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The relationship between dyslexia and Meares-Irlen Syndrome

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Meares-Irlen Syndrome (MIS) is characterised by symptoms of visual stress and visual perceptual distortions that are alleviated by using individually prescribed coloured filters. Coloured overlays (sheets of transparent plastic that are placed upon the page) are used to screen for the condition. MIS is diagnosed on the basis of either the sustained voluntary use of an overlay or an immediate improvement (typically of more than 5%) on the Wilkins Rate of Reading Test (WRRT). Various studies are reviewed suggesting a prevalence of 20–34% using these criteria. Stricter criteria give a lower prevalence: for example, 5% of the population read more than 25% faster with an overlay. It has been alleged that MIS is more common in dyslexia, but this has not been systematically investigated. We compared a group of 32 dyslexic with 32 control children aged 7–12 years, matched for age, gender and socio-economic background. Participants were tested with Intuitive Overlays, and those demonstrating a preference had their rate of reading tested using the WRRT with and without their preferred overlay. Both groups read faster with the overlay, and more so in the dyslexic group. ANOVA revealed no significant effect of group, but a significant improvement in WRRT with overlay ($p = 0.009$) and a significant interaction between group and overlay ($p = 0.031$). We found a similar prevalence of MIS in the general population to that in previous studies and a prevalence in the dyslexic group that was a little higher (odds ratio for >5% criterion: 2.6, 95% confidence limit 0.9–7.3). The difference in prevalence in the two groups did not reach statistical significance. We conclude that MIS is prevalent in the general population and possibly a little more common in dyslexia. Children with dyslexia seem to benefit more from coloured overlays than non-dyslexic children. MIS and dyslexia are separate entities and are detected and treated in different ways. If a child has both problems then they are likely to be markedly disadvantaged and they should receive prompt treatments appropriate to the two conditions. It is recommended that education professionals as well as eye-care professionals are alert to the symptoms of MIS and that children are screened for this condition, as well as for other visual anomalies.

Meares-Irlen Syndrome (MIS) is a condition characterised by symptoms of visual stress and visual perceptual distortions which are alleviated by individually prescribed coloured filters. The syndrome (previously known as Scotopic Sensitivity Syndrome) can occur in

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difference did not reach significance in our samples of 32 dyslexic and 32 control participants. Studies that set out to investigate MIS by studying a group of dyslexic or reading disabled participants are likely to include many participants who do not have MIS. Studies of MIS or the use of coloured filters should use one of the two widely used methods of detecting the condition that are outlined in the introduction.

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and accommodation. These problems affect a significant number of unselected school-children and are often undetected (Thomson, 2002a). Binocular instability and accommodative insufficiency are correlates of dyslexia, although these problems are not usually marked enough to have a significant impact on reading-like tasks (Evans, Drasdo & Richards, 1994a, 1994b). Similarly, although binocular vision and accommodative deficits are also weakly correlated with MIS, these problems are unlikely to account for the benefit from coloured filters in many cases and are unlikely to have a marked effect on the proportion of subjects reading >5% faster with their overlay (Evans, 2001; Evans, Busby, Jeanes and Wilkins, 1995; Evans et al., 1996; Scott et al., 2002). Nonetheless, we would stress that in the usual clinical protocol (Evans, 2005; Evans et al., 1999; Lightstone & Evans, 1995) it is recommended that children should have a full optometric assessment at the earliest possible stage of the investigation of any visual factors that may be contributing to reading or other academic difficulties (Evans, 2001).

Problems encountered with the WRRT were minor. One occasional difficulty was following the children's reading when they skipped many words or lines, or when words were mis-read or added. This could be overcome by tape recording the assessment process (Jeanes et al., 1997). In some cases even though participants were aware that the text had no meaning they would give meaning to two words in a row, such as reading: 'look cat see my dog', instead of what was written in the prose: 'look cat see my and dog'. This would suggest that some readers find it hard to not process words semantically and try and make sense out of a nonsense passage. Other common mistakes included 'my' misread as 'me', and 'is' as 'it'.

Educational implications

Professionals involved in the diagnosis and treatment of children and adults with reading disabilities should be aware of the possible beneficial effects that coloured filters can have. Knowledge of the main symptoms of MIS is important: sore, tired eyes and headaches when reading; blurred and unstable (e.g. moving, flickering) images of letters and words; and sensitivity to excessive light. Students who may benefit from the use of overlays can be identified and referred for further assessment by a teacher or eye-care practitioner who screens with coloured overlays. Even if there is no evidence of reading problems in normal readers, it is possible that many will benefit from the use of overlays and it is hoped that screening for this condition will become more widespread. These symptoms can be caused by other conditions (Evans, 2005), so a full eye examination is important in addition to screening for the effect of coloured filters.

