

COLOURED FILTERS IN THE EYE: protective functions and effects on visual performance with emphasis on colour vision

Applied Vision Research Centre
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Abstracts: 17 November 2006

(10.00am) Optical ocular filters: are they a benefit, a nuisance, or both?

Robert Weale

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It is widely held that the macular pigment xanthophyll exerts a protective function in the eye especially as regards the so-called "blue"-light hazard (BLH). Looked at from an evolutionary point of view, the only blue light our distant ancestors will have been exposed to will have been the blue sky. An analysis based on its spectrum and that of BLH shows that what protects the retina is the coloration of the lens, with that due to xanthophyll playing a negligible role. An important sequel of this theoretical approach is that young eyes are far more exposed to risk from BLH than is true of more mature ones. This analysis in no way detracts from whatever important role xanthophyll may play biochemically, but intends merely to emphasise the importance of the coloration of the lens.

(10.30am) Blue light as a co-factor or risk factor in AMD

John Marshall

KCL Department of Ophthalmology, The Rayne Institute, St Thomas' Hospital London, UK.

The current concepts of ageing in the outer retina will be reviewed and integrated with experimental data derived

from studies investigating the damaging effects of light. Type 1 damage being chronic, low-irradiance effects on photoreceptors will be contrasted to type 2, being higher irradiance, shorter exposure, initiating mechanisms within the retinal pigment epithelium. The inter-relationship between these two systems will be discussed and, in turn, related to pathological observations on phakic and pseudophakic eyes. These findings will be discussed in relation to diurnal rhythms and man-made environmental changes with some scaling against ophthalmic instruments and ocular examinations. Finally, the advantages and disadvantages of blue-blocking intraocular lenses will be highlighted.

(11.00am) Optical density of the aging human ocular media

Dirk van Norren and Jan van de Kraats

Department of Ophthalmology, University Medical Center, Utrecht.

We analyzed the nearly complete literature on absorbance of the eye media (lens, cornea, aqueous and vitreous humour) in the spectral region 300-700 nm. Five templates were needed for an adequate description. Two were found in all media. They stand for Rayleigh scatter and the absorbance of tryptophan. Three additional templates for the lens represent absorbance in 38-hydroxykynurenine glucoside, and absorbance in two substances that are exclusively found at older age. We also derived aging functions for all templates. With this material the transmission of any part of the media at any age can be calculated.

(12.00am) Effects of ocular filters on Visual Performance in the Mesopic Range

John L Barbur

Applied Vision Research Centre, City University, London, UK.

Visual performance in the mesopic range is affected by changes in the spatial and temporal properties of the retina and/or changes in the quality of the retinal image as a result of increased aberrations and scattered light. Differences in the level of selective absorption of blue light by the lens and the macular pigment can also contribute to the increased variability in visual performance we observe in the mesopic range. The effectiveness of blue light scatter and chromatic aberrations can be reduced by pre-receptor absorption of blue light. This is particularly important when the state of accommodation of the eye is dominated by the long wavelength content of the scene, but the subject's task is to attend to an object that consists mostly of out of focus blue light (that continues to be detected by L and M cones). Under such conditions the large chromatic aberration in the optics of the eye can affect significantly the resolving power that can be achieved. These effects become even more interesting (and potentially more important) at lower light levels in the mesopic range when rod signals are also involved. Rods are sensitive to blue light, but spatio-temporal vision is extremely poor in the mesopic / scotopic range (i.e., sluggish temporal responses and extensive spatial summation that results in very poor contrast acuity). Reduced rod signals as a result of blue light absorption may therefore benefit visual performance by extending the superior characteristics of photopic vision lower into the mesopic range (Kvansakul, J. et al. 2006). The aim of this study was to quantify the variability in visual performance in the mesopic range in normal vision and to establish the extent to which this variability is caused by inter-subject differences in ocular aberrations or / and the selective absorption of blue light.

(12.30am) Contrast acuity thresholds, chromatic sensitivity and the macular pigment optical density in the eye

Marisa Rodriguez-Carmona

Applied Vision Research Centre, City University, London, UK.

