physics Department, Imperial College, London.

The absorption spectra of human cones fall into three groups, but data for single cones show significant differences (H.J.A. Dartnall et al, 1983, Nature, 323*: 623-625; M. Alpern and E.N. Pugh, 1977, J. Physiol.,*

266: 613-646) and genetic sequencing (J. Nathans et al, 1986, Science, 232: 203-210) have also been reported. We have obtained small (1 deg 20 min) and large (10 deg) field colour matches in ten deuteranopes, nine albinos and twenty-five normal trichromats, in order to analyse the sources of variation in colour matches. Except for the albinos, all subjects were age matched. Inter-observer variations in the dichromatic matches could be accounted for by differences in light losses by the macular pigment, and under conditions which eliminate this factor, all ten yield closely similar responses. With one exception (one ocular albino), all albinos lacked macular pigment, and correspondingly their colour matches show little variation. Finally, the effects of macular absorption resulted in significant spread in the small field matches of the normal trichromats, and this spread is not observed in the large field matches. All forty-six subjects accepted a small field match designed to eliminate the effects of macular absorption (K. H. Ruddock, 1963, Vision Res. 3: 419-429). We calculate the intrinsic variations in cone absorption spectra implied by our data and compare these with the variations in the microspectrophotometric data.

Evidence that colour opponent-type horizontal cells receive direct input from luminosity-type horizontal cells in the turtle retina. P J ANDERTON[1] and T J MILLAR[2]. 1: School of Optometry, University of New South Wales, Kensington, New South Wales, Australia. 2: Department of Biological Sciences, University of Western Sydney, Kingswood, New South Wales, Australia.

A population of colour-opponent horizontal cells (C-type H-cells) depolarise to red light and hyperpolarise to green light (554 nm). The hyperpolarisation is due to direct input from green cones and the depolarisation is thought to be due to inhibitory feedback from luminosity-type horizontal cells (L-type H-cells) to green cones. Intracellular electrophysiology was combined with pharmacology and ultrastructural immuno-histochemistry to examine the nature of the input from L-type H-cells to C-type H-cells. N-methyl-D-aspartic acid (3.0 mM NMDA) or kainic acid (0.1 mM KA) both caused depolarisation and loss of light response in L-type H-cells, whereas photoreceptors were not affected by either drug. In C-type H-cells, NMDA caused an increase in the amplitude of the response to green light, and a reversal of the response to red light, to one of hyperpolarisation. This is consistent with the idea that the depolarising response is being driven by L-type H-cells. Kainate eliminated the hyperpolarising response to green before removing the depolarising response to red. This suggests that the input from L-type H-cells to C-type H-cells is feed forward, rather than feedback: input from L-type H-cells survived block of the synapse between green cones and C-type H-cells by KA. One C-type H-cell was filled with Lucifer Yellow during recording and subsequently prepared for electron microscopy using a photo-oxidation technique. L-type H-cells were counterstained using anti-GABA antibody. The tissue was serially sectioned and examined under the electron microscope. On the parts of the dendrites near the cell body of C-type H-cells, membrane specialisations indicative of synapses between C-types and L-types were observed. Taken together, the pharmacological and morphological evidence indicate that the depolarising response is carried in a feed-forward pathway from L-type to C-type H-cells, rather than feed-back pathway from L-type H-cells to photoreceptors.

ELECTIONS TO THE DIRECTORIAL COMMITTEE

The IRGCVD By-Laws require elections to be carried out by a postal ballot. Eighteen eligible IRGCVD members have been nominated for election for the term 1991-1995. There are 10 Committee places to be filled.

The President (A Roth) and General Secretary (J D Moreland) remain in office until 1993. The Local Organiser of the 1993 Symposium (E Zrenner) will be a *de facto* member of the Directorial Committee until 1993.

Existing officers have indicated their willingness to serve for another term. Their re-election would provide the guarantee of continuity which the Group needs. Other committee members have indicated their readiness to step down to make way for "new blood".

Eligibility to vote: Honorary members and all other members (full, "retired" and student) in good standing.

Abbreviations

Officers	Committee members
T: Treasurer	C: Ordinary Member
ST: Secretary-Treasurer	L1: Local Organiser (1991)
PE: Proceedings Editor	L2: Local Organiser (1993)

Note your vote in the boxes by a tick, check ☑ or cross ☒. Only 10 votes, please!

☐ A Adams	☐ J Birch (T)	☐ G Bresnick
☐ B Cole	☐ S Dain (L1)	☐ B Drum (ST, PE)
☐ A Eisner	☐ G Jacobs	☐ K Kitahara
☐ M Marré (ST)	☐ J D Mollon (C)	☐ D van Norren
☐ Y Ohta (C)	☐ J Pokorny (C)	☐ A Serra (C)
☐ H Scheibner	☐ H Sperling (C)	☐ E Zrenner (C, L2)

Please return this voting paper to:

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PLEASE NOTE: Do not remove or deface this label: it may invalidate your vote.

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