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Treatment of photosensitive epilepsy using coloured glasses

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A recently introduced optometric technique, colorimetry, enables the perceptual effects of ophthalmic tints to be evaluated subjectively, optimized, and then prescribed in tinted spectacles. The new technique is beneficial in reducing visual stress in patients with dyslexia and migraine. We describe an open trial designed to ascertain: (1) whether the colorimetry assessment, as it is now given, is safe for the investigation of photosensitive patients in optometry clinics where colorimetry equipment is most readily available, but where EEG control is not practical; (2) what proportion of patients with photosensitive epilepsy is likely to benefit to the extent already described in individual cases[1]; (3) whether a tint selected by colorimetry could be shown to reduce the incidence of paroxysmal epileptiform EEG activity in response to flicker and patterns, thereby validating the subjective methods and corroborating the reported seizure reduction.

Twenty-four females and nine males (aged 12–43 years) took part. All the patients had suffered visually-provoked seizures, had exhibited a photoparoxysmal response on at least one previous EEG recording, and had received a diagnosis of photosensitive epilepsy. Twenty-two were currently experiencing seizures. A further EEG was recorded in all except seven cases: a routine resting record, followed by hyperventilation. Colorimetry was performed after hyperventilation and before photic stimulation. Twenty-three (70%) reported beneficial effects during colorimetry and were prescribed glasses. There was a preponderance of lenses with a rose or purple colour, in contrast to patients with dyslexia.

Seventeen of the 23 patients were available at follow-up, an average of 2.4 years later. Thirteen (57%) reported benefits, and said they were still using the lenses. In six of the 13 the benefits were pronounced, including a reduction of dizziness from fluorescent lighting, elimination of aura when using computer screens etc. Only in three cases was there a reduction in seizures that could reasonably be attributed to the use of lenses; in two of these cases no medications were prescribed, and in the third the medications remained unchanged for four years, two before and two after the introduction of the glasses. In an additional four cases a reduction in seizures was observed but medication had been changed. There was a modest reduction in EEG photosensitivity with the coloured lenses but also to an equivalent or lesser extent with grey in all of the eight patients examined in this way. One patient had seizures during colorimetry, but the seizures were not accompanied by scalp EEG changes.

Key words: photosensitive epilepsy; visually-induced seizures; asthenopia; visual stress; precision ophthalmic tints; colorimetry.

INTRODUCTION

When plastic (resin) spectacles lenses became generally available it was possible for the first time to obtain inexpensive glasses tinted to almost any colour. Resin lenses can be coloured simply by dipping them into hot dye. The dye is absorbed into the surface of the resin, colouring the lens independently of its thickness. The advent of this technology has made it possible to select colours that are tailored to suit individual preference. The lenses can have a very wide range of spectral transmissions.

Although the dyeing techniques were initially used for cosmetic purposes only, it has become apparent that tinted spectacles can offer treatment for perceptual disorders. It has emerged that many people, and particularly those with migraine, report a perceptual distortion of stressful visual stimuli such as text, and

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that this distortion can be reduced or eliminated when the text is illuminated by light of a certain colour, different for each individual[2].

A new system enables a therapeutic tint to be selected on an individual basis[1,2]. A stressful high contrast stimulus (meaningless text) is illuminated by coloured light in a device called an *intuitive colorimeter*. The device uses a patented system of colour mixture which allows the colour (hue) and depth of colour (saturation) to be varied independently and continuously, without any associated change in brightness (luminance). While the luminance remains constant and at a suitable level, effects of small changes in colour on perceptual distortion and visual discomfort can be assessed rapidly. One advantage of the colorimeter is that assessment can be made whilst the eyes remain colour adapted. The adaptation helps to ensure that the colour chosen is as close as possible to the optimal tint for spectacles.