An extensive investigation of visual performance was

carried out in 34 subjects that participated in a carotenoid supplementation trial. We measured high mesopic contrast acuity thresholds (CATs), macular pigment optical density (MPOD), wavefront aberrations, scattered light and yellow-blue (YB) and red-green (RG) chromatic discrimination thresholds. The subjects were given daily supplementation of lutein, zeaxanthin or a combination of the two for six months and a further six months of doubled supplementation. The data reveal a trend toward lower CATs in all groups supplemented, with a statistically significant improvement in the lutein group ($p=0.001$). Light scattering in the eye and the rms wavefront aberrations show decreasing trends as a result of supplementation, but no correlation with MPOD.

Supplementation data reveal an increase in M-ROD that was almost uniform within a centre region around the fovea subtending $\pm 4\sigma$. RG sensitivity was high in all subjects with thresholds well within the normal range. Unexpectedly, YB thresholds were also normal and showed no correlation with MPOD. A model for threshold colour discrimination based on appropriate combinations of cone contrast signals was developed. The model accounts for the absence of correlation between MPOD and YB thresholds and predicts a marginal improvement in RG when MPOD is high (OPO, Vol. 26, 137-147, 2006).

(2.00pm) Macular pigment: Compensation mechanisms and effects on visual performance.

Billy R. Hammond

University of Georgia, Vision Sciences Laboratory, Department of Psychology, Athens, Georgia, USA.

Macular pigment (MP) lies anterior to the photoreceptors and filters short-wave light. At peak absorbance, this filtering can range from almost complete transmission to a low of about 3%. We studied compensation for these filtering differences across the central retina by measuring hue-cancellation functions and increment thresholds. Despite large between-and-within subject-differences in the transmission of shortwave light by MP, short-wave sensitivity and colour perception across the central retina was relatively constant. Large individual differences in MP might also be expected to be related to variations in visual performance. These purely optical hypotheses can be summarized as (1) increasing visual acuity by reducing chromatic aberration (2) increasing comfort and visibility by the reduction of glare and dazzle (3) enhancing detail by the absorption of 'blue haze' and

contrast. We evaluated the Acuity hypothesis (1) by measuring MP levels, gap and hyper acuity in the same observers using stimuli that were illuminated with white (absorbed by MP) or yellow light (not absorbed by MP). MP density did not correlate significantly with either gap or hyper acuity measured in the yellow or white conditions. In contrast, we found strong relations between MP and visual performance tested under glaring conditions. To test the glare hypothesis (2) we measured MP levels, photostress recovery, and grating visibility under veiling conditions. Visual thresholds under glare conditions were strongly related to MP density (e.g., $r = 0.76$, $p = 0.0001$ when using white light). Photostress recovery time, after exposure to xenon-white light, was significantly shorter for subjects with higher MP levels ($r = -0.79$, $p = 0.0001$). Finally, modelling data regarding the Visibility hypothesis (3) will be reviewed.

(2.30pm) Choosing the optimal filter in an intraocular lens

Dirk van Norren and Jan van de Kraats

Department of Ophthalmology, University Medical Center Utrecht, The Netherlands.

The spectral filter in the human lens is a trade-off between protecting the retina against dangerous radiation and unhampered stimulation of sensory systems, in particular the Short Wavelength Sensitive (SWS) cones. We made an inventory of spectral characteristics of natural lenses (old and young) and commercially available intraocular lenses. Next, we calculated the impact from diffuse sunlight filtered by these lenses on the blue light damage system, and that of sensory systems (SWS cones, rods, melatonin suppression, melanopsin). The outcome was expressed as log ratios to the young human lens. The 70 year old lens had 0.61 log less stimulation of the blue light damage system, and 0.36 log unit less rod stimulation. Commercial lenses showed a wide variety in their characteristics. We calculated that it should be possible to manufacture an intraocular lens with spectral characteristics that surpass those of the human lens.

(3.00pm) Does macular pigment have a role to play in age-related macular degeneration?

Nigel Davies

Consultant Ophthalmologist, Chelsea and Westminster Hospital, London, UK.

Age related macular degeneration is the most common form of registerable blindness in the developed world. The aetiology of the disease is not fully understood and appears to be multifactorial. Risk factors for the disease include genetic factors, gender, obesity, systemic factors such as cardiovascular disease and ocular factors including light iris colour and hypermetropia. Local oxidative stress has been implicated in the pathogenesis of the disease. The roles of the macular pigments in reducing oxidative stress by filtering incident short wavelength light and by acting as free radical scavengers have both been proposed as mechanisms whereby the risk of ARMD may be reduced. This presentation will review the current state of knowledge around the above hypotheses and will also explore the possibility of oral supplementation in preventing and treating the problem.

