Visual discomfort in the classroom

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Abstract

Treatment of reading difficulties with coloured overlays and Irlen filters is reviewed. The accumulated anecdotal evidence for beneficial effects in certain children can no longer be ignored, but scientific evidence is lacking. Advice for the classroom management of visual discomfort and associated perceptual distortion is offered.

What is visual discomfort?

Visual discomfort is a term that refers to eye-strain and visually-induced headaches. Light-sensitive people who suffer visual discomfort are frequently liable to disturbances of visual perception (Wilkins, *et al.*, 1984). When they look at certain patterns, such as Figure 1, they find the patterns unpleasant and report a variety of perceptual distortions (illusions of colour, shape, and motion). The pattern shown in Figure 1 is a particularly unpleasant one, and most people (not only those who are light-sensitive) report illusions of some kind. People with migraine are particularly affected (Marcus and Soso, 1989), and susceptibility is increased prior to a headache (Nulty, Wilkins and Williams, 1987).

Figure 1 is unpleasant because it has certain very specific spatial characteristics. Printed text can resemble this pattern to an extent that depends upon the spacing of words and lines of text (Wilkins and Nimmo-Smith, 1987). When the words are closely spaced horizontally,

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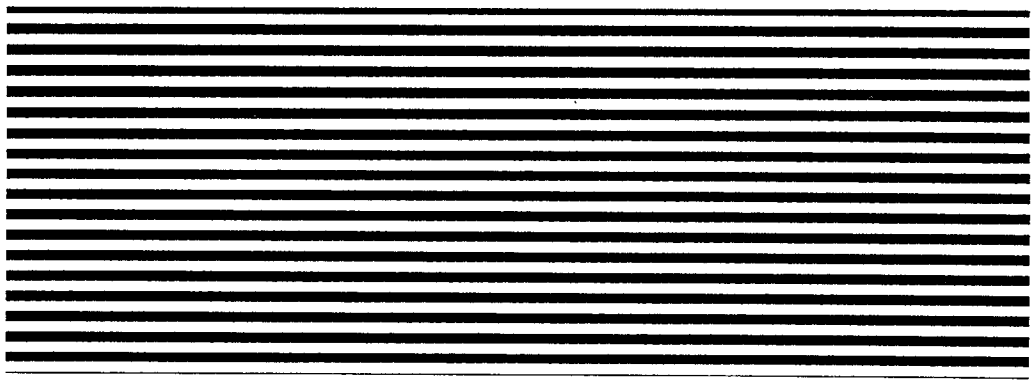


Figure 1 A pattern with spatial characteristics that make it unpleasant to look at. It induces illusions of colour, shape and motion to which some people are far more susceptible than others.

WARNING. This pattern may induce an attack of migraine or epilepsy in those who are disposed to such attacks. Do not show the pattern to children.

the lines of text resemble 'stripes' that can be uncomfortable to look at, inducing perceptual distortions. Covering the lines above and below those being read reduces these distortions and can prevent headaches and eye-strain in those who are susceptible to these problems when they read (Wilkins and Nimmo-Smith, 1984).

More than 20 years ago Weston (1962) observed that:

> It is also possible for acute strain to be caused by . . . repetitive patterns . . . For example, a dress fabric having very narrow black and white stripes of equal width — forming what is known as a dazzle pattern — has proved so difficult to work with as to be intolerable except for quite short periods. In such cases it is sometimes possible to lessen the strain by wearing coloured glasses which appear to subdue the glaring contrast of the pattern.

Helen Irlen, an educational psychologist from California, discovered just how effective colour can be. In 1983 she was engaged on a research project at California State University exploring the visual and perceptual factors contributing to reading difficulties. One of her clients observed a page of text held in a coloured plastic wallet and remarked how much clearer the text was. This chance observation was taken up by Irlen who soon found that many people reported improvements in clarity when the text was covered by coloured plastic.

Irlen has drawn attention to the fact that eye-strain and perceptual disturbances often occur during reading, particularly amongst those with reading difficulties. She has used the name SCOTOPIC SENSITIVITY SYNDROME (SSS) to refer to a heterogenous collection of symptoms associated with visual discomfort. This term is unfortunate and has given rise to confusion amongst professionals. The word SCOTOPIC comes from the Greek *skotos* meaning 'darkness' or 'gloom' and is usually taken to refer to the function of the rod cells in the retina. These cells enable us to see at twilight. There is no evidence that rod cells in particular are implicated in SSS.

