VISION & READING DIFFICULTIES PART 4 COURSE CODE: C-10855

Coloured Filters - How Do They Work?


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This article is the fourth in a series of five about vision and reading difficulties. The first article provided a general overview and the second covered conventional optometric correlates of reading difficulties (e.g. binocular vision problems). The present article continues on from the third article by describing the use of coloured filters in treating a condition now known as visual stress. Visual stress is often associated with reading difficulties, but also a variety of other neurological conditions. This article concentrates on the possible mechanisms for the benefit from coloured filters, beginning with obvious peripheral factors. The terminology for this condition has changed over the years (e.g. Scotopic Sensitivity Syndrome, and Meares-Irlen Syndrome) and the issue of terminology is discussed at the end of this article. **Warning: DO NOT LOOK AT FIGURE 6 ON PAGE 33 IF YOU HAVE MIGRAINE OR EPILEPSY.**

Light scatter

Scatter of light within the eye might be expected to reduce the contrast of the retinal image. Short wavelength light is scattered more than longer wavelengths. Tinted lenses that absorb short wavelength light might therefore be expected to increase the contrast of the retinal image (whilst reducing its luminance). Most precision tints, however, absorb long wavelength light. Each point in Figure 1 shows the chromaticity of a precision tinted lens in a consecutive series of 1000 tints. The majority of tints are green, turquoise or blue, the latter two of which preferentially absorb long wavelengths rather than short wavelengths. Even if scatter of light within the eye is responsible for a reduction in image contrast, it is not immediately apparent why such a contrast reduction would contribute to the perceptual instability that precision tints are reported to reduce.

Retinal mechanism

Individuals who benefit from coloured filters generally have no retinal abnormality on fundus examination. They are just as likely as anyone else to have anomalous colour vision, at least on the basis of conventional clinical tests. Subtle impairments of short wavelength sensitive cone (S-cone) function have, however, been discovered in individuals with migraine[1] and migraine is relatively common among individuals who benefit from coloured filters.[2]

Individuals differ considerably with regards to the relative proportion of long wavelength sensitive cones (L-cone) and medium wavelength sensitive cones (M-cone) they possess.[3] Although this might appear to offer an explanation for the individual differences in optimal tint,[4] there are indications to the contrary.[5] Individuals with relatively few M-cones and those with relatively few L-cones give exactly comparable responses when mixing red and green light to produce unique yellow light.[3] Evidently there are gain mechanisms that compensate for the differences in L-cone and M-cone ratios. The gain mechanisms may ultimately explain the individual differences in optimal tint, but there is no evidence as yet.

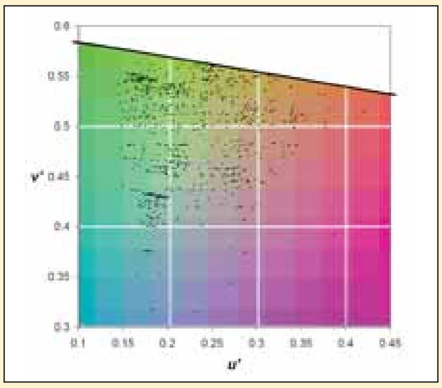

Figure 1

Chromaticities of 1000 consecutive precision tints (courtesy of Tim Noakes, Cerium Visual Technologies)

A class of melanopsin-containing retinal ganglion cell is intrinsically photoreceptive, codes for retinal irradiance, and contributes to the pupillary light reflex.[6-8] The action spectrum peaks at 482nm, which might mean that coloured lenses preferentially transmitting short wavelengths of light alter the size of the pupil, with consequences for retinal image quality. As yet however, there is no evidence as to any selective effects of precision tinted lenses on pupil size.

Accommodation

Coloured tints affect the spectral composition of light entering the eye, and might therefore be expected to affect chromatic aberration, and with it accommodation. However, there is no relationship between the type of refractive error and the chromaticity of the chosen lenses,[9, 10] and the results of clinical tests of accommodation do not seem to suggest an explanation for visual stress.[9-11] Nevertheless, abnormally large fluctuations of accommodation have been recorded in patients who use precision tinted lenses.[12] Precision tinted lenses reduce the fluctuations, without affecting the magnitude of the accommodative response,[13] but this effect is also achieved with spectrally neutral grey lenses of equivalent photopic transmission.[12] Evidently accommodative fluctuations are a correlate of visual stress, but would not at present appear to provide a mechanism for the reduction of stress with coloured filters.

Binocular vision anomalies

The binocular coordination of patients with visual stress sometimes exhibits subtle anomalies, but these are by no means always obtained[14] and there are patients with perfectly normal binocular function who nevertheless benefit from tints.[9-11, 15] Precise measurement of binocular coordination during reading is an active research area,[16] but in any event, binocular or accommodative anomalies should be considered and treated before precision tints are prescribed.