(4.00pm) Macular pigment optical density determined by reflectometry and flicker: Is flicker the gold standard?

Richard A. Bone and Mark Adams

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Heterochromatic flicker photometry (HFP) is often regarded as setting the standard with which other methods of determining macular pigment optical density (MPOD) should be compared. We have developed a reflectometry method employing a retinal camera modified with multi-bandpass filters that provides the reflectance of the retina at a number of specific wavelengths. Based on a simple model of sequential absorbers (MP, cone and rod photopigments, and melanin), image analysis software is employed to derive the optical density distribution of the MP. We have tested the procedure on a group of 15 subjects in the age range 18 to 24, whose MPOD was also determined by HFP. We found a less than perfect correlation ($R^2 = 0.65$, $P < .001$) between MPODs obtained by the two methods that led us to re-examine one of the basic assumptions of HFP. It is assumed that photoreceptor relative spectral sensitivity is the same for the fovea and parafoveal locations where measurements are made.

Preliminary data indicate that this may not be a valid assumption. We modified the flicker photometer to determine the complete MPOD spectrum from 410 to 680 nm. The spectrum should be essentially flat with an OD of zero above – 540 nm, yet we found for the 3 subjects tested an apparent OD increasing with wavelength from zero at – 560 nm and, in one of the subjects, reaching a value of – 0.3 at 680 nm. This suggests that the LWS/MWS cone ratio may be significantly lower, at least in some subjects, in the fovea than in the parafovea. The result would be a decreased sensitivity to longer wavelengths in the fovea, equivalent to the effects of an absorbing pigment. It is possible that, from these measurements, we could determine the LWS/MWS cone ratio in the fovea relative to the parafovea and make appropriate corrections to the MPOD spectrum.

(4.30pm) Macular pigment measurement by colour matching and by motion photometry

Jack Moreland

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Colour matching: Fifteen normal subjects made colour matches, using a Moreland arromaloscope, for foveal (circular)- and 9 extrafoveal (annular) fields at eccentricities 1° to 9° . Stimulus mixtures were $460 + 570$ nm and $490 + 610$ nm respectively in the right and left half-fields. The match point was white: a feature favouring rapid and reasonably precise matches by untrained subjects. The short wave component of each mixture is strongly absorbed by macular pigment MP.

Motion photometry: Twenty different (with one exception) normal subjects made luminance matches using the same apparatus, modified for motion photometry. A grating (spatial frequency 0.38 c.deg^{-1}), whose alternate bars were filled respectively with 460 nm and 580 nm lights, drifted steadily at $37^{\circ}.\text{sec}^{-1}$ horizontally across the field of view. Motion photometry uses a minimisation paradigm, similar to that of flicker photometry but is particularly suited to untrained subjects. Here, the luminance contrast between the 460 and 580 nm bars of the grating was adjusted by varying the 580 nm radiance so that perceived motion was minimised. Two foveal fields (0.9° and 2.2° diameter) and 11 extrafoveal annular fields at eccentricities 0.8° to 7.5° along the upper vertical meridian) were used. Subjects made measurements for both eyes: some with replications.

Individual MP retinal absorbance profiles were calculated from changes in the colour and luminance matches. Foveal absorbance ranged from 0.2 to 0.9 (colour) and from 0.2 to 0.8 (motion, 0.9° field). Mean MP profiles were calculated for each method. Foveal data were optimally aligned with annular data in the mean profiles when plotted at 0.8 (colour) and 0.7 (motion) of the field radius. Precision in both techniques was limited by fixation errors foveally and by Troxler's adaptation effect parafoveally. Rod intrusion affected colour matches beyond 80° .

(5.00pm) Objective assessment of isoluminance at different eccentricities and estimation of macular pigment distribution using steady-state VEPs.

Robson AG^{1,2} and Parry NRA³

Moorfields Eye Hospital, London¹. Institute of Ophthalmology, London². Vision Science Centre, Manchester Royal Eye Hospital, Manchester M13 9WH³.

Purpose: To specify isoluminance at different retinal eccentricities and determine macular pigment distribution using the steady-state VEP.

