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A preliminary investigation into the aetiology of Meares–Irlen syndrome

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Summary

A recent double-masked placebo-controlled trial has confirmed that some children experience a reduction in symptoms of eyestrain and headache when they read through individually prescribed coloured filters and has shown that this benefit cannot be solely attributed to a placebo effect. People who are helped by coloured filters in this way have been described as having 'Meares–Irlen syndrome'. We investigated the mechanism of this benefit by studying the optometric and visual perceptual characteristics of the children in the double-masked study. This population had normal refractive errors and heterophorias (none of the subjects had strabismus). They demonstrated slightly, but significantly, reduced amplitudes of accommodation and vergence and poor stereo-acuity. However, these factors seemed to be correlates of Meares–Irlen syndrome rather than the underlying cause. Pattern glare, a sensitivity to striped patterns (e.g. lines of text), was prevalent in our sample and was significantly associated with the subjects' symptoms. The spatial contrast sensitivity function was normal.
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Introduction

Meares (1980) and subsequently Irlen (1983, 1991) described a new visual disorder which Irlen (1983) called *Scotopic sensitivity syndrome*. This term is likely to be etymologically inappropriate and the description *Irlen's syndrome* has been used as an alternative (Irlen, 1990; Evans and Drasdo, 1991; Carr, 1993). In view of the description of the condition by Meares before Irlen, the term *Meares–Irlen syndrome* may be more appropriate. Irlen (1991, p. 50) stated that the condition affects 12% of the general population and 65% of people with dyslexia. Meares–Irlen syndrome has not been clearly defined in the literature, but previous descriptions have all been characterised by symptoms and a benefit from colour (Meares, 1980; Irlen, 1983, 1990, 1991). Irlen (1991, pp. 158–159) claimed that the colour of the required filter is idiosyncratic and often needs to be highly specific. Although the symptoms can be described in general terms as asthenopia (sore, tired eyes; headaches; photophobia) and visual perceptual distortions (illusions of shape, motion and colour), their precise nature does not appear to have been clearly identified using statistical survey techniques (Evans and Drasdo, 1991). Most of these symptoms are non-specific, whereas the alleged benefit from coloured filters in patients without ocular pathology does appear to be specific to Meares–Irlen syndrome (Evans and Drasdo, 1991). Therefore, for the purposes of the present study, Meares–Irlen syndrome is defined as being present when subjects report a sustained benefit from using coloured filters when reading.

A review of the literature (Evans and Drasdo, 1991) showed that Meares–Irlen syndrome lacked a sound theoretical basis and, until recently, the efficacy of the coloured filter therapy had not been demonstrated with a rigorous double-masked placebo-controlled trial. Such a trial became possible with a new instrument: the intuitive colorimeter (Wilkins *et al.*, 1992a). With this apparatus the subject views text which is illuminated by light whose hue,

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saturation and luminance can be varied independently throughout a large region of colour space (Wilkins *et al.*, 1992b). It would be predicted that, with this instrument, people with Meares–Irlen syndrome should be able to find a colour that reduces their symptoms (the optimal colour). Irlen's assertions would also suggest that it should be possible to find a second colour which is very similar to the optimal one but which does not greatly improve their symptoms (the control colour).

During intuitive colorimetry subjects have no reference colours with which to compare the colour of surfaces in the colorimeter. Subjects rapidly adapt to the colour and become unaware of the exact colour that they are viewing so that, if the specifications of the optimal and control colours are translated into coloured lenses, subjects should be unable to remember which corresponded with their choice in the colorimeter. It is this feature that has allowed a double-masked placebo-controlled trial of the therapeutic use of tinted lenses for reading difficulty (Wilkins *et al.*, 1994).

The data from this trial that relate to intuitive colorimetry and symptoms have been reported by Wilkins *et al.* (1994). The first aim of the present paper is to describe in detail the optometric characteristics of the population in the double-masked trial. These optometric data will be compared with norms, and with recent data from a dyslexic group and control good readers (Evans *et al.*, 1994a, b, 1996), and a control group of poor readers who were asymptomatic and did not report a benefit from coloured filters (Evans *et al.*, 1996). The latter group of control poor readers were matched for age, reading age, and IQ with a subgroup Meares–Irlen syndrome subjects from the present study (Evans *et al.*, 1995). The dyslexic group and control group of good readers of Evans *et al.* (1994a, b, 1996) were slightly younger than the present group with Meares–Irlen syndrome (mean 10 years; c.f. 12 years), but also had a slightly higher IQ (110; c.f. about 90). The dyslexic and control good readers were selected according to psychometric data, and without regard to their symptoms, nor to their response to coloured filters (Evans *et al.*, 1994a, b, 1996).