The visual problems assessed by this experiment are not seen as the primary symptoms of dyslexia. Indeed, our results suggest that MIS and dyslexia are separate conditions, which may be present in isolation or sometimes coexist in the same individual. It is recognised that even if overlays help a person with dyslexia to read, the person will probably still experience other difficulties. Reading is a complex activity that involves many visual and cognitive factors. Even social and meta-cognitive factors can have an influence on how a child learns to read and consequently views their reading ability. The diagnosis and treatment of MIS and dyslexia are completely different. Most certainly, coloured filters are not a treatment for dyslexia.

Our results add to the growing evidence (Table 1) suggesting that MIS is surprisingly common and affects many so-called normal readers. Our data suggest that the prevalence of MIS may be a little higher in dyslexic than in non-dyslexic children, although this

green. In two cases participants decided that the double overlay was better than the single, but when asked directly whether it was actually clearer and easier to read with the single or the double they chose the single. Perhaps these participants thought that they were expected to find two overlays better than one. Recently, a computerised version of the overlay test has been produced which may overcome the possible problems outlined in this section of order of testing and combining overlays (Thomson, 2002b).

Analysis of WRRT errors

It might have been expected that the dyslexic group would have made more errors in the form of skipping lines during the WRRT. This was not the case: the control group skipped more lines. It might also be thought that more people with MIS would skip lines, since this is thought to be an indicator of MIS (Evans, 2001; Irlen, 1991; Wilkins, 2003). This was not found either: only four out of fourteen of the control group and two out of eight in the dyslexic group who skipped lines were found to have MIS (using the $>8\%$ faster criterion). This may be because of the small size of the text and/or close line spacing. Another explanation might be the presence of visual problems other than MIS, as discussed below.

Limitations

MIS, in common with many other conditions, lacks a completely objective diagnostic test. However, it is interesting to note that a recent review and survey of the criteria that optometrists use when prescribing for low refractive errors revealed an even less desirable situation (O'Leary & Evans, 2003). In most cases, practitioners simply rely on symptoms in deciding whether to prescribe. With MIS, symptoms are one factor but in addition precision tinted lenses are only prescribed after either an immediate improvement in visual performance with the WRRT or a sustained benefit from coloured overlays, which are an inexpensive intervention. Attempts have been made to find additional tests for MIS (Wilkins & Lewis, 1999), and a new pattern glare test might provide useful additional information (Stevenson and Evans, forthcoming). A recent study showed that the Developmental Eye Movement test is, like the WRRT, another useful tool to evaluate the effect of coloured overlays (Northway, 2003).

Several studies of MIS, including the present study, have concentrated on the effect of coloured overlays. Overlay testing is well suited to research as it is both rapid and designed to be easily used in the classroom. The current 'gold standard' treatment is precision tinted lenses that have been individually prescribed after systematic testing with a wide and comprehensive range of colours, for example using the Intuitive Colorimeter (Wilkins & Sihra, 2000). This instrument is quite widely used clinically (Lightstone, 2000) and has been used in double-masked randomised controlled trials of the use of coloured filters in MIS (Wilkins et al., 1994) and migraine (Wilkins et al., 2002). It has also been demonstrated that coloured lenses should be prescribed using a method that leaves the patient colour adapted (e.g. the Intuitive Colorimeter): tinted lenses should not be prescribed to match overlay colour (Lightstone, Lightstone & Wilkins, 1999). However, there is a lack of research on the system as a whole, using coloured overlays, the WRRT, the Intuitive Colorimeter and precision tinted lenses. For example, it would be interesting to investigate which of the diagnostic criteria in Table 1 best predicts sustained voluntary use of precision tinted lenses.

The present study did not include an optometric assessment. It is therefore quite likely that some of the participants had uncorrected errors of refraction, binocular co-ordination

The results differ from the estimates of prevalence provided by Irlen, but it is difficult to comment on this because Irlen did not provide any data or diagnostic criteria (Irlen, 1997). However, Irlen's figure for the non-dyslexic population of 12–14% is most similar to the prevalence that we obtained in our non-dyslexic group (12.5%) for the criterion of > 10% faster. This criterion was associated with a prevalence in our dyslexic group of 31%, which is lower than Irlen's prediction of 46%. People with a combination of dyslexia and MIS might be especially likely to consult Irlen Institutes because they would be likely to have more problems at school. If Irlen's estimates are based on her clinical experience at the Irlen Institutes, then this could perhaps have led to an overestimation by Irlen of the prevalence within the dyslexic population. Care was taken in our study to ensure that the participants were not pre-selected as having (or not having) visual symptoms.