Methods: Red/Green (R/G) and Blue/Green (B/G) gratings (2 cycles/deg) were generated within a circular stimulus field (radius 1 degree) and within 4 annular fields (maximum radius 8 degrees) on a colour monitor. Isoluminance was determined for each stimulus using minimum flicker photometry. 15Hz onset-offset VEPs were recorded to spatially identical stimuli as the luminance ratio between adjacent chromatic components was swept from 0.25 to 0.85 in 11 discrete steps. VEP isoluminance was determined by Fourier analysis, whereby colour-specific responses are dominated by the fundamental and achromatic VEPs by the 2nd harmonic. Macular pigment optical density was computed by comparing the the isoluminant point at any location with that for the most eccentric annulus and by introducing a correction coefficient to compensate for phosphor overlap (Moreland et al., 2001).

Results: There was close correlation between the isoluminance values determined by minimum flicker and VEPs, for both R/G and B/G stimulation. Eccentricity had minimum effect on R/G isoluminance but B/G flicker and VEP values varied according to the distribution of macular pigment.

Conclusions: The steady-state VEP may be used to determine isoluminance at different retinal

eccentricities. Macular pigment distribution may be estimated by steady-state VEPs to B/G stimuli.

References:

Moreland, ID., Robson, A.G. & Kulikowski, .1:1 (2001). Macular pigment assessment using a colour monitor. *Color Res Appl.* 26, S26-1-S263.

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(10.00am) A decrease in serum carotenoid concentration, as caused by stanols and sterols has no impact on the macular pigment

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Background: Observational epidemiological studies have shown that individuals with low carotenoid intake and/or low carotenoid blood levels have an increased risk of degenerative diseases. Products enriched with sterols or stanols could help manage overweight, but a possible concern is that they can lower concentrations of serum carotenoids. Studies on the longer-term health effects of decreased carotenoid concentrations are lacking.

Methods: We performed a 18 month randomized, double-blind, placebo-controlled parallel trial with three treatment groups to determine the effects of margarines enriched with sterols and stanols on serum carotenoids concentrations and macular pigment optical density (MPOD). Subjects were randomly assigned to one of the three treatment groups: margarine without added plant sterols or stanols, plant sterol enriched margarine (25 g / day), or plant stanols enriched margarine (25 g / day). Serum cholesterol, 0-carotene, a-tocopherol and lutein concentrations and the macular pigment optical density were evaluated during the study.

Results and Conclusions: The 13-carotene serum concentrations at the study end was significantly lower in- the sterols and stanols groups compared to the control group. The change in serum lutein was significantly lower in the sterol group compared to the stanol group. Macular pigment optical density showed no difference between the three treatment groups, despite the difference in decrease in the lutein concentration.

(10.30am) A Study of Macular Pigment Supplementation: can we increase macular pigment optical density?

C.J. Hammond^{1,8}, S.H.M. Liew¹, C.E. Gilbert², T.D. Spector¹, Mellerio⁴, J. Marshall^{4*}, F.J.G.M. Van Kuijk⁵, S. Beatty⁶, F. Fitzke⁷

¹Twin Research & Genetic Epidemiology Unit, St. Thomas' Hospital, London, ²International Centre for Eye Health, London School of Hygiene and Tropical Medicine; ⁴Department of Ophthalmology, The Rayne Institute, St. Thomas' Hospital, London; ⁵Department of Ophthalmology and Visual Sciences, University of Texas Medical Branch, Galveston TX; ⁶Department of Chemical and Life Sciences, Waterford Institute of Technology, Ireland; ⁷Institute of Ophthalmology, London; ⁸Princess Royal University Hospital, Bromley Hospitals NHS Trust, Orpington, UK.

Objective: Dietary supplementation with carotenoids has a potential role in preventing age-related macular degeneration and there are numerous formulations of lutein/zeaxanthin supplements available. This study was performed to assess the effect of a high-dose- lutein and zeaxanthin supplement on macular-pigment density levels in a large group of healthy subjects.

Design: Prospective, non-randomized supplement study.

Participants: 322 healthy female twin volunteers, aged 1-6-50 years (mean age 39+/8.7 years).

Main outcome measure: Macular and serum carotenoid (lutein/zeaxanthin) levels, measured by optical density and high performance liquid chromatography respectively.