The double-masked placebo-controlled trial showed that the benefit from coloured filters in Meares–Irlen syndrome is not solely attributable to a placebo effect. Therefore, other possible explanations for this benefit need to be considered. The second aim of this paper is to investigate potential mechanisms for Meares–Irlen syndrome. Several potential mechanisms were described by Evans and Drasdo (1991), most notably 'pattern glare' (Wilkins and Neary, 1991; Wilkins, 1995). Pattern glare has been studied in detail (Wilkins *et al.*, 1984) and describes the symptoms (asthenopia and perceptual distortions) that many people experience on viewing repetitive striped patterns, including text (Wilkins and Nimmo-Smith, 1987). Wilkins (1995) proposed that a cortical hyperexcitability accounted for pattern glare and that filters of specific and idiosyncratic chromaticity could possibly reduce this hyperexcitability, hence alleviating associated symptoms.

Another explanation attributes Meares–Irlen syndrome to the high prevalence of optometric problems, mostly ocular motor (accommodative and binocular) anomalies, that has been found in potential Irlen lens wearers (Scheiman *et al.*, 1990). A subsequent study by Blaskey *et al.* (1990) found that, in most cases, vision therapy was as effective at reducing the symptoms of Meares–Irlen syndrome as are coloured filters. However, this study only employed small groups: the number of subjects completing the study was 11 wearing Irlen lenses, 8 having vision therapy, and 3 having 'control' coloured filters. Further, the groups were not matched for IQ or the type of visual problem, and placebo effects of vision therapy were not addressed.

A third hypothesis that has been proposed to account for Meares–Irlen syndrome relates to a 'deficit of the transient visual system' in dyslexia (Lovegrove *et al.*, 1986). Visual processing occurs in parallel, via the transient (magnocellular) and sustained (parvocellular) visual subsystems (Kulikowski and Tolhurst, 1973; Green, 1981). The transient subsystem does not demonstrate chromatic opponency and predominantly responds to rapidly moving or flickering, coarse, peripheral stimuli. The sustained subsystem does demonstrate chromatic opponency and predominantly responds to static or slowly moving, central, fine detailed stimuli. There is considerable psychophysical (Lovegrove *et al.*, 1986) and, controversially (Victor *et al.*, 1993), some electrophysiological evidence (Livingstone *et al.*, 1991) demonstrating a deficit of the transient visual system in the majority of dyslexic children. Several researchers have suggested that the 'transient deficit' in dyslexia might account for the benefit from coloured filters (Solman *et al.*, 1991, 1995; Williams *et al.*, 1992; Irlen, 1994; Scheiman, 1994). Evans *et al.* (1996) showed that the sensory visual correlates of dyslexia (transient deficit) were associated with the ocular motor visual correlates. Surprisingly, low-level transient subsystem function has not been assessed in subjects with Meares–Irlen syndrome.

Methods

The investigations concentrated on near point functions and all visual acuity, binocular vision and psychophysical tests were carried out with any refractive correction that was usually worn at the appropriate distance. All near vision tests were carried out with incandescent lighting to give a light level between 103 and 240 $cd\,m^{-2}$. No ocular pathology was detected by direct ophthalmoscopy. The colour vision test results have been reported elsewhere (Wilkins *et al.*, 1994) and did not reveal an abnormal prevalence of colour vision defects in our sample.

Subjects

Children from four schools and a dyslexia institute who

were either failing in reading or who reported asthenopia or perceptual distortions were tested with coloured overlays. Subjects who reported a benefit from these and continued to use an overlay when reading without prompting for at least three weeks were entered in the double-masked trial (Wilkins *et al.*, 1994). IQ data were only available for a few of the subjects, who participated in the matched-group study described elsewhere (Evans *et al.*, 1995). It is claimed that some people with Meares–Irlen syndrome do not have specific reading difficulties (dyslexia) (Irlen, 1991, p. 50). Therefore, it was not appropriate to use a measure of reading retardation as a selection criterion.

The only optometric reasons for excluding subjects or postponing entry to the study were: (1) decompensated heterophoria (according to conventional clinical criteria: Pickwell, 1989) or (2) blurred vision due to uncorrected refractive or accommodative anomalies. Nine subjects were excluded for these reasons. These exclusion criteria were applied because it was felt that it would be unethical to delay conventional optometric treatment in these cases. There is no agreement on precise criteria for determining whether a heterophoria is decompensated and the study optometrists applied their usual clinical judgement, basing their decisions on factors described in a standard text on binocular vision (Pickwell, 1989) (details are given below in Discussion).

The average age at first appointment was 12 years 2 months (SD 1 y 9 m, range 9 y 9 m to 15 y 5 m). The present paper reports the optometric data that were available for 53 of the 68 children (42 boys and 26 girls) who entered the double-masked study. A recent paper gives a detailed comparison of optometric and psychometric data of 16 of the subjects in the double-masked trial who all came from one school with 25 controls who came from the same school and had the same mean chronological age, reading age and IQ (Evans *et al.*, 1995).