Magnocellular deficit

The distinction between the characteristics of the magnocellular (M) and parvocellular (P) divisions of the visual system was reviewed in the second article in this series. It is an over-simplification to think of these systems as distinct. Their functions overlap and there are numerous inter-connections between the two pathways. There is also a third pathway, the koniocellular pathway, which is comparatively little studied but may turn out to be of considerable importance.[17]

There is convergent research evidence to suggest that a proportion of people with dyslexia have a deficit of the M visual system but there is surprisingly little evidence that the deficit is specific to dyslexia. Indeed such a deficit has been found in several diseases, including glaucoma,[18-23] diabetes,[24-27] retinitis pigmentosa,[24, 28, 29] and migraine.[30-32] There is no evidence for a double dissociation i.e. patients with P deficits having different profiles of disability to patients with M deficits. Without such a double dissociation it remains possible that M deficits simply reflect damage to a relatively fragile part of the visual system (larger M cells have greater metabolic demand), and that such damage can occur in a variety of retinal and neurological conditions.

Children with signs of an M deficit are more likely to make reading errors that are suggestive of visual confusion than are other children,[33] and they are less likely to be aware of the precise position of letters in a word.[34] It remains to be seen whether the M deficit directly causes these visual confusions, whether the M deficit causes binocular instability which in turn causes confusions, or whether both confusions and binocular instability are the result of some other causal link. It might seem reasonable to suppose that people with dyslexia with signs of the M deficit tend to be those with the dyseidectic form of dyslexia, which is characterised by the types of reading errors that one would expect to result from visual confusions. Surprisingly, it is the individuals with a phonological, rather than a dyseidectic, weakness who tend to have the M deficit.[35]

Several studies have offered explanations for the improvements in reading speed with coloured filters in terms of magnocellular deficits.[36, 37] Recently, these explanations have been questioned on the following grounds. Two studies have failed to show M deficits in children who benefit from coloured filters.[11, 38] Another recent extensive study of 22 individuals with dyslexia found two individuals with evidence of a M deficit, and six with visual stress, but there was no overlap between these two groups.[39]

Among adults and children selected as poor readers, the proportion that

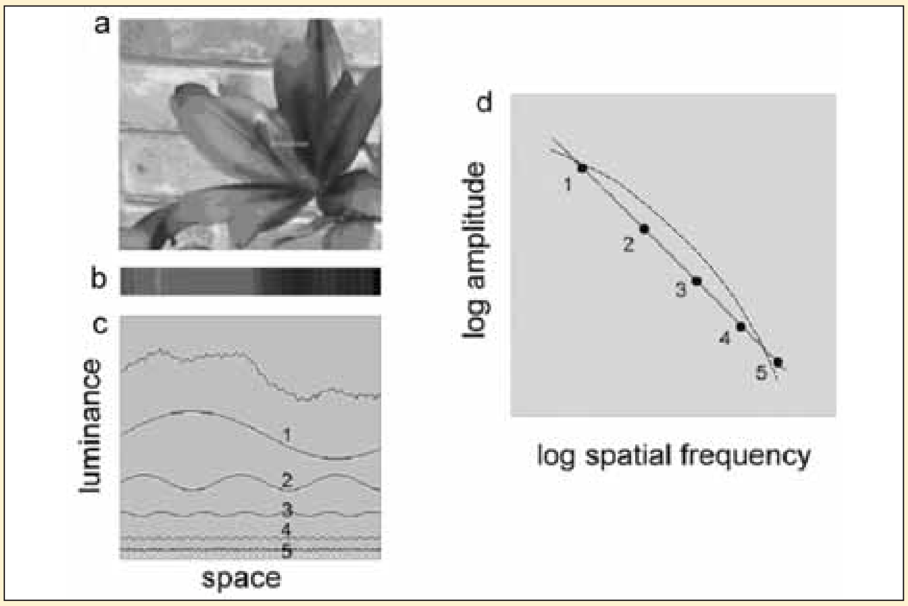

Figure 2
Panel a: image of a flower including a horizontal bar showing a section enlarged in Panel b. Panel c: the luminance profile of the section (top curve) and its decomposition into Fourier components (curves beneath). Panel d: the amplitude of these components expressed as a function of their spatial frequency

Figure 3
Jesmond Barn, 2004, by Debbie Ayles ©. Acrylic, 128cm x 100cm x 2cm. The painting won 1st prize in the 'Art meets Science' award in the Daily Telegraph/Novartis 'Vision of Science' Photographic Awards, for its depiction of an attack of basilar artery migraine

read more quickly with overlays is greater than in the general population.[40] According to one criterion, visual stress affects about 30% of dyslexic children compared with 12% of controls.[40]

Vision therapy

Visual therapy covers conventional and less conventional interventions, some of which are evidence-based whilst others are not.[41] The therapies have been reviewed in the second article of this series. Studies have indicated that binocular vision and accommodative anomalies are unlikely to provide an explanation for visual stress in most cases.[10, 11] However, these anomalies can be present together with visual stress, and a detailed assessment of binocular vision and accommodative function (see article two of this series) is important in every case before precision tinted lenses are prescribed. A clinical protocol for such assessment will be described in the fifth article in this series.