Results: At baseline, mean MPOD was 0.43 density units (SD 0.21; range 0.04 to 1.25), and exhibited a normal distribution. After 3 months of L/Z supplementation, there was no statistically significant increase in MPOD levels and after 6 months, a marginal increase in MPOD was seen (mean increase: 0.025+/-0.16, p=0.02). Subdivision of baseline MPOD into quartiles revealed that baseline levels made no difference to the treatment effect of supplementation. Serum L and Z levels were significantly raised from baseline at 3 months, following commencement of supplementation (mean increase 123% and 459% respectively, p<0.0001 for both).

Conclusions: Despite dramatic increases in serum concentrations of its constituent carotenoids, MPOD exhibited only a marginal increase (3.7 and 5.7%, measured using two different methods) in response to 6 months, high dose, daily supplementation with L and Z. Widespread lutein/zeaxanthin supplements cannot be routinely recommended to a general population.

(11.00am) Influences of supplementary Lutein and Zeaxanthin on macular pigment optical density and serum concentrations of these carotenoids: The LUNA Study (Lutein Nutrition Effects measured by Autofluorescence)

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Background: As low levels of macular pigment (MP) are supposed to represent a potential risk factor for development of age related macular degeneration (AMD) the question if the concentration of MP in the eye be influenced by supplementation of Lutein (L) and Zeaxanthin (Z) is of clinical interest.

Methods: Retinal (by 2-wavelength autofluorescence method) and serum (HPLC) response to 6 months supplementation with 12mg esterified Lutein (L) and 1mg esterified Zeaxanthin (Z) (Intervention group, I, n=108) were investigated on five occasions during the period of supplementation, and once again 3 months following discontinuation of the supplement. A control group (C, n=28) received no supplementation and was examined at baseline and once again after a mean of 29.4 (SD± 9.3) weeks.

Results: At baseline mean value MP optical density at 0,5/ eccentricity (MPOD_{0,5}/baseline) was 0,51D.U. (density units) in the I and 0,53D.U. in the C group. Following supplementation of L and Z the MPOD_{0,5}/ values increased outlasting the intake for three months (visit 6). Rise in MPOD at 0,5/ eccentricity in I (+0.1 ODU) was significantly (p<0.0008) stronger than that seen in C (+0.03 ODU), this rise was significant for I only (p<0.001) and was accompanied by significant increments in serum L and Z (p<0.01). Calculation of quartiles of I due to (MPOD_{0,5}/visit6)-(MPOD_{0,5}/baseline) resulted in a quartile of no increase of MPOD_{0,5}/ although elevation of L and Z serum levels proved resorption.

Conclusions: Concentration of MP proved to increase under intake of 12mg L and 1mg Z. One quartile of the probands showed no increase of MPOD although serum levels increased. These findings suggest that low levels of MP in the eye may be a result of individual local metabolism and not of deficiencies in the intake.

(12.00pm) A twin study of macular pigment optical density

S.H.M. Liew¹, C.E. Gabert², T.D. Spector¹, J. Mellerio⁴, J. Marshall⁴, F.J.G.-M. Van Kuijk⁵, S. Beatty⁶, F. Fitzke⁷, C.J. Hammond^{1,8}

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Purpose: Several studies have found that higher levels of macular pigment (MP) are associated with a reduced risk of age related macular degeneration (ARMD), which is known to have a genetic predisposition. A classical twin study -was performed to determine the heritability of MP in the healthy eye.

Methods: One hundred and fifty twin pairs (76 monozygotic [MZ] twin pairs and 74 dizygotic [DZ]), aged 18-50 years, participated. MP density was measured with a psychophysical method using heterochromatic flicker photometry (HFP), and with a physical imaging method using fundus autofluorescence (AF). The covariance of MP within MZ and DZ twin pairs was compared, and genetic modelling techniques were used to determine the relative contributions of genes and environment to the variation in MP.

Results: The mean MP density, measured using HFP, was 0.43±/0.21. Using AF, the mean MP density measured at 1/2-degree eccentricity, was 0.41±/0.11. MP density values were more highly correlated in MZ twins compared with DZ twins, using both HFP (MZ 0.65, DZ 0.24) and AF methods (MZ 0.83, DZ 0.50), suggesting genes have an important influence. A model combining additive genetic and unique environmental effects provided the best fit and resulted in a MP heritability of 0.67 (95% CI 0.52-0.77) and 0.85 (95% CI 0.78-0.90), using HFP and AF values respectively. Results showing different patterns of MPOD distribution and relationship to retinal thickness will also be discussed.