Visual acuities and refraction

Monocular and binocular near presenting visual acuities (VAs) were assessed on an externally illuminated (115 cd m^{-2}) Lighthouse test (Lighthouse Low Vision Products, New York, USA) similar to the log MAR design of Bailey and Lovie (1976). The refractive errors were assessed by distance retinoscopy (Taylor, 1988) and subjective refraction (O'Leary, 1988) using negative cylinder notation. The spherical equivalent refractions (SERs) were calculated by adding one half of the cylindrical component to the spherical component. The mean SER and mean cylindrical correction for each subject were calculated from the data for the right and left eyes (Ray and O'Day, 1985).

Binocular vision and orthoptic tests

Binocular ocular motility (Pickwell, 1989) was used to assess the comitancy and smoothness of the ocular movements. The objective cover/uncover test was carried out at distance and near, and any deviation was estimated by observation to the nearest 1 Δ.

The distance dissociated horizontal deviation was measured with a von Graefe cover/uncover technique (Mallett, 1988). The Maddox wing (IOO Marketing Ltd, London, UK) was used for the near dissociation test (Lyle and Wybar, 1967). The magnitude (not the direction) of any vertical dissociated deviation was recorded. The right eye was covered and uncovered so as to measure the horizontal dissociated deviation five times to obtain a measurement of the mean and of the range of readings. Each result was recorded to the nearest 0.5 Δ. In some subjects the AC/A ratio varies with target distance (Rosenfield and Ciuffreda, 1991), so it was measured at both distance and near. The gradient method (Pickwell, 1989, p. 53) was used employing the dissociation tests described above with −3.00 D lenses at distance and +2.00 D lenses at near.

The associated heterophoria (Pickwell, 1989), when measured on an instrument with a good central fusional lock, is better at predicting whether a heterophoria is symptomatic than measuring the dissociated heterophoria or forced vergence disparity curve (Yekta *et al.*, 1989). The Mallett Fixation Disparity Unit (Mark 2; IOO Marketing Ltd, London, UK) is one of the few fixation disparity instruments with a good foveal lock and was used to measure the horizontal and vertical near associated heterophoria, to the nearest 0.5 Δ (Mallett, 1966).

The near point of convergence was measured with the standard RAF Near Point Rule (Clement Clark International, Harlow, Essex, UK) using the conventional line target (Evans *et al.*, 1992). The rate of movement was approximately 1 Δ/second and the mean of two subjective break and recovery points was obtained. The horizontal vergence reserves were measured with a variable prism stereoscope where binocular rotary prisms were manually adjusted at a rate of approximately 1 Δ/second. The subject viewed a vertical row of five numbers, which subtended 2° vertically at the distance of 30 cm. The print size was equivalent to a decimal acuity of 0.4. Two measurements of the negative (divergent) vergences were taken and then two of the positive (convergent) vergences. Subjective results for the near point of convergence and vergence reserve testing were confirmed by observing the subjects' eye movements.

The Randot Circles Test (contoured circles on random dot background; Clement Clark International, Harlow, Essex, UK) was used to measure stereo-acuity. Foveal suppression was detected and measured with the Binocular Status (polarised letters) test of the near Mallett Unit (Mallett, 1966). The monocular acuities under haploscopic (polarised) conditions were compared with those under monocular conditions (polarisers still in place, but monocularly occluded).

ts of accommodation

e amplitude of accommodation was measured monocu-y and binocularly with the RAF rule by the push-up thod (Reading, 1988), with any significant refractive or corrected. The target was moved in at approximately /second.

The 'accommodative error' was also recorded, as the erical correction to balance the red and green duo-ome targets on the near Mallett Unit, when viewed ler haploscopic (polarised) conditions (Mallett, 1966). e results were inconsistent and illogical, presumably ause subjects' preferences for colour were confounding ir response and, therefore, the results were not analysed.

chophysical data

vegrove *et al.* (1982) studied the spatial contrast sensi-ty function (SCSF) in dyslexia and detected a reduced ntrast sensitivity to low, but not to high, spatial fre-encies. It was argued that the transient channel was ticularly sensitive to low spatial frequencies and this ult was thus interpreted as evidence of a 'transient tem deficit' (Lovegrove *et al.*, 1986). We used the stech VCTS Near Vision Test to assess SCSF. Although s test has limitations (Bradley *et al.*, 1991), another study ans *et al.*, 1994b) demonstrated that it can be used to ctively replicate the experimental conditions of Lovegrove *al.* (1982) within the tolerances established by Martin l Lovegrove (1984). The experimental procedure was as ailed in Evans *et al.* (1994b): all three test cards were ployed with binocular viewing, without a time limit.