The Irlen Institutes

Irlen has set up institutes not only in the USA but also in Australia and in the UK, with much accompanying attention from the media. Her company (Perceptual Development Corporation) distributes sets of plastic overlays with a matt surface and fairly light tint. The overlays cost about £2.50 each and can be purchased from the Irlen Institute, 9

Orme Court, London W2 4RL (tel. 071 229 8810) or, in Scotland, from the charity Reading Through Colours (tel. 031 445 3710).

The overlays cannot be used for written work, and so Irlen has developed a technique for providing appropriately tinted spectacles. Children who seem to benefit from coloured overlays are invited to undergo a 1–2 hour procedure to select an appropriate tint. The client goes through a large set of trial tints, picking out those that appear to make a page of Dutch text clearer to read. (Dutch text is used with English speakers to emphasise the visual rather than semantic aspects of reading.) The examiner asks the client to describe the visual distortions they see using their own words, and then employs this description when comparing the lenses. By a lengthy process of elimination the best tint is eventually selected and other tints added to fine-tune the colour. The selection eventually arrived at can involve a combination of three or more tinted trial lenses and the combination is often quite dark. This might be partly because one colour is being added to another to get the right tint. The code for the selected lenses is then sent off to Irlen's organization in the USA for provision of the tint. Unfortunately the cost is such that many people cannot afford the lenses.

Costs and opposition to them

Nowadays it is very simple and inexpensive to colour plastic lenses to virtually any shade. The lenses are simply dipped into hot dye. Any combination of dyes can be used. Despite the simplicity of the process, it can sometimes be difficult to reproduce a precise colour because the rate of deposition of the dye depends on a large number of factors, some of which are difficult to control. Although the material costs involved are small (less than £3 for the lens and less than 3p per lens for the dye) it can take trial, error, and some skill to obtain a precise colour.

The charges made by the Irlen Institute cover overheads and the labour involved in the assessment procedure and the precision tinting. Nevertheless the apparent disparity between the charges made and the costs of tinting have aroused a lot of opposition and have perhaps contributed to the following strictures from the ophthalmological profession in the United States (Helveston, 1990):

(1) SSS has not appeared in any peer-review journal.
(2) The reports of success have been challenged.

(3) They are based only on anecdotal information and testimonials.
(4) The Institute solicits clients and charges for consultations.
(5) A variety of coloured overlays is now being marketed indiscriminately in the US.

With respect to (2), (3) and (4), the Irlen Institute is no different from other alternative medicine. Even established medical practice takes advantage of treatments that have little or no scientific backing, although these treatments usually have instead the weight of tradition behind them. At present, Irlen's treatment lacks any such tradition and, rightly or wrongly, scientific credentials will have to be demonstrated before the treatment can be introduced into established medical or educational practice.

Scientific evidence

So far there is little scientific evidence for or against treatment with coloured glasses. There are a number of studies in the literature, but their quality is not high. In the main, the studies that have shown positive findings have been conducted by individuals connected in some way with the Irlen Institute, and those that have failed to show effects have been conducted by others. The literature has been reviewed recently in a publication from the Australian Institute of Health (Lea and Hailey, 1990) and the British College of Optometry (Evans and Drasdo, 1991). The reviews reach an open verdict. Recently, however, evidence has emerged that children with reading difficulty can have specific visual deficits.

Visual problems in children with reading difficulty

Lovegrove, Martin and Slaghuis (1986) working in Australia have shown a variety of visual difficulties in children with reading disorders. They find the children have difficulty on psychophysical tasks that measure the function of the so-called 'transient system' — that part of the visual system that analyses changes in the visual image. The children score normally on other visual tasks that measure the 'sustained system'. There is a limited amount of evidence that the colour sensitivity of the transient system differs from that of the sustained (Breitmeyer and Williams, 1990). Reading may make heavy demands on the transient system, and, in time, this area of research may provide justification for treatment with tinted lenses.

The colour of the Irlen lenses

Colour can be represented in a large number of ways but one of the best for our purposes is the so-called u'v' chromaticity diagram shown in Figure 2. Highly saturated colours are located around the edge of the triangular space and less saturated pastel shades towards the centre. The distance between any two points roughly corresponds to the dissimilarity of the colours. All the colours of the rainbow are represented on the so-called 'spectral locus' (the curved perimeter), and the colours that are not in the rainbow such as purple are shown by the straight line joining the ends of the spectrum.