Conclusion: This classical twin study demonstrates that genetic factors have an important and significant influence on MP density yielding heritability estimates

of 0.67 and 0.85, using HFP and AF methods of MP quantification.

(12.30pm) Macular pigment in two continents

John Mellerio & Shervin Ahmadi-Lari

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Purpose: Reports of macular pigment optical density (MPOD) in populations from different countries and regions of the USA sometimes show differences and sometimes do not. Of those studies that find a difference, it is difficult to discern if it is significant and thus arises from some biological or environmental cause, or results from the use of different measuring instruments and techniques. This study therefore used the same instrumentation and operator to measure MPOD in London (UK) and Sydney (Australia).

Methods: An instrument based on Heterochromatic Flicker Photometry (HFP) using LEDs which switched in 180 degree counterphase between 470 nm and 530 nm in either a centrally fixated test field or quarter-arcs arranged horizontally at ± 5 degrees from the fixation point. Subjects adjusted the luminance of the 470 nm LED until they perceived minimum flicker and the MPOD was found from the log of the 470 nm central field luminance to that of the eccentric arcs.

Results: MPOD in 124 UK eyes was 0.41 ± 0.16 (mean \pm SD), whilst that from 90 Australian eyes was 0.29 ± 0.07 : the difference was highly significant ($p < 0.0001$). Factors such as smoking, female sex, light iris colour, decreased fruit and vegetable intake, and increased light exposure, were associated with significantly reduced MPOD in the UK data but the Australian data only showed significant reductions in females and eyes with light irides. There was no correlation between MPOD and age in either group.

Conclusions: The MPOD of Australian eyes was found to be significantly less than that in UK eyes, a difference that might be explained by the higher mean solar irradiation in Australia. Factors previously associated with reduced MPOD in the UK follow the same pattern in Australia, although the differences were not all statistically significant.

(2.00pm) Longitudinal stability of macular pigment assessed by minimum motion photometry: 4 to 8-year-follow-up.

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Purpose: To monitor normal subjects with different macular pigment (MP) profiles, over several years to assess fluctuations in MP levels as well as the reliability of repeated measurements using the psychophysical technique of minimum motion photometry.

Methods: Four subjects with significantly different macular pigment distribution profiles were monitored over periods of 4 (2 subjects) and 8 (2 subjects) years. MP optical density (OD) profiles were obtained on 4-7 occasions based on photometric matches between 460nm and 580nm lights. Optical density values were computed at 12 retinal locations relative to the most eccentric setting at 7° eccentricity.

Results: MP profiles varied in shape (best fit by a logistic, exponential or polynomial function) and in magnitude (mean peak OD ranged from 0.2 to 0.8). Standard deviations correlated positively with the MPOD distribution gradient computed ($r = 0.64$). Linear regressions for all data measured longitudinally for each of 4 the subjects were virtually flat. In particular, foveal gradients were 0.0053yr^{-1} and -0.0012yr^{-1} (range 4 yr) and 0.0005yr^{-1} and 0.0041yr^{-1} (range 8 yr).

Conclusions: MP retinal distribution profiles differ widely between subjects but individual MP density and distribution exhibit a high degree of long-term stability. Measurement errors are greatest where the MPOD profile is steepest.

(2.15pm) Integrating Macular Pigment into Retinal Function

Max Snodderly

Dept of Human Ecology and Institute for Neuroscience, University of Texas at Austin, USA.

The macular pigment is composed of xanthophylls that prevent light from damaging plants. Various lines of evidence indicate that macular pigment protects the

retina and retinal pigment epithelium from damage as well. Recent work shows that macular pigment, or lack of it, can affect the distribution of retinal pigment epithelial cells and the density of foveal photoreceptors. In addition, macular pigment reduces discomfort due to bright lights, and it alters the gain of the short-wavelength mechanisms of the visual system. For a deep understanding of functioning of the retinal fovea, we need to integrate the influence of macular pigment into our thinking about the perceptual mechanisms of the fovea. This is particularly important as we pursue ways to characterize visual-aging and to prevent age-related macular degeneration, the leading cause of new cases of blindness in many countries.