When is vision stressful?

Vision may be uncomfortable when the neurological processes that underlie vision are not functioning appropriately. This can occur under a wide variety of circumstances, for example: (1) when the eyes are inappropriately aligned (as in vergence insufficiency), (2) when the visual image provides insufficient or inappropriate vergence information (as in 3D viewers), (3) when the visual image is impoverished (as when the illumination is low or glaringly high), and (4) when the visual image itself provides for an unusually strong neurological response. This latter cause is described next.

The visual images that occur in nature exhibit a simple relationship between the contrast energy and the spatial scale at which it occurs. The contrast is greater at large spatial scales (low spatial frequencies), and falls off with increasing spatial frequency. Consider the image of the flower in Figure 2a. Part of the image in the rectangular section shown is reproduced in Figure 2b. The luminance profile of this section is represented as a graph in the top curve in Figure 2c. The remaining curves in Figure 2c show the Fourier components into which the luminance profile can be decomposed i.e. the curves, which when added together, sum to give the top curve. The decrease in contrast amplitude of the Fourier components decreases as their spatial frequency increases. The amplitude is shown as a function of spatial frequency and is a straight line when plotted as a graph with log-log scales in Figure 2d. Images in nature have approximately linear functions with slopes between -0.8 and -1.5.[42, 43]

Fernandez and Wilkins[44] obtained ratings of the discomfort from a wide variety of complex images derived from works of contemporary non-representational art such as Figure 3, photographs of rural and urban scenes and images of filtered noise. They found that whereas the amplitude spectrum of the comfortable images had a linear function similar to the solid line in Figure 2d, the uncomfortable images had a curvilinear function similar to the broken line in Figure 2d, with a relatively greater amplitude at mid-range spatial frequencies. Figure 4 (left panel) shows, for one of their studies of contemporary art, the ratio of

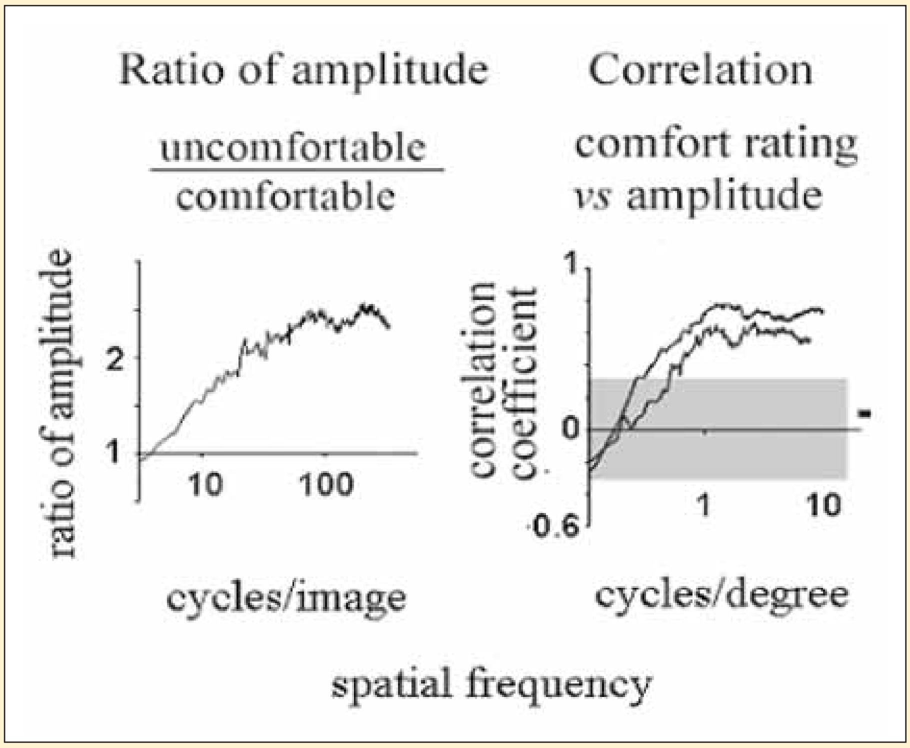

Figure 4
Mean Fourier amplitude as a function of spatial frequency shown separately for uncomfortable images (bold) and comfortable images. Right: Ratio of the amplitude for uncomfortable and comfortable images

amplitude in images rated as "uncomfortable" relative to that for images rated as "comfortable". The ratio is shown as a function of spatial frequency. Uncomfortable images had greater Fourier amplitudes than comfortable images at mid-range spatial frequencies close to 3 cycles per degree. The correlation between discomfort and contrast energy is shown in the right panel of Figure 4 as two curves for individuals at different viewing distances. In Figure 5 (solid line), the average of similar functions for four studies is shown. Figure 5 (fine line) shows the contrast sensitivity function for sine-wave gratings of equivalent subtense. The similarity in spatial frequency tuning suggests that images are uncomfortable when they have an excess of contrast energy at those spatial frequencies to which the visual system is generally most sensitive. The phase of the Fourier components however appears to be irrelevant.[44]