The conventional method of assessing pattern glare is to w subjects an appropriate grating and to quantify any orted anomalous visual effects (illusions) (Wilkins *et al.*, 34). To control for suggestibility with children, Evans *l.* (1994c) used a control target and, based on the recent rk of Conlon (1993), a low spatial frequency control was sen in the present research. The 'experimental' and ntrol' gratings had similar size, space-averaged lumi-ce, and contrast, but at 30 cm had spatial frequencies of nd 0.2 c/deg, respectively. After subjects with a personal ory of epilepsy had been excluded, the subjects' initial nments on viewing a small (9° diameter) experimental ting were recorded. For ethical reasons, any who orted discomfort and had to avert their gaze were luded from further pattern glare testing and those who ntaneously reported definite perceptual distortions with grating were only tested with the smaller stimuli. The aining subjects were then shown the large (17.6° meter) experimental grating and their initial responses e recorded. Next the subjects were asked to answer h of the questions in *Table 1* in turn, viewing the centre each grating for approximately 5 s for each question. order of presentation of the gratings was alternated for secutive questions.

Table 1. Questions asked in the pattern glare testing

Questions
Do you see a colour or colours?
Do the lines appear to bend?
Do the lines seem to blur?
Does the pattern flicker?
Do the lines wobble or shimmer?
Do parts of the pattern disappear and reappear?
Do you see any other patterns, shapes, or glare? (please specify)

Cytoarchitectonic cerebro-cortical abnormalities have been found in some cases of dyslexia (Sherman *et al.*, 1989), involving focal cortical dysplasias, in areas including the occipital cortex (Galaburda and Kemper, 1979). Since these subtle lesions have been found almost exclusively in the left hemisphere, the above procedure was repeated using hemi-gratings. Where subjects reported the same illusion with both hemi-field targets they were asked to choose the one with which it was most severe.

Symptomatology

A questionnaire (copies available from the first author) was issued to all subjects to complete with the help of their parents. At the beginning of the eye examination the optometrist collected the questionnaire and checked the answers.

Results

Visual acuities and refraction

Refractive data are given in *Table 2*. The mean refractive

Table 2. Descriptive statistics for visual acuity (log MAR units) and refractive error (in dioptres) for the right eye (RE), left eye (LE) and both eyes (BE) by retinoscopy (ret) and subjective refraction (sub)

Variable	*Count*	*Mean*	*SD*	*Minimum*	*Maximum*
RE N vision	52	+0.11	0.21	−0.10	+1.3
LE N vision	52	+0.11	0.20	−0.10	+1.2
BE N vision	44	+0.05	0.21	−0.10	+1.2
RE ret sph	48	+0.74	1.0	−1.75	+5.25
RE ret cyl	48	−0.43	1.1	−5.75	0
RE ret SER	48	+0.53	0.91	−1.89	+3.00
LE ret sph	48	+0.67	0.94	−1.75	+5.00
LE ret cyl	48	−0.55	0.95	−5.5	0
LE ret SER	48	+0.48	0.73	−1.75	+2.25
RE sub sph	53	+0.59	1.20	−2.75	+7.00
RE sub cyl	53	−0.76	1.42	−6.00	0
RE sub SER	53	+0.39	0.92	−2.75	+4.00
LE sub sph	53	+0.35	0.71	−1.50	+4.25
LE sub cyl	53	−0.56	0.97	−4.75	0
LE sub SER	53	+0.19	0.63	−1.63	+2.75

sph, sphere; cyl, cylinder; SER, spherical equivalent refraction; SD, standard deviation.

error was the low hyperopia that is typical of this age group (Borish, 1975) and the prevalence of myopia (15%), hyperopia over 1.25 D (3.8%) and astigmatism over 0.75 D (4.4%) were similar to age-matched norms cited by Borish (1975) (12.5, 6.2 and 5.5%, respectively). Interestingly, the mean subjective SERs were significantly dissimilar for the right and left eyes (paired *t*-test, $P = 0.036$). This result was not found in a previous study with either dyslexic or control children (paired *t*-test, $P > 0.20$) (Evans *et al.*, 1994b).

Binocular vision and orthoptic tests

Ocular motility testing detected one case of incomitant ocular movements (out of 51 records available). The ocular movements were described as 'jerky' (c.f. 'smooth') in 11 cases. Other researchers have detected saccadation of smooth pursuit eye movements to be a correlate of reading difficulties (Black *et al.*, 1984; Eden *et al.*, 1994; Evans *et al.*, 1994b). This may be because of motor impersistence (Shapira *et al.*, 1980) which is often associated with attention deficit disorder (Heilman *et al.*, 1991), which in turn has a high co-morbidity with reading difficulties (Weinberg and McLean, 1986; Richards, 1994).

Cover test results were available for 50 subjects, none of whom had a strabismus or vertical heterophoria at either distance or near. Only one subject had a horizontal heterophoria at distance (6 Δ esophoria) and six subjects manifested a heterophoria at near (mean and median zero, range 2 Δ exophoria to 3 Δ esophoria).