When an appropriate colour setting in the colorimeter has been obtained, the setting is precisely matched by a particular combination of standardized trial lenses. The lenses have smooth spectral transmission (to reduce the influence of the illuminating source, metamerism). Any chromaticity can therefore be obtained by a lens combination that itself has a smooth spectral transmission. The combination that matches the colorimeter setting is worn by the patient when viewing both text and natural scenes and the colour refined, if necessary, by adding or subtracting trial lenses. The combination of trial lenses finally selected constitutes a tint 'prescription'. The prescription is sent to a dyeing company and used to guide the dyeing of matching spectacle lenses.

A double-masked study in children with perceptual distortion or asthenopia during reading has compared spectacles having the appropriate optimal colour with others having a sub-optimal colour. The optimal and sub-optimal colours were selected in the colorimeter: the optimal colour reduced or eliminated perceptual distortions, and the sub-optimal tint was just sufficiently different to permit distortions. Spectacles matching these colour settings were worn for four weeks in random order. The occurrence of headaches was significantly reduced with the optimal, as compared with the sub-optimal pair. Notwithstanding the difference in symptoms, when forced to choose, patients were unable to determine which of the two pairs of spectacles was the optimal pair, confirming that the mask had been maintained[3]. The difference in colour between the optimal and sub-optimal settings was small, and averaged only six times the minimum discriminable colour difference.

A theory of visual stress[4] draws together common features between (1) susceptibility to perceptual distortion and asthenopia (visual fatigue), (2) photophobia accompanying migraine, and (3) the light sensitivity shown in photosensitive epilepsy. According to this theory, the perceptual distortions are a manifestation of a hyper-excitability of cells in the visual system, localized in the case of photophobia and more widespread in the case of photosensitive epilepsy. Success in treating the photophobia that accompanies reading difficulty using coloured filters, raises the question as to whether patients with photosensitive epilepsy might benefit from specifically and individually tinted coloured spectacles.

Carterette and Symmes[5] were the first to suggest a significant effect of colour on epileptic photosensitivity. Two of their patients were free of seizures without medication using blue glasses that absorbed long-wavelength light. There have been several subsequent reviews in the literature, including those by Newmark and Penry[6], and by Harding and Jeavons[7]. The most recent report is by Takahashi and Tsukahara[8].

The effect of colour on the photoparoxysmal EEG response to intermittent photic stimulation has received considerable study, but its relevance in the present context is unclear. The effect remains controversial[8,9], although it is generally agreed to be slight and perhaps idiosyncratic[7]. The use of blue glasses for the treatment of photosensitive epilepsy was prompted by the early findings of a greater sensitivity to red intermittent light. This sensitivity has now been attributed to a reduction of retinal inhibition in response to deep red light[9], a finding of limited relevance to the use of coloured glasses in treatment. Furthermore many patients are sensitive not only to intermittent light, but also to patterns which occur in the everyday world. The effect of colour on pattern sensitivity has received little investigation. It is known that contours that differ only in colour and not in brightness are not usually epileptogenic, but the effects of overall changes in colour have not been studied[4].

The following study was an open trial to assess the potential for the use of the new subjective tinting methods in the treatment of photosensitive epilepsy. It differs from previous studies in so far as each patient was allowed to select a tint individually so as to reduce perceptual distortion and visual discomfort. Some of the glasses absorbed long-wavelength light, some had quite different spectral absorbencies.

The study had the following objectives. (1) To determine whether the colorimetry assessment, as it is now given, is safe for the investigation of photosensitive patients in optometry clinics where colorimetry equipment is most readily available, but where EEG control is not practical. (2) To determine whether the success already observed in individual cases of photosensitive epilepsy[1] could be repeated in a large group, and, if so, in what proportion of patients. (3) To discover whether a tint selected by colorimetry could be

shown to reduce the incidence of paroxysmal epileptiform EEG activity in response to flicker and patterns, thereby validating the subjective methods and corroborating the reported seizure reduction.

The assessment procedures used were the same as those previously employed for patients with reading difficulties and those with migraine. Most of the assessments were conducted under EEG control as a precaution. If coloured glasses were prescribed, they were provided in addition to more conventional therapy. If refractive correction was worn, a pair of coloured glasses incorporating this correction was supplied. No restrictions were placed on antiepileptic medication or other aspects of normal clinical management.