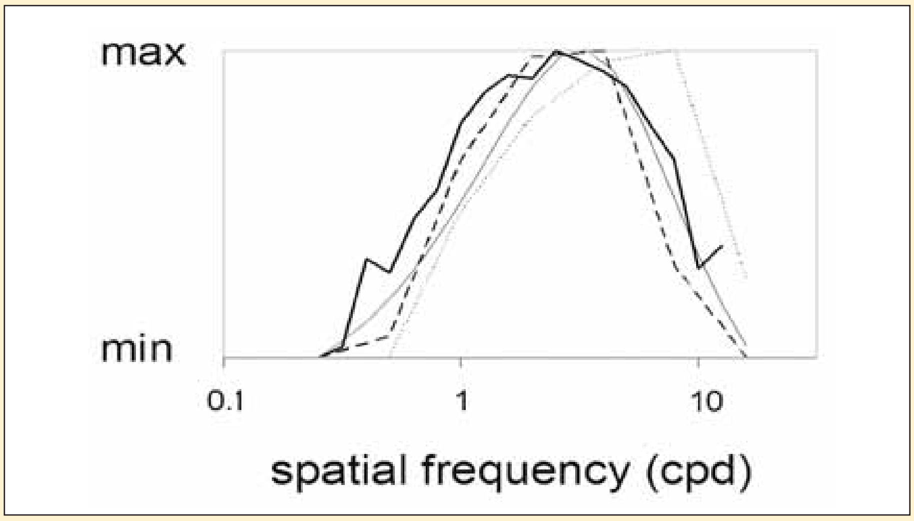

Figure 5
Bold line: Correlation between Fourier amplitude and discomfort averaged over four studies. Fine line: contrast sensitivity function for sine-wave gratings of equivalent subtense. Dotted line: rated aversion in response to a grating with square-wave luminance profile. Broken line: Probability of paroxysmal epileptiform EEG activity in patients with photosensitive epilepsy, in response to a similar grating[41].

Discomfort from periodic patterns

If all the contrast energy in an image is concentrated in one orientation and at one spatial frequency, the image approximates a grating. Gratings with a spatial frequency of 3 cycles per degree induce a strong neurological response within the visual system to judge from the fact that (1) they are readily seen at low contrast;[45] (2) they interfere with vision, masking low contrast images,[46] and (3) they induce a visual evoked potential of relatively high amplitude.[47] The gratings also give rise to perceptual distortions and can be uncomfortable to look at.[48] The cluster of symptoms of perceptual distortion and discomfort that such periodic visual patterns evoke is sometimes called pattern glare. Pattern glare can be appreciated by viewing Figure 6 (DO NOT LOOK AT THIS PATTERN IF YOU HAVE MIGRAINE OR EPILEPSY). The Pattern Glare test[49] contains three patterns, one with a spatial frequency of about 3 cycles per degree, similar to that of Figure 6, and two control patterns, one with a low spatial frequency and one with a high spatial frequency. The relative number of perceptual illusions/distortions reported in response to the 3 per degree pattern are greater for individuals with migraine, and in individuals for whom coloured overlays improve reading speed.[50] The individuals who are helped by overlays can also be recognised by the reduction in the speed of visual search that they exhibit when the search area is surrounded by a grating pattern.[51, 52]

Text as periodic patterns

The successive lines of printed text approximate a periodic pattern similar to a grating, as can be appreciated by inspecting the filtered image in Figure 7. This helps explain why a simple mask that covers the lines above and below those being read can improve the clarity of text. Such a mask is known as a typoscope, and it acts as a spatial filter, reducing the power in the periodic pattern. The individuals who report improvements in clarity with a typoscope are generally those who report many distortions in patterns of stripes.[53]

There are also stripes, not only from the lines of text, but also in the vertical strokes of letters. Words such as "mum" are more striped than other words such as "over", and striped words take longer to read. The stripes can be measured using a mathematical technique called autocorrelation. Imagine two identical images of a word reproduced in black ink on overhead transparencies, and placed in register on the surface of the overhead projector. As one transparency is moved horizontally across the other, the overall light transmitted through the combined transparencies decreases initially, but then increases as one letter stroke is superimposed on its neighbour. The way the light transmitted varies with the relative horizontal position of the two transparencies resembles the horizontal autocorrelation function, shown for the words mum and over in Figure 8. The first peak in this function provides a measure of the similarity in

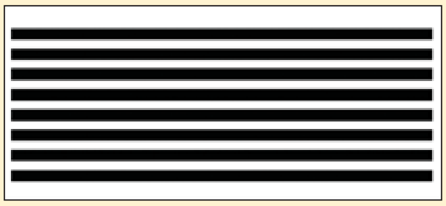

Figure 6
A grating with square-wave luminance profile. From a reading distance of 40cm the grating has a spatial frequency close to that at which aversion is maximal. DO NOT LOOK AT THIS PATTERN IF YOU HAVE MIGRAINE OR EPILEPSY