Although both groups read faster with overlays than without (Figure 3), the improvement was much greater in the dyslexic group and only reached significance in this group. This might indicate that it is especially important to treat MIS in people with dyslexia. It could be argued that people with dyslexia and MIS have two burdens when they read: the visual perceptual distortions of MIS (Wilkins et al., 2001) and the phonological processing deficits associated with dyslexia (Snowling, 1997). The symptoms of MIS are relatively easy to treat and if they are just one difficulty among those experienced by a child who has dyslexia then it would seem particularly appropriate to prescribe coloured filters in addition to treating the dyslexia. We would therefore argue that children who report reading difficulties of any type ought to be screened for MIS, and indeed for other visual problems as well (Evans, 2001).

Observations on overlay testing

In the control group, a majority of 12 (37.5%) participants selected a mint green overlay, and nine (28%) selected a grey overlay. Also, in the dyslexic group mint green had the highest number of selectors at nine (28%), whereas only three (9%) selected the grey overlay. It is worth noting that both overlays were presented at the end. It is possible that participants could see from the pile that there were not many overlays left, and therefore thought in order to complete the task successfully they must select an overlay (even though it was made clear at the outset that not everyone selects an overlay and it may not aid their reading). A way of dealing with this effect would be by concealing the pile so that the participants are not aware of when the overlays are going to stop being presented. It would be interesting for further research to study the effect of the order of testing.

It is also interesting to note that all apart from one of the controls selected an overlay, in comparison to five of the dyslexics who did not select any. It was made clear to all participants prior to testing that overlays do not help everyone, and that they may not have an advantageous effect on their reading. Other factors that may have encouraged participants to select an overlay when not needed are: novelty reasons and aesthetic reasons (children may have merely picked their favourite colours). The higher number of dyslexic children who did not select an overlay may be due to them responding more honestly, being less susceptible to suggestibility or being more used to formal assessment procedures. This problem could be resolved by introducing a placebo overlay as in some previous studies (Evans & Joseph, 2002; Tyrrell, Holland, Dennis & Wilkins, 1995).

Double overlays also seemed to cause some confusion. Mint green again featured in the majority of double overlay combinations: four dyslexic participants selected the lime and mint green combination, one selected double mint green, and another aqua and mint

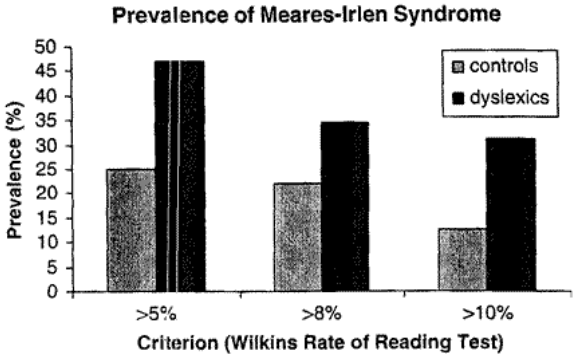

Figure 4. Comparison of prevalence of MIS in dyslexia and control groups, for various diagnostic criteria (see text for explanation).

Although Table 4 shows that the dyslexic group were more likely to skip lines, only two of the participants who skipped two lines met the >8% criterion for MIS. In the control group, four participants who skipped lines met the >8% criterion. Two only skipped one line, one skipped three lines and the fourth skipped seven lines.

Discussion

Our data support previous studies that have shown MIS to be prevalent in the general population. We found a higher prevalence of MIS in dyslexia, but chi-squared analyses of the proportion of each group with MIS did not reach significance. In participants who chose a coloured overlay, there was a significant improvement in rate of reading with the preferred overlay in the dyslexic group but not in the control group.