Out of the 51 available data sets, 38 manifested a horizontal dissociated heterophoria at distance. The mean result was 0.87 Δ esophoria (SD 2.7 Δ, range 3 Δ exophoria to 13 Δ esophoria). Out of 53 subjects tested, 43 had a deviation with the near horizontal dissociation test, and the mean result was 1.1 Δ exophoria (SD 3.4 Δ, range 9 Δ exophoria to 8.4 Δ esophoria). The mean spread (variability) of the result was 1.5 Δ, with a standard deviation of 1.3 Δ and a range of 0–4 Δ. The mean near vertical dissociated heterophoria was 0.3 Δ (SD 0.6 Δ, range 0–3 Δ).

The mean distance AC/A ratio was 1.6 Δ/D (SD 1.0) and the mean near AC/A ratio was 2.6 Δ/D (SD 1.7). We know of no norms for this result in our age group, although the results were lower than the description of the normal range of 4–6 Δ/D given by Pickwell (1989, p. 52). A *t*-test showed that the near results were significantly greater than the distance result ($P < 0.005$). The significance of this finding is reduced by the fact that different test methods were used for distance and near, but it may suggest that the present population has an unusual effect of proximal vergence on the gradient AC/A ratio.

The associated heterophoria results are summarised in *Table 3*. These data will not be compared with norms since they were key factors that were used in the selection criteria for the study.

A 'ceiling effect' was evident with the near point of convergence (NPC) data and the median near point of convergence was 6.25 cm (range 4.5–22.5 cm). In the present sample the prevalence of an NPC more remote than 10 cm (14%) was similar to norms given by Pickwell and Stephens (1975) (12%, $n = 200$).

Measurements of vergence reserves are strongly influenced by test conditions, particularly in children with reading difficulties (Eames, 1934; Stein *et al.*, 1988), so that clinical norms may be inappropriate. Therefore, the vergence reserves of the experimental group were compared with those, measured with a similar technique, of the control group (Evans *et al.*, 1994a) described above. The divergent and convergent vergence reserves of the experimental group are very much below those of the control group (*Table 4*). This is particularly significant in view of the fact that subjects with a decompensated heterophoria were excluded from the present study.

Simons (1981) obtained norms for the Randot Contoured Circles Stereotest from 8 normal adults and 35 young children (mean age 5 years). It is probably inappropriate to quote his mean results since his data suggest a 'ceiling effect'. Simons (1981) did give median values on a graph and this is redrawn in *Figure 1*. The mean age of the population in the present study has been marked on *Figure 1* and interpolated to give an expected median stereo-acuity of 31″. The median stereo-acuity of our sample (50″) was thus below that which would be expected from the age of the subjects.

Data on foveal suppression were available for 38 subjects, 17 of whom had some degree of foveal suppression. The suppressed eye was the right in 9 cases, the left in 4 cases, and both eyes in 4 cases. The median foveal suppression was 0 and the range was 0 to >20′. No norms or relevant comparative data are available.

Table 3. Descriptive statistics for associated heterophoria (in Δ)

Variable	*Mean*	*SD*	*Range*
Distance horizontal associated heterophoria	0.32 eso	0.68	1 exo to 2 eso
Distance vertical associated heterophoria	0.09	0.23	1
Near horizontal associated heterophoria	0.23 exo	0.84	3 exo to 2 eso
Near vertical associated heterophoria	0.09	0.25	1

SD, standard deviation.

Table 4. Descriptive and comparative statistics for vergence reserves (in Δ)

Variable	*Group*	*N*	*Mean*	*SD*	*P*
Divergent blur	Experimental	28	9.5	3.8	0.0058
	Control	19	14.2	7.4	
Divergent break	Experimental	50	12.7	4.2	0.0031
	Control	43	16.1	6.2	
Divergent break-recovery	Experimental	36	2.6	1.2	0.0003
	Control	43	4.5	2.9	
Convergent blur	Experimental	24	8.6	6.3	0.0024
	Control	16	16.7	9.6	
Convergent break	Experimental	50	12.0	6.9	<0.0001
	Control	43	19.0	7.8	
Convergent break-recovery	Experimental	36	3.4	3.1	0.0003
	Control	43	6.7	4.3	
Amplitude break	Experimental	50	24.5	8.7	<0.0001
	Control	43	35.1	10.7	

The *P* values in the right hand column were calculated using the unpaired *t*-test.

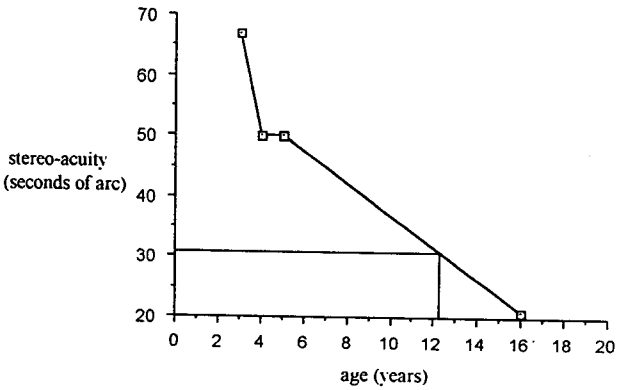

Figure 1. Graph of stereo-acuity (seconds of arc) versus age (years) for the Randot Circles Stereo-acuity test based on the data in Figure 4 of Simons (1981). For further details see text.