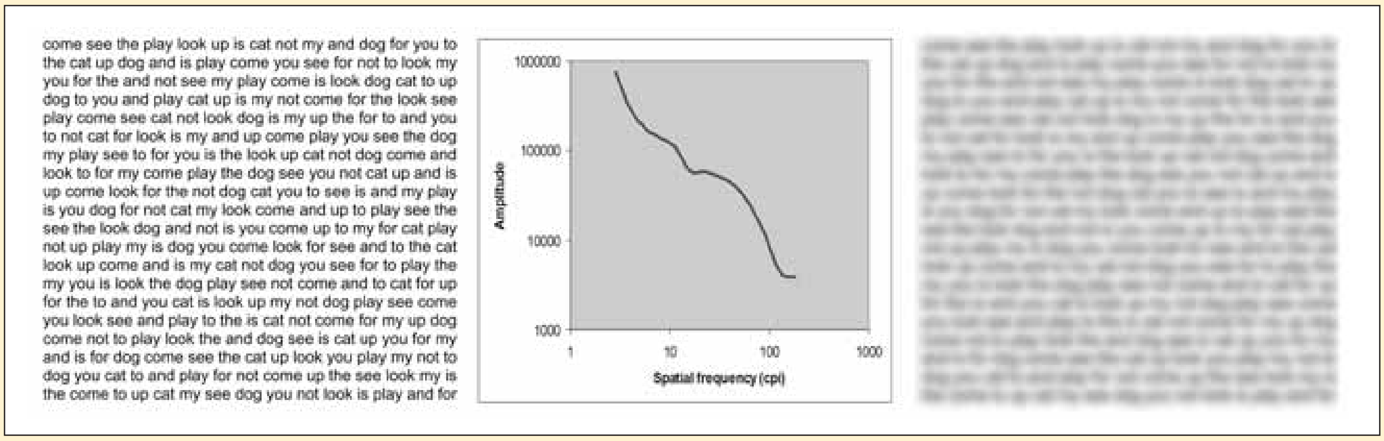

Figure 7
A passage of text. Centre: The Fourier amplitude spectrum of the image. Right: The image has been blurred to show the mid-range spatial frequency components

shape between neighbouring letter strokes within a word. The height of the initial peak predicts the appearance of a word as "striped" and, more importantly, also predicts the speed at which the word can be read. Reducing the stripes by means of a distortion that interferes with the spatial periodicity of the letter strokes increases reading speed.[54]

The periodic strokes of letters may affect reading acquisition. As children learn to read, the text they are required to see initially has large letters (x-height of about 4mm) and over a period of about 5 years the size of the letters decreases by a factor of two, to reach adult size by the age of about 11. There is evidence to suggest that the decrease in letter size occurs too early in life, compromising reading speed[55] and comprehension.[56]

Letter size affects the measurement of reading age. Reading age was assessed using conventional test material in which the letters decreased in size as the test progressed, and was compared with the reading age obtained on an equivalent version of the test in which the letters stayed at their original large size throughout. The reading age was increased by an average of 4 months when the text remained in large font throughout.

The periodic strokes differ from one font to another. Sassoon Primary, a font used in schools, has a higher spatial periodicity than the adult font Verdana.[56] Perhaps for this reason it is read more slowly by 7 year olds even though they are more familiar with Sassoon than Verdana.[56]

Another factor that is likely to affect children's reading is the illumination of their classrooms. The illuminance is high, with levels in excess of 1000 lux being common.[57] In 80% of classrooms,[57] the lighting still exhibits 100Hz variation in brightness and chromaticity as a result of inefficient and unhealthy[58] 50Hz control circuitry. The adverse effects of spatial periodicity in text are likely to be enhanced under these conditions.

Neurological basis for the aversion to periodic patterns

Individuals who see most distortions in periodic patterns are generally those who experience frequent headaches.[48] On days when they have a headache, they see more illusions, up to 24 hours before the onset of the headache.[59] If the headaches are on one side of the head, the illusions predominate in one lateral visual field,[48] suggesting a