MATERIALS AND METHODS

Subjects

Patients with photosensitive epilepsy were recruited from Epilepsy Clinics at the National Hospital for Nervous Diseases, and the Maudsley Hospital, London. Ethical committee approval was obtained. A few patients were also initially examined at the Park Hospital for Children, Oxford, and Addenbrookes Hospital, Cambridge. All the patients had suffered visually-provoked seizures, had exhibited a photoconvulsive response on at least one previous EEG recording, and had received a diagnosis of photosensitive epilepsy. Thirty-three patients took part, 24 females and nine males. The mean age was 21 years (range 12–43 years). At the time of initial examination, 22 patients continued to have seizures.

Procedure

An EEG was recorded during the colorimeter examination in 26 of the 33 cases, preceded by a routine resting record, and hyperventilation and followed by photic stimulation. For the colorimeter examination the patient was seated in front of the *intuitive colorimeter*[1] and viewed a page of text in the colorimeter, illuminated with coloured light. The text comprised random letter strings, arranged to resemble words in a paragraph of text. Over the course of 5 seconds the saturation of the light was slowly increased from a neutral setting, a white similar to daylight (CIE 1976 $u' = 0.21$; $v' = 0.75$) to one with a moderate strength of colour or saturation (CIE 1976 $s_{uv} \sim 7$). It remained at this setting for 5 seconds before returning to the neutral setting over a similar time period. The patient was asked to judge whether the change in colour had any effect on the perceptual clarity or comfort of the text. The process was repeated until 12 different hues had been assessed. The hues systematically sampled perceptual space (they differed in hue angle, h_{uv}, by about 30°). If any of these hues improved the clarity or comfort of the text the saturation was optimized for each, usually by asking the patient to adjust the saturation using a wheel. The hues were then compared, typically by forced choice between two alternatives successively presented by the examiner. At the best hue, saturation was re-optimized and small deviations in hue ($h_{uv} \sim 10°$) were then successively compared. Saturation and hue were alternately optimized until a stable chromaticity had been selected. This chromaticity was then matched with a combination of tinted lenses. The lenses were held in front of an aperture through which could be seen a spectrally even surface illuminated with 'white' fluorescent light (CIE type F3). The combination of lenses was adjusted until the appearance of the aperture through the lenses matched that of a second aperture. The second aperture revealed a similar surface within the colorimeter illuminated with light of the chosen colour. The match in the colour appearance of the two apertures was ratified by the patient. The patient was then invited to wear the lenses and compare them with neutral lenses of similar photopic transmission.

Twelve patients were examined before the colorimeter was commercially available using prototype instruments and techniques that differed slightly from those described above.

Where clinically appropriate, the patient's sensitivity to intermittent photic stimulation (Grass stimulator) and patterns was compared with the coloured and neutral tints. (The patterns were gratings with square-wave luminance profile, contrast 0.8, space-averaged luminance about 100 cd.m^{-2}, circular in outline and centrally fixated, radius selected to suit patient's sensitivity.) Coloured spectacles were supplied for patients who described a subjective benefit from the tint. Patients were followed up, usually after a minimum of one year.

RESULTS

Thirty-three patients with photosensitive epilepsy were assessed. Twenty-three (70%) reported beneficial effects during colorimetry and were prescribed glasses. Seventeen of these patients were available at follow-up, an average of 2.4 years later (standard deviation 1.7 years). Thirteen (57%) reported benefits, and said they were still using the lenses. In six of the 13 the benefits were pronounced, including a reduction of dizziness from fluorescent lighting, and elimination of aura when using computer screens. Only in three cases was there a reduction in seizures that could reasonably be attributed to the use of lenses; in two of these cases

no medications were prescribed, and in the third the medications remained unchanged for 4 years, two before and two after the introduction of the glasses, see Fig. 1.