Tests of accommodation

The data for the amplitudes of accommodation are shown in *Table 5*. Applying the Hofstetter formulae (Reading, 1988) to the children in the present study, the minimum expected amplitude is 12 D and the anticipated mean amplitude is 15 D. The results in *Table 5* therefore indicate unusually low amplitudes of accommodation.

Psychophysical data

The data for the spatial contrast sensitivity function were available for 68 subjects and are shown (*Figure 2*) with comparable results from a dyslexic and a control group of good readers (Evans, 1994b). The previous research showed the dyslexic group in *Figure 2* to have significantly worse contrast sensitivity than the control group at low and intermediate spatial frequencies, but not at higher spatial frequencies. In contrast, analysis of variance reveals that the experimental group in the present study were not significantly different from the controls in the previous study at any spatial frequency.

Table 5. Descriptive statistics for amplitude of accommodation (in D)

Variable	*Count*	*Mean*	*SD*	*Minimum*	*Maximum*
Right eye	50	11.1	3.6	3.25	18
Left eye	51	11.3	3.8	3	18
Both eyes	50	12.3	3.6	3.5	19

Pattern glare

Of the 44 subjects tested, 32 spontaneously reported anomalous visual effects on viewing the experimental grating. It is instructive that two of the subjects reported seeing a diamond shape, which Wilkins *et al.* (1984) attributed to a cortical mechanism. Six of the subjects reported significant illusions on viewing the small grating and were tested only with this size: all the others were tested with the large grating. The subjects reported significantly more perceptual distortions with the experimental grating than with the control (Mann–Whitney *U*-test, $P < 0.0001$). The pattern glare of the present population was compared with that of a control group (Evans *et al.*, 1995) who were asymptomatic and did not benefit from coloured filters. Compared with this control group, the 44 children in the present study reported significantly more pattern glare on viewing the experimental grating (Mann–Whitney *U* test, $P < 0.01$), but an insignificantly different amount on viewing the control grating (Mann–Whitney *U* test, $P > 0.4$).

The number of anomalous visual effects that subjects reported with the right hemi-field grating was not significantly different from those with the left hemi-field grating (Wilcoxon signed rank test, $P > 0.7$).

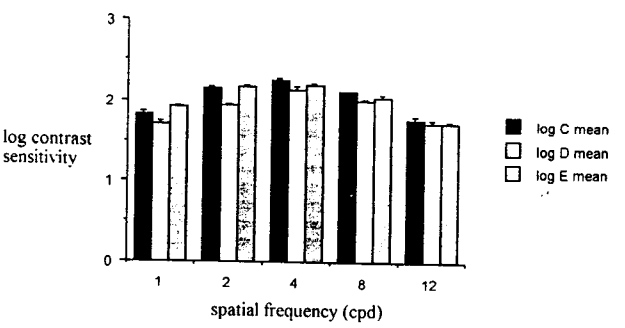

Figure 2. Graphs of the mean log contrast sensitivity at five spatial frequencies of the experimental (E) group in the present study and the dyslexic (D) and control (C) groups in a previous study (Evans *et al.*, 1994b). The error bars show the standard error of the mean.

Symptomatology

In interpreting results from the symptom questionnaire it is important to note that some of the subjects were pre-selected to be those who reported eye strain and headaches. The key results from the symptom and history questionnaire are summarised in *Table 6*.

Six subjects reported taking medications for asthma, hay fever or other allergies, one for migraine medication (Sanomigran; active ingredient pizotifen); and one for epilepsy (Tegretol; active ingredient carbamazepine). Twenty-two of the respondents reported details of allergies, including hay fever and asthma.

The mean estimated number of headaches per year was 46. Of all the respondents, 53% experienced more than one headache a month, 20% more than one a week, and 10% more than two a week. 42% of subjects said that their headaches were severe enough to make them take time off school or be put to bed. Of 41 respondents, 39% described their headache as unilateral. Thirty-one subjects attempted to describe their head pain and 29% of these said the pain was pulsatile. 32% of respondents said that their head pain lasted for more than two hours. Most of the concomitant symptoms accompanying headaches were suggestive of migraine and there was an average of 4.1 concomitant symptoms per respondent (45 respondents). Nine subjects (21% of respondents) said that they experienced some of the concomitant symptoms as a warning before the headache.