The diagnostic criterion most commonly used in the literature (Table 1) is the >5% faster criterion. Using this, our control group had a prevalence of MIS of 25% which is higher than the 20% obtained in a study of 77 unselected children aged 8–11 years (Wilkins et al., 1996), but less than the 33% obtained with 426 unselected children aged 6–8 years (Wilkins et al., 2001) and the 34% in a sample of adult university students (Evans & Joseph, 2002). Clearly, this is a fairly 'easy' criterion to pass, and we wonder whether the >10% criterion might be more appropriate. As we point out below, there is a need for research on which criterion best predicts sustained use of precision tinted lenses, which can be thought of as the 'gold standard' treatment for MIS.

Table 4. The number of lines skipped by dyslexic and control participants.

Number of lines skipped	Dyslexic group	Control group
1	2	7
2	5	2
3	0	3
4	0	1
6	1	0
7	0	1
Total	8	14

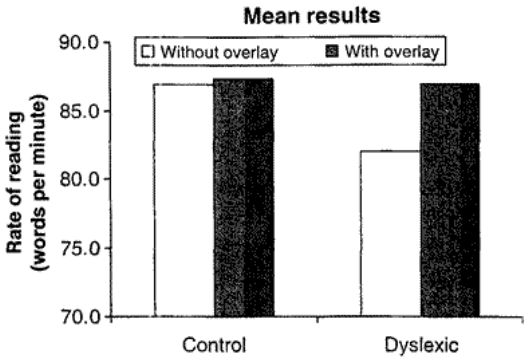

Figure 3. Comparison of mean WRRT results for dyslexic and control groups with and without overlays.

Calculation of prevalence

As noted in the introduction, various criteria have been used to estimate the prevalence of MIS, and prevalence will inevitably vary with the criterion. Indeed, we think it likely that MIS exists on a continuum. An increase on WRRT with an overlay of >5% is commonly used as a criterion (Table 1). However, according to Jeanes et al. (1997) an increase of about 8% in rate of reading with the overlay indicates a likelihood of prolonged use of the coloured overlay, and thus could be used as an indicator of MIS. Figure 4 shows these two criteria and an additional criterion of >10%. A >25% criterion is not included because none of the dyslexic group and only one of the control group read >25% faster with their overlay: in view of the number of participants and the previous data for the >25% criterion (Table 1) this is not surprising.

It should be noted that, in contrast to the preceding section but in common with some previous studies, the total number of participants in each group (32) is used as the denominator in prevalence calculations. In other words, it is assumed that participants who did not report a benefit from any overlay would have failed to show an improvement greater than the relevant criterion.

It was found that 11 out of the 32 (34%) in the dyslexic group had an increase of >8% on the rate of reading test with the overlay, compared with 7 out of the 32 (22%) in the control group. The prevalence for a >5% criterion is 47% in the dyslexic group and 25% in the control group; and for the >10% criterion is 31% in the dyslexic group and 12.5% in the control group. The odds ratios and associated 95% confidence limits were calculated (Garb, 1996) from the data represented in Figure 4. The odds ratio is 2.6 (95% confidence interval 0.9–7.3) for the >5% criterion, 1.8 (0.6–5.4) for the >8% criterion and 3.0 (0.8–10.3) for the >10% criterion. In view of the fact that the lower 95% confidence intervals did not exceed 1.0, it is not surprising that comparisons of the proportion of dyslexic and non-dyslexic participants with MIS did not reach significance for each of the three criteria in Figure 4 (chi-square test, $p>0.065$).

Analysis of WRRT errors

The WRRT results for each participant were inspected to look for common errors made by each group. Table 4 shows the number of participants that skipped lines whilst performing the WRRT.

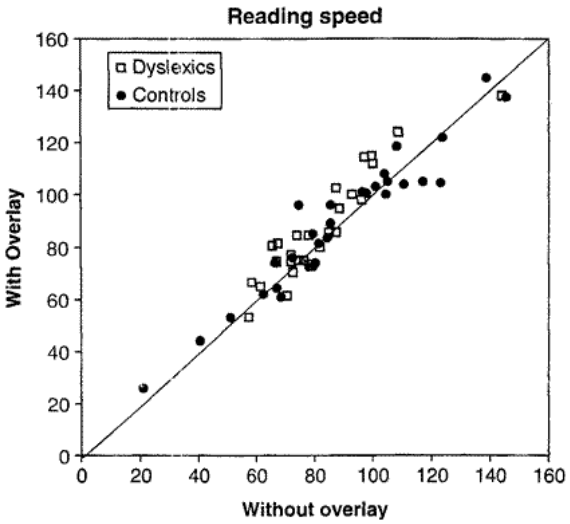

Figure 2. Scatter plot of WRRT results.