The colour of the lenses is shown by points in the chromaticity diagram in Fig. 2a, with different symbols for patients, according to the benefit derived. As can be seen, there is a preponderance of lenses with a rose, blue or purple colour: few lenses were green, a colour commonly chosen by children with reading difficulty, as shown in Fig. 2b.

In eight patients it was possible to assess EEG sensitivity to patterns or to intermittent photic stimulation with and without lenses. In all eight cases there was a modest reduction in photosensitivity with the coloured lenses but also to an equivalent or lesser extent with the grey. Only in one case was the reduction clearly greater with the coloured than that with the grey. In another patient lenses of the selected colour were compared with other coloured lenses and the selected colour reduced the photosensitivity frequency range by the greatest amount. In one patient EEG discharges occurred during colorimetry when uncomfortable colours were shown, but in all the remaining patients colorimetry did not alter the record.

One patient had an attack during colorimetry, and she did so on each of the two occasions. There was an apparent loss of muscle tone, she was unresponsive for a few seconds, and was then briefly disoriented. The attack was not accompanied by ictal electrographic changes in the scalp EEG. It was not clear whether this was a brief complex partial seizure or some type of non-epileptic attack.

DISCUSSION

Patients were given lenses only if they reported subjective beneficial effects. Seventy percent of the patients examined reported benefits and were offered lenses. Thirteen out of 17 patients reported continued use at follow-up. Although the study was an open trial and placebo effects are not controlled, the length of the period of continued use is rather longer than that typically associated with placebo treatments.

Most patients reported beneficial perceptual or somatic effects, and were prepared to suffer the social disadvantages of wearing the glasses. One patient stopped wearing her glasses because they called attention to her epilepsy, with unfortunate social consequences.

It is possible that the patients who failed to find a colour beneficial might nevertheless have benefited from lenses with neutral density, but in this study such lenses were not offered.

The colour most commonly chosen for the lenses was a shade of rose, blue or purple, rather than green. The colour was selected by subjective methods independently of brightness. Previous EEG studies in patients with photosensitive epilepsy have suggested that blue lenses generally provide the most protection. Clearly a blue tint is not universally the most effective at reducing symptoms, although it remains possible that a blue tint offers a greater protection against seizures. It is still to be determined whether the reduction of symptoms of visual stress provides the best guide as to the colour of tint most effective at reducing seizures, although *a priori* it seems unlikely that tints that reduce visual discomfort and aura will differ from those that reduce seizures.

The colour of lens selected by patients with photosensitive epilepsy appears to differ on average from that selected by patients with reading difficulties using identical subjective methods, suggesting differences in the physiological basis for the perceptual distortion and photophobia in dyslexia, and the seizures of photosensitive epilepsy, notwithstanding the similarities[4].

The proportion of patients with photosensitive epilepsy who reported beneficial perceptual effects from coloured light is about 70% and therefore larger than that in the general population: for example, about 50% of children report beneficial perceptual effects from coloured overlays[10].

The following conclusions can be drawn.

(1) The proportion of patients with photosensitive epilepsy who reported beneficial perceptual effects from coloured light is larger than in the general population.

(2) Coloured glasses may provide relief from seizures in some patients with photosensitive epilepsy, including, occasionally, those for whom antiepileptic therapy is not indicated and those for whom such therapy is insufficient.

(3) Although coloured glasses may reduce seizures in relatively few patients, they may have other beneficial effects such as a reduction of symptoms of discomfort. These benefits can be sufficient to encourage patients to wear their spectacles despite continuing seizures.

(4) During colorimetry there was only one patient who suffered an attack that might have been a seizure, suggesting that the likelihood of epileptic seizures during colorimetry assessment is small. The colorimetry assessment appears to be very much less provocative than intermittent photic stimulation or pattern stimulation.

The findings are sufficient to justify a follow-up study in which lenses of the chosen colour are compared with other tints, including grey.