Posters

(Exhibit hall, Oliver Thompson Foyer)

Measurement of macular pigment optical density: Densitometer™ versus Maculometer™

Edward Loane, Jim Stack, Stephen Beatty, and John M. Nolan

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Objectives: To compare the macular pigment optical density (MPOD) values obtained with two different heterochromatic flicker photometry (HFP) devices, and to explore the implications of our findings with respect to the general principles of HFP methodology.

Methods: We recruited 109 healthy subjects. Demographic and health details were recorded. MPOD was measured using the two HFP devices (the Maculometer™ and the Densitometer™). The Maculometer™ uses a reference location of 5.5o and has a fixed flicker frequency (fovea) target: 13 Hz and parafoveal target 18 Hz), whereas the Densitometer™ uses a reference location of 7o and has the option to adjust flicker frequency.

Results: The mean difference in MPOD (Maculometer™-Densitometer™) was -0.00054, standard deviation 0.0882. The 95% confidence interval for the mean difference was -0.017 to 0.016. For 50 of the 109 subjects (45.9%), the Maculometer™ MPOD measurement was lower than that of the Densitometer™, for 4 subjects (3.7%) the readings were identical, and for 55 subjects (50.5%) the Maculometer™ reading was higher. Regression of Maculometer™-Densitometer™

difference on the variables age, gender, body mass index, family history and average MPOD produced the equation: $\text{diff} = 0.131 - 0.002(\text{age}) - 0.128(\text{avgMPOD})$, the other variables not being significant at the 5% level ($R^2 = 0.107$).

Conclusions: As the 95% confidence interval for the mean difference contains 0, we conclude that there is, on average, no difference in measurements provided by the two methods. However, it appears from the regression analysis that the Maculometer™ -Densitometer™ difference becomes more negative the older the subject and/or the greater their MPOD.

The Macular Assessment Profile (MAP) test - a new VDU based technique for measuring the spatial distribution of the macular pigment

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Although the effect of macular pigment (MP) on colour matches has long been recognised, the extent to which MP diminishes yellow-blue chromatic discrimination sensitivity remains controversial. The measurement of MP optical density therefore remains of great interest, and this is often performed using optical systems for heterochromatic flicker photometry (HFP) that employ short- and long-wavelength (SW and LW, respectively), narrow-band lights. 2D profiles of MP optical density are

more difficult to measure using optical systems, largely because of the mechanical constraints imposed on generating stimuli of varying size at a number of locations in the visual field. The use of full, square-wave modulation also makes-it difficult to set a flicker null point and this affects the accuracy of the match. MP systems based on visual display units have numerous advantages and can be designed to overcome most of the problems associated with optical systems, but their use in MP measurement has been limited, largely because of the restricted luminance range of the blue phosphor and the extended spectral bandwidth of the blue and green phosphors. The latter causes the MP density to be underestimated (Moreland, J. D. et al. 2001).

In order to overcome these problems we designed a new

MAP test using a visual display that can be arranged to achieve high luminance with stable operation. A "notch" optical filter was incorporated in the design to separate the three phosphor outputs into two beams that can be modulated independently: one beam that is absorbed selectively by the MP (i.e., the SW beam) and the other that is not (i.e., the LW beam). A mean luminance level of 30 cd/m² can be achieved using this system with a maximum range of 1.3 log units for the SW beam. Stimuli of varying sizes are generated within the uniform background at the same location on the display using only 15% modulation of the long-wavelength beam and appropriate counter phase modulation of the short wavelength beam. The fixation stimulus is moved appropriately so as to position the flickering stimulus at a number of locations around it. Two techniques have been developed and tested. The first is based on nulling the flicker generated by the long-wavelength beam by appropriate adjustment of the short-wavelength beam.

The second method is based on measurement of flicker detection thresholds (20 Hz flicker) at each location for each of the two beams. The latter technique provides a more accurate estimate of flicker thresholds, but takes longer to perform. A model was also developed to predict the expected relationship between peak MP density and that measured using the display-based technique. MP data measured using these two techniques, together with comparison data obtained in the same subjects using a Moreland anomaloscope modified for motion photometry. Since the Moreland anomaloscope employs narrow band stimuli, we were also able to test the model and to produce the calibration curve needed to convert the display estimates of MP density to expected peak values.

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