Note: Each point is a participant: filled circles are control participants and unfilled squares are dyslexic participants.

significantly different from a normal distribution, suggesting that parametric ANOVA is appropriate. As a precaution, a key analysis below is confirmed with a non-parametric test.

Figure 2 is a scatter plot showing the WRRT results for each participant, labelled to identify members of the dyslexic and control groups. Points above the diagonal represent faster reading with the overlay than without, which is particularly apparent for the dyslexic group. The improvement with an overlay does not seem to be related to reading speed.

Table 3 and Figure 3 show the descriptive statistics for the WRRT results. Only participants who chose an overlay are included in these analyses. Children in the control group have slightly higher scores than the dyslexic group, both with and without overlays. Also, there is a difference between the mean test scores with and without the overlay for the controls of only 0.47, compared with 4.91 for the dyslexic group.

Using a repeated measures analysis of variance (ANOVA), the effect of group was not significant ($p = 0.67$), but the effect of overlay was significant ($p = 0.009$). There was a significant interaction between overlay and group ($p = 0.031$). The effect of overlay was further investigated with the non-parametric Wilcoxon signed ranks test. The effect of the overlay on WRRT results reached significance in the dyslexic group ($p = 0.005$) but not in the control group (0.75).

Table 3. Descriptive statistics for WRRT results.

Mean Score	N	Mean with overlay	Standard deviation	Mean without overlay	Standard deviation
Dyslexic group	27	86.91	20.31	82.00	18.31
Control group	31	87.37	27.13	86.90	28.46

instructed to begin. As the participant was reading, each error was noted by marking the score sheet above the word that was misread. The participant was stopped after one minute and the score sheet was marked to indicate how far they had read. If they finished the passage before the minute was up, then the number of seconds taken was noted. The process was repeated with version B and no overlay, then with version C again without an overlay and lastly version D with the overlay.

Results

Overlays chosen

Table 2 shows the number of participants choosing each colour or combination of overlay. More members of the control than the dyslexic group selected overlays, but the difference between the two groups was not statistically significant (Fisher's exact test, 2-tailed, $p = 0.20$). It is interesting that a marked number of participants in both groups selected mint-green overlays.

WRRT results

The Rate of Reading test was scored according to the test instructions: the number of errors was subtracted from the total amount of words read in one minute. The mean was found of scores on tests A and D, which were read with an overlay. Tests B and C were read without an overlay and the mean of these two scores was also calculated. An inspection of the frequency distributions for these four variables (WRRT mean result with overlay and mean result without overlay in each group) revealed data that approximated normal distributions, but were slightly skewed towards lower values in the dyslexic group. Kolmogorov-Smirnov tests showed that these distributions were not

Table 2. Number of participants choosing each colour or combination of overlay.

Colour of overlay	Dyslexic group	Control group
None	5	1
Rose	0	0
Lime green	1	0
Blue	1	0
Pink	2	0
Yellow	0	2
Aqua	1	2
Purple	0	2
Orange	2	2
Mint green	9	12
Grey	3	9
Mint & lime green	4	0
Double grey	1	0
Purple & pink	1	0
Double mint green	1	0
Double lime green	1	0
Aqua & mint green	0	1
Double orange	0	1
Total	32	32

Participants

Sixty-four children were tested, 32 in the dyslexic group and 32 controls. The groups were matched for age and gender so that, in each group, the mean age was 9.4 years and the age range was 7–12 years, with 21 males and 11 females in each group. Participants were recruited from various state schools and dyslexia clubs; socio-economic background was loosely matched by the area in which the participants lived. During the process of informed consent it was made clear that the research did not constitute an 'eye test' and did not detract from the need for routine eye care.

Selection criteria for all participants were as follows: aged between 7–12 years and able to read the 15 words in the WRRT. An additional criterion for the dyslexic group was a diagnosis of dyslexia by an educational psychologist. Teachers selected control participants as having no suspicion of dyslexia and a reading age that is not significantly worse than that predicted for their age and intelligence. Intelligence was not formally assessed in the study, but teachers were asked to select children whose intelligence was within the average range. No other criteria were applied in selecting participants and children who had received previous optometric treatment, including coloured filters, were neither actively sought nor excluded. Care was taken to ensure that subject sources did not attempt to select children whom they felt may, or may not, have a visual problem.