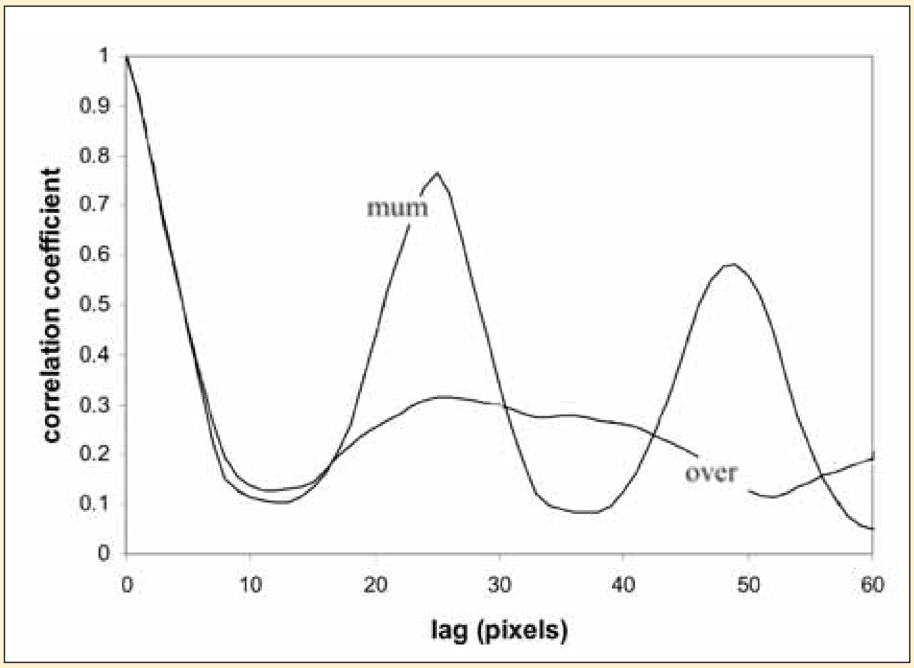

Figure 8
The horizontal autocorrelation of the words mum and over

neurological mechanism. Individuals with migraine are particularly susceptible to the illusions, and can find the patterns very aversive; viewing the patterns may even induce a migraine attack.[60-62]

Patients with migraine are not the only individuals at risk from such patterns. Many patients with photosensitive epilepsy who are liable to seizures from flickering light are also liable to seizures from patterns of stripes. The patterns responsible for illusions have characteristics similar to those that induce seizures. Figure 9 (broken lines) shows the number of illusions as a function of line length, pattern size, spatial frequency, duty cycle and contrast. The solid lines show the probability of epileptiform EEG activity in patients with photosensitive epilepsy, indicating the likelihood of seizures. Note that the functions are similar. The shaded areas in Figure 9, show the parameters of the stripes formed by the successive lines of printed text, and as can be seen the parameters resemble those of aversive periodic patterns.

It would therefore appear that periodic patterns with mid-range spatial frequency could provoke a strong neurological response in the visual cortex, to which patients with migraine and photosensitive epilepsy are particularly susceptible.

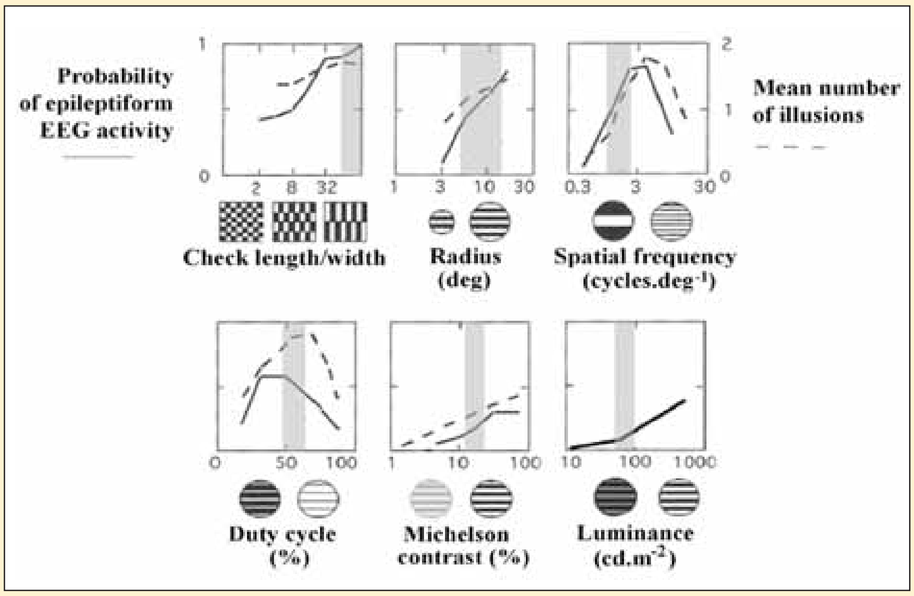

Figure 9

Mean number of illusions (broken lines) and probability of epileptiform EEG activity in patients with photosensitive epilepsy (solid lines), shown as a function of various pattern parameters indicated schematically below the horizontal axes. The shaded bars show the parameter range for text considered as a striped pattern

What are the physiological mechanisms of pattern glare?