Discussion

Adequacy of selection criteria

Because there is little other than anecdotal evidence to

Table 6. Summary of some of the subjects covered by the Subject Questionnaire. Some of the questions in the table are a paraphrase of the actual question asked

No.	*Summary of question/data analysed*	*Count*	*% Yes*
1	Have you had an eye examination with an optometrist (optician)?	47	72
2	Were you given glasses at your last eye examination?	39	18
3	Has the child ever had a turning eye, eye operation, eye exercises or patching?	51	28
4	Was the birth premature/overdue or complicated or were there any severe illnesses/ operations in the first year?	51	57
5	Has your child ever suffered from epilepsy, or any fits or convulsions?	50	6
6	Is your child in good physical condition and healthy?	51	94
7	Is your child taking any medication?	50	16
8	Is the distance vision normally clear?	49	69
9	Does distance vision ever blur?	49	74
10	Are reading and writing in a book normally clear?	49	49
11	Do words in a book ever go blurred?	48	79
12	Do words in a book ever jump around?	49	59
13	Do words in a book ever go smaller/bigger?	49	41
14	Do words in a book ever fade or disappear?	49	35
15	Do words in a book ever get faint colours around them?	49	55
16	Do you ever experience double vision (see two things when there is only one)?	49	57
Have you or anyone else ever noted the following with respect to your child?			
17	Holding reading or materials unusually close or far away?	48	27
18	Closing or covering one eye?	50	10
19	Frequent eye rubbing?	50	52
20	Excessive blinking?	50	22
21	Tilting head when reading or writing?	51	41
22	Moves head when reading?	50	32
23	Uses finger as marker?	49	83
24	Confuses letters or words?	49	86
25	Reverses letters or words?	49	63
26	Skips, re-reads or omits words or lines?	51	90
27	Reads slowly?	48	71
28	Tires easily/short attention span?	50	76
29	Light sensitive?	47	68
30	Did parents or any other children in the family have learning problems?	51	45
31	Did parents or any other children in the family have a turning eye, patching or eye exercises?	50	22
32	Did parents or any of the other children in the family ever have migraine headaches?	51	57
33	Are the parents or any of the other children in the family colour-blind?	49	20
34	Did any relatives have epilepsy?	48	8

'Count' refers to the number of respondents and '% Yes' gives the percentages of respondents who ticked the 'yes' box.

describe the characteristics of Meares–Irlen syndrome, the double-masked trial studied a heterogeneous group of children whose only universal feature was reports of a sustained benefit from a coloured overlay. This self-selection was supported by a statistically significant reduction in symptoms with the optimal tinted glasses relative to the control tints (Wilkins *et al.*, 1994).

Subjects with a heterophoria which, according to conventional criteria, would be unequivocally described as decompensated, were excluded from the study. These criteria were, in order of importance, associated heterophoria (on the Mallett Unit), speed of recovery on cover test, and ability to meet Sheard's and Percival's criteria (Pickwell, 1989). Subjects with an associated heterophoria were only included if their cover test results were normal and Sheard's or Percival's criteria were met. Only two subjects manifested a vertical associated heterophoria of more than 0.5 Δ (both 1 Δ) and both were orthophoric by cover testing. Only three subjects had an amplitude of accommodation less than 6 D and none of these had a significant refractive error or heterophoria. Two had normal near visual acuities and the other had a binocular near visual acuity of equivalent to N8.

Aetiology of Meares–Irlen syndrome

Accommodative and binocular anomalies. Our data confirm earlier observations that subtle binocular and accommodative dysfunctions are a feature of Meares–Irlen syndrome (Blaskey *et al.*, 1990; Scheiman *et al.*, 1990). Our sample had no strabismus and normal heterophorias, yet we found reduced vergence and accommodative amplitudes, as in a previous study of dyslexia (Evans *et al.*, 1994a). Although Evans *et al.* (1994a) found stereo-acuity to be normal in a dyslexic population, the present study confirmed some previous claims (Evans and Drasdo, 1991) that stereo-acuity is subnormal in Meares–Irlen syndrome. We agree with other workers that it is good clinical practice to treat any clinically significant ocular motor (binocular and accommodative) anomalies before considering a tinted lens treatment (Blaskey *et al.*, 1990; Scheiman *et al.*, 1990). However, we believe, for reasons given below, that many cases of Meares–Irlen syndrome still benefit from coloured filters even after any ocular motor anomalies have been corrected.

Despite the exclusion of subjects who were judged to require treatment for binocular or accommodative anomalies, those who completed the double-masked trial nevertheless benefited from coloured filters. The criteria that were used for deciding whether to treat ocular motor anomalies were conservative and some practitioners might have adopted more liberal criteria and prescribed vision training for subjects whom we included in the study. Therefore, we carried out the following further analyses to investigate whether the benefit from coloured filters was likely to be linked to the subjects' performance at tests of binocular vision and accommodation.

Blue wavelengths have a shorter focal length than red wavelengths. Many of our subjects had a slightly reduced amplitude of accommodation, so it could be argued that their optimal coloured glasses (active lenses) should be bluer than their control lenses. We calculated the hue angle (h_{uv}) of active and control lenses (for whatever reason, there were no purple lenses). The mean hue angles were very similar (243.2° for experimental and 243.7° for control), suggesting than an accommodative mechanism is unlikely. Nevertheless, it would be advisable for future research to look at other measures of accommodation, such as accommodative facility and accommodative lag.