Procedure

Participants were tested with the Intuitive Overlays (Wilkins, 1994), as described in the test instructions (Wilkins, 2001). The test used the following colours: rose, lime green, blue, pink, yellow, aqua, purple, orange, mint green and grey. They were presented in this order to avoid presenting similar or complementary colours one after the other. Double overlays were also investigated, so that a total of 30 colours were presented. The effect of the chosen overlay was assessed with the WRRT (Wilkins et al., 1996) as specified in the test instructions (Wilkins, 1996).

Participants were asked to wear during the testing any glasses that were usually worn for reading. In each situation where testing took place (typically a normally illuminated classroom), care was taken to avoid glare from the windows and overhead lights, and to ensure that the room was fairly quiet and that there were no distractions during the test procedure. Participants were shown a sheet of paper with 15 high frequency English words, as used in the WRRT, but in large type. They were asked to read these aloud, and were corrected if they made errors. Participants who produced errors after re-reading the list of words were excluded from the experiment, as they would not be able to read the same words in the WRRT. All participants who demonstrated a preference for an overlay, or for a combination of overlays, were tested with the WRRT with and without their chosen overlay.

In the administration of the WRRT, participants were asked to read the text aloud as quickly as possible and without errors. The subject was asked to read the first three lines of passage B or C (selected at random) as a practice trial, without any overlay. The goal of this practice attempt was to familiarise the subject with the task of reading randomly ordered text. The participant was presented with version A of the test with the small typeface, unless they were unable to read it or it caused discomfort. If this happened then there was a larger version of the test that would have been used, although this was not found to be necessary for any of the participants. The selected overlay or combination of overlays was placed on the text, and the stopwatch was started as the participant was

Table 1. Prevalence of Meares-Irlen Syndrome in unselected populations.

Study	Sample	Criterion	Proportion (%)
Wilkins et al. (1996; Fig. 3)	77 unselected children, aged 8–11 yrs	initially selected an overlay to use	49
		>5% faster at WRRT	20
		sustained (8 weeks) voluntary use	20
		sensitivity of 5% criterion for sustained use	73
		specificity of 5% criterion for sustained use	90 (74)
Jeanes et al. (1997)	152 unselected children, aged 5–11 yrs	initially selected an overlay to use	53
		sustained (3 month) voluntary use	36
		sustained (10 month) voluntary use	24
Wilkins et al. (2001; Table 3 & Fig. 7)	426 unselected children, aged 6–8 yrs	initially selected an overlay to use	60
		>5% faster at WRRT	36
		>25% faster at WRRT	5
		sustained (8 months) voluntary use	31
		sensitivity of 5% criterion for sustained use	68
		specificity of 5% criterion for sustained use	79 (50)
Evans & Joseph (2001)	113 unselected university students, aged 18–44 yrs	Initially selected an overlay	88
		>5% faster at WRRT	34
		>25% faster at WRRT	2

Source: (modified after Evans and Joseph, 2001).
Notes: The proportion column gives the proportion of the full study population who meet the adjacent criterion. Sensitivity is defined as the percentage of the full study population who chose an overlay and continued to use it – who initially showed an improvement of >5% in the rate of reading. Specificity is defined as the percentage of the full study population who either did not choose an overlay or did not continue to use one – who did not initially show an improvement of >5% in the rate of reading. An alternative method, used by Wilkins et al. (2002, Fig. 7) and included here in parentheses, defines specificity as the percentage of participants who chose an overlay but did not continue to use it – who did not initially show an improvement of >5% in the WRRT.

prevalence of MIS in people diagnosed with dyslexia. Irlen has claimed that MIS has a prevalence of 12–14% in the general population, and 46% in those with dyslexia, but no data or diagnostic criteria were given to support this statement (Irlen, 1997). A PubMed search for the keywords *dyslexia* AND (*Meares-Irlen Syndrome* OR *Irlen Syndrome* OR *Scotopic Sensitivity Syndrome*) revealed only four papers, none of which gave estimates of prevalence. The aim of the present study is to compare the prevalence of MIS in a cross-sectional sample of dyslexic and control children.