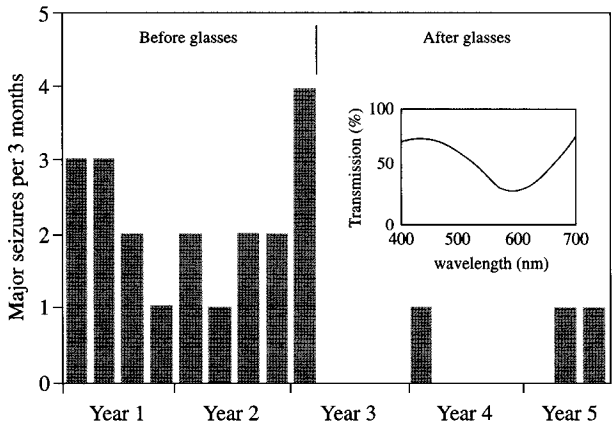

Fig. 1: Incidence of tonic–clonic seizures in a 17-year old girl with photosensitive epilepsy before and after blue glasses were provided. The transmission of the glasses is shown in the inset. There was no change in medication throughout the period shown. The seizure incidence is recorded in consecutive 3-month periods. Sadly the epilepsy deteriorated after the period shown.

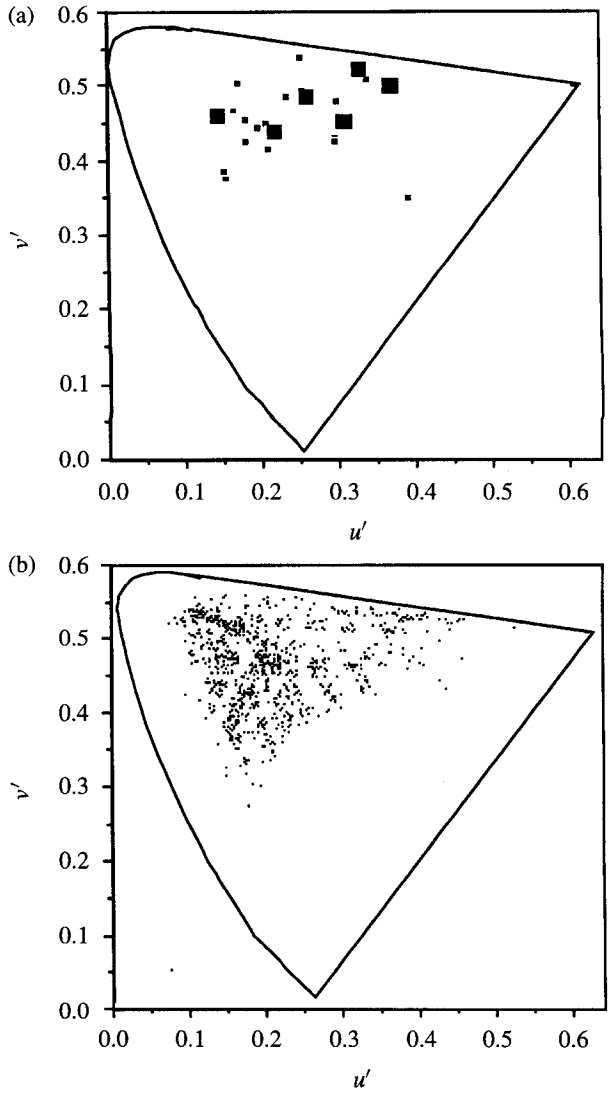

Fig. 2: (a) Chromaticities of lenses selected by patients with photosensitive epilepsy using the intuitive colorimeter system. The large points identify the patients who had a particularly good therapeutic response. (b) Chromaticities of lenses selected by the first 1000 patients to use the colorimeter system, for comparison. Most of these patients had reading difficulties.

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DECLARATION OF INTEREST

The rights to the intuitive colorimeter are owned by the Medical Research Council of Great Britain. Under their 'Awards to Inventors' scheme the senior author received a proportion of the royalties on the sales of the two colorimeters used in this study; this he has donated to the Epilepsy Research Fund.

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