Using functional magnetic resonance imaging (fMRI) Huang and colleagues[63] measured the blood oxygenation level dependent (BOLD) response in the visual cortex when volunteers viewed gratings with various spatial frequencies. In normal volunteers, patterns with mid-range spatial frequencies that induce pattern glare produced a slightly larger BOLD response than those with higher and lower spatial frequencies. Huang et al. compared these responses in migraineurs. The response at mid-range spatial frequencies was abnormally high in migraineurs, consistent with their greater susceptibility to pattern glare and perceptual distortions[48, 60, 62] (Figure 10). The elevated response is consistent with other evidence for a hyperneuronal response in migraine: (1) the threshold for phosphenes in response to transcranial magnetic stimulation of the occipital cortex is lower in migraineurs than in controls[64] (2) the visual evoked potential has a greater amplitude (e.g. Sand et al.[65]) and shows reduced habituation.[65] It is possible that in individuals with headache the visual cortex is hyper-excitable in some way; indeed four categories of antiepileptic drugs have been shown to prevent migraine attacks.[66] If the cortex is hyper-excitable, it is likely that the hyper-excitability is not diffuse, but patchy, as it is in photosensitive epilepsy, where a subset of orientation columns of complex cells may be involved in triggering seizures.[67]

Why does the tint have to be specific?

The evidence that the tint has to be specific comes from two randomised controlled trials of precision tinted lenses.[68, 69] Even stronger evidence comes from a study in which patients' reading speed was measured repeatedly under light of randomly chosen chromaticity.[70] The reading speed was maximum at a particular chromaticity, different for each patient, but consistent for that individual. The reading speed decreased with the difference in colour between the individual optimum and the colour under which the reading speed was measured, whether that difference reflected a change in hue, in saturation or in both. However, when the difference in colour exceeded a certain value (delta E* ~ 80) the reading speed showed no further decrease and remained similar to the reading speed under white light. It was not possible to relate the way in which reading speed changed with chromaticity to any of the colour confusion axes that might have suggested a peripheral mechanism. Instead, central cortical mechanisms appeared to be implicated.

Cortical hyperexcitability

One possible cortical mechanism for the effects of tinted lenses relates to the hyper-excitability described above. In patients with photosensitive epilepsy there is a hyper-excitability of the visual cortex[67] that is not necessarily diffuse, but can involve complex cells with particular orientation tuning.[67] Sometimes these patients can be treated with coloured lenses.[71] Within V2 of the

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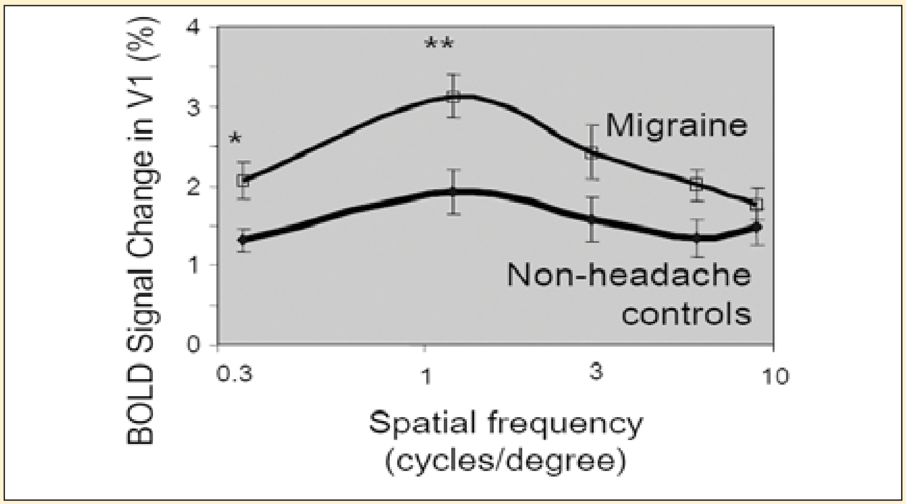

Figure 10

The blood oxygen level dependent (BOLD) signal change in normal volunteers and patients with migraine when they observed a grating with square-wave luminance profile, shown as a function of spatial frequency. After Huang et al.[60]

macaque cortex, neurons detecting differently coloured gratings are disposed across the cortical surface in an arrangement that is reminiscent of the CIE UCS diagram.[72] It has been argued that precision tints rearrange cortical activity in such a way as to avoid strong excitation in hyper-excitable orientation columns of the cortex.[73] The avoidance of strong excitation in hyper-excitable columns may prevent the spread of excitation, and with it the inappropriate firing of visual neurons that gives rise to illusions and distortions.

The above hypothesis is admittedly speculative, and has the disadvantage that it cannot predict which colours of tint will help which patients. Until a physiological correlate of the optimum colour can be found, any explanation is incomplete. The hypothesis does however have some strength; it predicts that precision tints will be of benefit in a range of neurological conditions that affect the hyper-excitability of the visual cortex. Such conditions include not only migraine and photosensitive epilepsy, but also autism (which has a high co-morbidity with epilepsy)[74-76] and multiple sclerosis (which has a co-morbidity not only with epilepsy[77] but also with migraine),[78] and in the latter there is physiological evidence of (motor) cortex hyperexcitability.[76, 77] Recent studies have shown benefits of precision tints in both autism and multiple sclerosis. Ludlow et al.[79, 80] showed that 80% of children with autistic spectrum disorders improved their reading speed with overlays by more than 5%, compared to 20% of controls matched for age and intellectual level.[81, 82] They also reported the case of a boy whose sensory sensitivity improved dramatically with the use of a pair of blue tints.[83] Newman Wright et al.[84] showed that 25 of 26 patients with multiple sclerosis improved their reading speed with an overlay by more than 5%. Grey overlays, included as a control, had no effect on reading speed. After a period of coloured overlay use, there was an improvement in reading speed without the overlay.