Method

The study was a 2 × 2 mixed factorial design experiment, with dyslexic and control group being the between-participants variable and testing with and without overlay being the within-participants variable.

come see the play look up is cat not my and dog for you to
the cat up dog and is play come you see for not to look my
you for the and not see my play come is look dog cat to up
dog to you and play cat up is my not come for the look see
play come see cat not look dog is my up the for to and you
to not cat for look is my and up come play you see the dog
my play see to for you is the look up cat not dog come and
look to for my come play the dog see you not cat up and is
up come look for the not dog cat you to see is and my play
is you dog for not cat my look come and up to play see the

Figure 1. A passage from the Wilkins Rate of Reading Test (reproduced with permission of Prof Arnold Wilkins and of i.o.o. Sales Ltd, London).

are designed to evaluate high-level reading skills, but not the contribution of visual factors to reading: the WRRT evaluates this aspect. For example, the Neale Analysis of Reading Test (Neale, 1997), which revealed an improvement from coloured overlays in reading accuracy and comprehension but, surprisingly, not speed (Robinson & Foreman, 1999), uses relatively large text and widely spaced lines. The WRRT uses smaller, closely spaced text and consists of words that occur with a very high frequency in the English language, which should be familiar to children aged 7 years and above. The WRRT is scored for reading rate and errors, and is simple as far as cognitive and language skills are concerned. The text size and spacing has been selected to make it well suited to detecting visual problems.

Diagnosis and prevalence of Meares-Irlen Syndrome

Both methods of detecting MIS described above have been used to diagnose the condition. The prevalence will, of course, vary with the criteria that are used. A problem with diagnosing MIS (Evans & Joseph, 2002) is that there is likely to be a continuum ranging from people who experience no help from coloured filters, through those who show a mild benefit, to the more severe cases who may experience a marked reduction in symptoms and a very marked improvement in reading performance.

Studies have shown that, using the sustained voluntary use criterion, the prevalence of MIS in unselected school populations is approximately 20% (see Table 1). Jeanes and colleagues showed that children who demonstrated sustained voluntary use of their overlay showed a mean improvement of 14% in reading speed with the WRRT (Jeanes et al., 1997). The WRRT predicts the children who subsequently will use their overlay, and does so before they have become acquainted with its use (Wilkins et al., 1996). Two single-masked randomised placebo-controlled trials confirmed that the benefit in rate of reading with overlays is not attributable to placebo effects (Bouldoukian, Wilkins & Evans, 2002; Wilkins & Lewis, 1999).

Several studies have calculated the prevalence of MIS in unselected samples, for example by screening large groups of unselected children in schools (Jeanes et al., 1997; Wilkins et al., 1996; Wilkins, Lewis, Smith, Rowland & Tweedie, 2001). These studies are summarised in Table 1, which gives figures for prevalence according to various diagnostic criteria. Table 1 also includes one study of adult university students which suggests that the prevalence in adults is similar to that in children (Evans & Joseph, 2002).

Although there is now good evidence for the prevalence of MIS in the general population, we know of no previously published studies that have determined the

An initial system for prescribing tinted lenses by non-eyecare professionals (Irlen, 1991; Evans & Drasdo, 1991) has been supplemented by the Wilkins/MRC system mentioned above (Wilkins, Nimmo-Smith & Jansons, 1992). This is now widely used in the UK by optometrists in primary care practice and by some orthoptists and optometrists in secondary-care hospital eye departments. The Wilkins/MRC system was used in the present research and is described in more detail below.

Detection of Meares-Irlen Syndrome

The possible presence of MIS in an individual is sometimes indicated by a recollection of symptoms experienced during reading. However, there are limitations to the use of symptoms for the detection of MIS (Jeanes et al., 1997): symptoms may be exaggerated (for example, by suggestible children), some children fail to recognise symptoms until they have been eliminated because to the child the symptoms are 'normal' and the symptoms of MIS are non-specific. This last point is important since the symptoms of MIS can be caused by a variety of other visual problems (Evans, 2005). Although symptoms should never be ignored, these limitations restrict their potential use in screening for MIS and most screening programmes use coloured overlays.

Coloured overlays are transparent plastic sheets that are placed on the page to allow a comparison of text that is covered by an overlay with text that is uncovered. Both of the major systems (Evans, 2001) that are used for treating MIS in the UK use coloured overlays in this way (Irlen & Lass, 1989; Wilkins, 1994). The protocol that is typically followed (Lightstone & Evans, 1995) starts with a screening test using coloured overlays, which is usually administered by teachers or optometrists. The coloured overlays in the Wilkins/MRC system were designed to sample comprehensively and systematically CIE 1976 UCS chromaticity (Wilkins, 1994). If children express a preference for a coloured overlay then this preference is tested in one of two ways: voluntary sustained use or an immediate improvement in rate of reading. To meet the criterion of voluntary sustained use, the person is issued with their preferred coloured overlay and invited to use the overlay for reading, if it is found to be helpful. Instructions are given that if the overlay is still being used after a half to one school term then the child should seek further testing. To test for an immediate benefit in rate of reading, the Wilkins Rate of Reading Test is used and this is described below (Wilkins, Jeanes, Pumfrey & Laskier, 1996).