It is possible that there was a tendency for our subjects to choose a colour which would modify their accommodation so as to reduce any heterophoria through the accommodation–convergence link. However, the correlation between the hue angle difference (between active and control lenses) and heterophoria (dissociated at near) was low ($r_s = 0.146$; $P = 0.44$) suggesting that the difference in colour between the active and control lenses was not associated with the type and magnitude of heterophoria. The correlation between heterophoria and degree of symptomatic benefit from the active coloured filter (relative to the control) was also insignificant ($r_s < -0.25$; $P > 0.20$).

There is some experimental support (Sheedy and Saladin, 1978, 1983) for Sheard's (1930) assertion that symptoms occur when the vergence reserves opposing a heterophoria are inadequate. More recent research showed that the associated heterophoria, when measured on an instrument with a good foveal lock, is an effective method of detecting symptomatic heterophoria (Jenkins *et al.*, 1989; Yekta *et al.*, 1989). We calculated the difference between the near horizontal heterophoria and the opposing vergence reserves (Sheard's value). Sheard's value and the near associated horizontal heterophoria (signed or absolute) were not significantly correlated ($r_s < 0.10$; $n = 44$), suggesting that subjects with symptomatic heterophorias had been successfully excluded. This conclusion was supported by investigating the correlation between the individual symptoms in *Table 6* (numbered 10–16; 17–29) and both Sheard's value and the near horizontal associated heterophoria (signed or absolute). Using an appropriate level of significance for this number of variables ($P < 0.025$), no significant relationships were found.

Finally, Irlen (1991, pp. 158–159) claims and our double-masked trial (Wilkins *et al.*, 1994) confirms that, at least in some cases, the required tint needs to be chosen with a high degree of specificity. We know of no ocular motor explanation which could account for this.

Pattern glare. Pattern glare has also been proposed as a potential mechanism for Meares–Irlen syndrome (Wilkins, 1995). Our subjects did report significantly more anomalous visual effects on viewing a grating that should cause pattern glare (experimental grating) than on viewing a control

grating. This association with pattern glare was not found in poor readers who did not have Meares–Irlen syndrome (Evans *et al.*, 1995).

The typical symptoms of pattern glare (Wilkins and Nimmo-Smith, 1984) are very similar to those of Meares–Irlen syndrome (Evans and Drasdo, 1991; Wilkins, 1995). Accordingly, we investigated the relationship between symptoms (10–16 and 17–29 in *Table 6*) and pattern glare. The amount of pattern glare with the experimental grating was significantly ($P < 0.025$) associated with 'light sensitivity' (no. 29 in *Table 6*) ($P = 0.018$) and with words in a book 'jumping around' (no. 12 in *Table 6*) ($P = 0.0017$). There were no significant associations between any of the symptoms and pattern glare from the control grating.

In view of the similarity of some of their symptoms, we investigated the relationship between pattern glare and binocular anomalies. Increasing near associated exophoria was moderately correlated with pattern glare from the experimental grating (corrected $r_s = -0.281$; $P = 0.096$), but not with the control grating. The correlation between Sheard's value and pattern glare was moderate for the experimental grating (corrected $r_s = -0.262$; $P = 0.085$), and high for the control grating (corrected $r_s = -0.43$; $P = 0.0056$). The latter correlation is unexpected and warrants further investigation.

The 'transient deficit hypothesis'. The low spatial frequency spatial contrast sensitivity deficit that has been used to identify the transient deficit in dyslexia was not present in our sample of children with Meares–Irlen syndrome. This is surprising, since the Meares–Irlen syndrome subjects exhibited the motor optometric correlates of dyslexia and Evans *et al.* (1996) showed that the dyslexic subjects with weakest binocular function tend to be those with weakest transient function (as indicated by flicker threshold). Evans *et al.* (1995) also found 20 Hz flicker perception to be normal in a small group of subjects with Meares–Irlen syndrome. However, we feel that it may be premature to conclude that children with Meares–Irlen syndrome do not manifest a 'transient visual system deficit'. The perceptual tests we employed were designed for use in the classroom and are psychophysically primitive. We feel that more detailed analysis of visual processing in Meares–Irlen syndrome is required before a firm conclusion can be drawn.

Conclusions

Our data suggest that pattern glare is most likely to be at least part of the mechanism of Meares–Irlen syndrome. Binocular and accommodative anomalies seem to be often associated with Meares–Irlen syndrome and it is good clinical practice to treat any clinically significant conventional optometric anomalies as a first priority. Only if symptoms remain should the effect of coloured filters be investigated. Our data suggest that these ocular motor anomalies are most likely to be a correlate of Meares–Irlen syndrome, rather than the sole underlying cause. It has been suggested that both conditions share a common aetiology. The hypothesis that this common aetiology may be a deficit of the transient visual system is parsimonious, but is not supported by our preliminary data.

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