Terminology

The terminology used to describe visual stress has changed over the years. In the 1780s spectacles with green or blue tints were used to 'ease eyestrain from heavy reading'.[85] Irlen[86] initially used the term Scotopic Sensitivity Syndrome, and then Irlen Syndrome. The first of these terms is probably scientifically inappropriate and the second fails to recognize the first detailed description of the condition by Olive Meares.[87] For this reason, Evans[88] described the condition as Meares-Irlen Syndrome, and this term gained some popularity. Recently, as the aetiology of the condition has started to become more understood, it has increasingly been referred to by the descriptive title of "visual stress", which is more easily remembered by the public. The term visual stress has therefore been used in these articles.

Conclusion

There is a growing body of research on the causes of visual stress and of its reduction with coloured filters. None of the obvious candidate peripheral mechanisms as yet offer a sufficient explanation, and central, cortical mechanisms appear likely. Precision spectral filters may be of limited use in retinal disease,[89, 90] but they appear to offer relief of symptoms of visual stress in a wide variety of neurological conditions that affect the visual system.

About the authors

Arnold Wilkins is Professor of Psychology at the University of Essex and Director of the Visual Perception Unit. His career has been spent mainly in research at the Medical Research Council Applied Psychology Unit in Cambridge where for many years he studied photosensitive epilepsy, a study that later generalised to an investigation of visual stress.

Peter Allen is a Principal Lecturer and Director of Clinics at Anglia Ruskin University. Peter is an examiner and assessor for the College of Optometrists. He is an active member of the Myopia and Visual Function research group including research in recent years on visual stress, reading, and accommodative facility.

Bruce Evans is Director of Research at the Institute of Optometry and Visiting Professor to City University. He spends most of his working week in an independent optometric practice in Essex. Bruce first started researching visual factors in dyslexia in 1988 and he is author of the book "Dyslexia and Vision".

References

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1) Why does light scatter in the eye appear NOT to play a role in the clinical efficacy of most precision tints?
a) Most precision tints absorb long wavelength light
b) Most precision tints transmit long wavelength light
c) Light scatter does not reduce the contrast of the retinal image
d) Short wavelength light is scattered more than long

2. Which of the following is TRUE? Among patients who wear precision tints, accommodation:
a) Is normal
b) Shows fluctuation that is relatively large
c) Is unaffected by the precision tints
d) Is unaffected by luminous transmission

3. The proportion of Long and Medium wavelength sensitive cones varies from one individual to another. This variation:
a) Is correlated with an individual's choice of tint
b) Affects the perception of yellow
c) Is not likely to explain an individual's choice of precision tint
d) Affects the perception of green

4. Which of the following is TRUE? Binocular coordination of patients with visual stress:
a) Is invariably abnormal
b) Offers an explanation of the effects of precision tints
c) Is important to treat
d) Is not associated with similar symptoms

5. Which of the following is TRUE? The magnocellular deficit in dyslexia:
a) Is usually associated with visual stress
b) Occurs in the vast majority of patients
c) Is associated with a phonological deficit
d) Offers a good explanation for the effects of tints

6. Which of the following is TRUE? Vision may be uncomfortable when:
a) The eyes are inappropriately aligned
b) There is insufficient vergence information
c) The visual stimulus provides for a strong neurological response
d) All of the above

7. There is often a simple relationship between the contrast in an image and the spatial scale over which it is measured. This relationship is not found in:
a) Images of natural scenes
b) Comfortable images
c) Photographs
d) Uncomfortable images

8. Which of the following is TRUE? Periodic patterns occur in text and they:
a) Impair reading speed
b) Cause discomfort when reading
c) Have a greater effect when the letters are small
d) All of the above

9. Visual stress can be helped by precision tints in all EXCEPT which one of the following?
a) Migraine
b) Glaucoma
b) Autism
d) Multiple sclerosis

10. Which of the following is TRUE? The conditions in which precision tints can reduce symptoms of visual stress:
a) Have co-morbidity with epilepsy
b) Are those in which the visual cortex may be hyper-excitable
c) Are not generally those that involve disease of the retina
d) All the above

11. The pattern glare test requires patients to report the perceptual distortions seen in three gratings. At a viewing distance of 40cm which spatial frequency induces the most glare?
a) 0.5 cycles per cm
b) 4 cycles per cm
c) 16 cycles per cm
d) 60 cycles per cm

12. Which of the following has NOT been used as a term to describe visual stress?
a) Asthenopia
b) Irlen syndrome
c) Scotopic sensitivity
d) Meares-Irlen syndrome

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