Whichever criterion is used, people who demonstrate a benefit from an overlay ultimately may be tested with the Wilkins/MRC Intuitive Colorimeter. This is an instrument which allows the very precise determination of the optimal specification for tinted lenses and it is used in conjunction with a range of precision tinted lenses to prescribe tinted spectacles (Wilkins, Milroy et al., 1992). People almost invariably report more benefit from precision tinted lenses than from coloured overlays because precision tinted lenses are easier to use (e.g. with white boards and when writing) and because the colour can be prescribed with more precision.

The Wilkins Rate of Reading Test (WRRT)

Wilkins developed the Rate of Reading Test (WRRT; see Figure 1) in order to isolate and measure the effect of visual factors on reading (Wilkins et al., 1996). Most reading tests

good readers but is said to be particularly prevalent in people diagnosed with dyslexia (Irlen, 1997). There is a large body of literature on MIS, reviewed by Evans (2001), and to date there have been two rigorous double-masked randomised placebo controlled trials (Wilkins et al., 1994; Robinson & Foreman, 1999). These trials support the existence of this syndrome and validate the treatment with individually prescribed coloured filters. In particular, both randomised controlled trials demonstrate that the benefit from coloured filters is idiosyncratic and specific: different people need different colours and the colour needs to be defined with some degree of precision. This accounts for a great deal of controversy in the literature: studies using individually prescribed filters tend to be positive whilst those that test all participants with the same colour, or with a very limited range of colours, tend to be negative (Evans, 2001).

The first double-masked randomised placebo-controlled trial found that individually prescribed coloured filters (precision tinted lenses) brought about a significant reduction in symptoms of eyestrain and headache compared with control lenses of a similar but different colour (Wilkins et al., 1994). The lenses were prescribed using an instrument, the Intuitive Colorimeter, that had been developed by Wilkins and patented by the Medical Research Council (Wilkins, Nimmo-Smith & Jansons, 1992).

The second double-masked randomised-controlled trial investigated the effects of coloured filters on reading speed, accuracy, comprehension and self-perception of academic ability, with the widely used Neale Analysis of Reading Test (Robinson & Foreman, 1999). A total of 113 participants were divided into three groups either using placebo filters, standard blue filters or optimal (individually prescribed) filters. Compared with the other groups, the group using optimal filters increased markedly in reading accuracy and comprehension, but not in speed (see below). This study used the Irlen system (Irlen, 1991).

An audit of a clinical population found that one-and-a-half years after patients had been prescribed precision tinted lenses, 73% were still using them on a daily basis (Evans et al., 1999). In the open trial of precision tints by Maclachlan et al. (1993), a similar figure of 81% was obtained. Patients' perceptions of the benefit they received from their precision tints compared favourably with other interventions, with nearly 80% reporting that tints improved their problems or difficulties (Evans et al., 1999).

The aetiology of MIS has been reviewed elsewhere (Evans, 2001; Wilkins, 2003). Although many theories have been proposed, few can account for the individual and sometimes precise nature of the tints required. The most plausible explanation at present relates to pattern glare (Wilkins et al., 1984) and cortical hyperexcitability (Wilkins, Huang & Cao, 2003). Striped patterns can be unpleasant to look at and some people experience eyestrain and visual perceptual distortions when viewing these. In fact, these symptoms are remarkably similar to those reported by people with MIS. Some people with photosensitive epilepsy are particularly prone to these symptoms, as are others with migraine, and the mechanism for these symptoms is likely to be a hyperexcitability of the visual cortex (Huang, Cooper, Satana, Kaufman & Cao, 2003). Lines of print on a page form a striped pattern, which can have the spatial properties that may cause pattern glare (Wilkins & Nimmo-Smith, 1984). It seems likely that this mechanism is responsible for at least some patients' symptoms of 'visual stress' when reading, which characterise MIS. The peak responses of some colour sensitive areas of the visual cortex are spatially arranged in the order of the hues of coloured stimuli (Xiao, Wang & Felleman, 2003) and this could account for the benefit from specific coloured filters. Recent research suggests that individually prescribed coloured filters can also help people with visually precipitated migraine (Wilkins, Patel, Adjamian & Evans, 2002) and epilepsy (Wilkins et al., 1999).

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