The Irlen Institute kindly supplied information from which the spectral transmission of 135 pairs of lenses could be measured. From each transmission curve was calculated the point in colour space that described the colour that the lenses appeared when seen in (standard) daylight (D65). Each point in Figure 3 represents the colour of a pair of lenses. Most are clustered near white — they are not strongly coloured. The few filters that are strongly coloured tend to be any colour other than green. On the plot shown in Figure 3a the colour is shown irrespective of the 'darkness' of the lens: a neutral grey would have the same position as a completely clear lens on this diagram. The

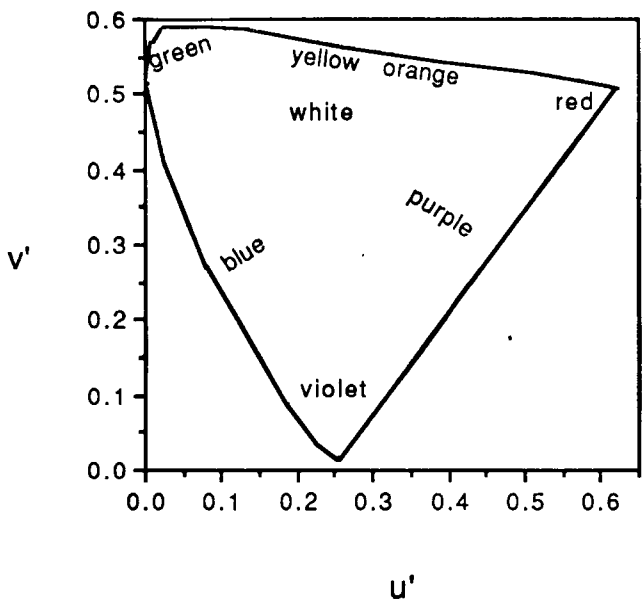


Figure 2 The CIE u'v' chromaticity diagram.

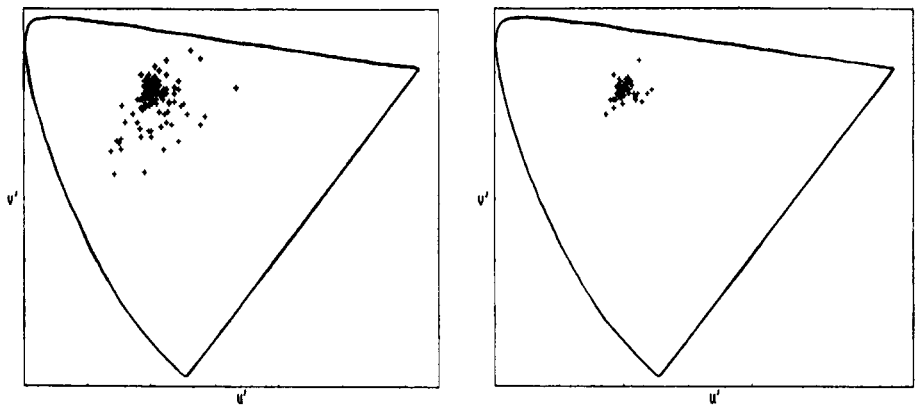


Figure 3 Chromaticity coordinates for Irlen lenses under standard daylight (D65). (a) A consecutive series of 139 spectacles; (b) 67 spectacles having a (photopic) transmission above the mean for the series (42%).

average (photopic) transmission of the 135 pairs of lenses was 42%. If we separate out just the lenses that transmit more than this mean, then the graph shown in Figure 3b is obtained. As one might expect, the lighter lenses have a weaker (less saturated) colour.

An initial MRC study

We conducted a study to evaluate the effects of tinted lenses on reading. We deliberately selected clients referred to us by the Irlen Institute as having shown beneficial effects. This selection ensured that any failure to find beneficial effects could not be attributed to the selection of clients. The Irlen Institute supplied the names of 26 people and 20 eventually attended for examination. We administered a wide range of conventional optometric tests together with a few that were less conventional. The tests were performed without any lenses, with a coloured lens of the client's choice, with a grey lens of similar density, and with a combination of conventional ophthalmic spectacle lenses to correct any residual focussing insufficiency (refractive error). We found the coloured glasses slightly improved the speed with which letters could be found in a text-like array of random letters. The coloured glasses also reduced the reported perceptual distortions in a pattern of striped lines. Nearly half the children had ocular muscle imbalance, that is, the eyes had a tendency to be misaligned. In some this tendency was reduced by the coloured glasses and in others it was increased (Wilkins and Neary, 1991).

Must the tint be individually selected?

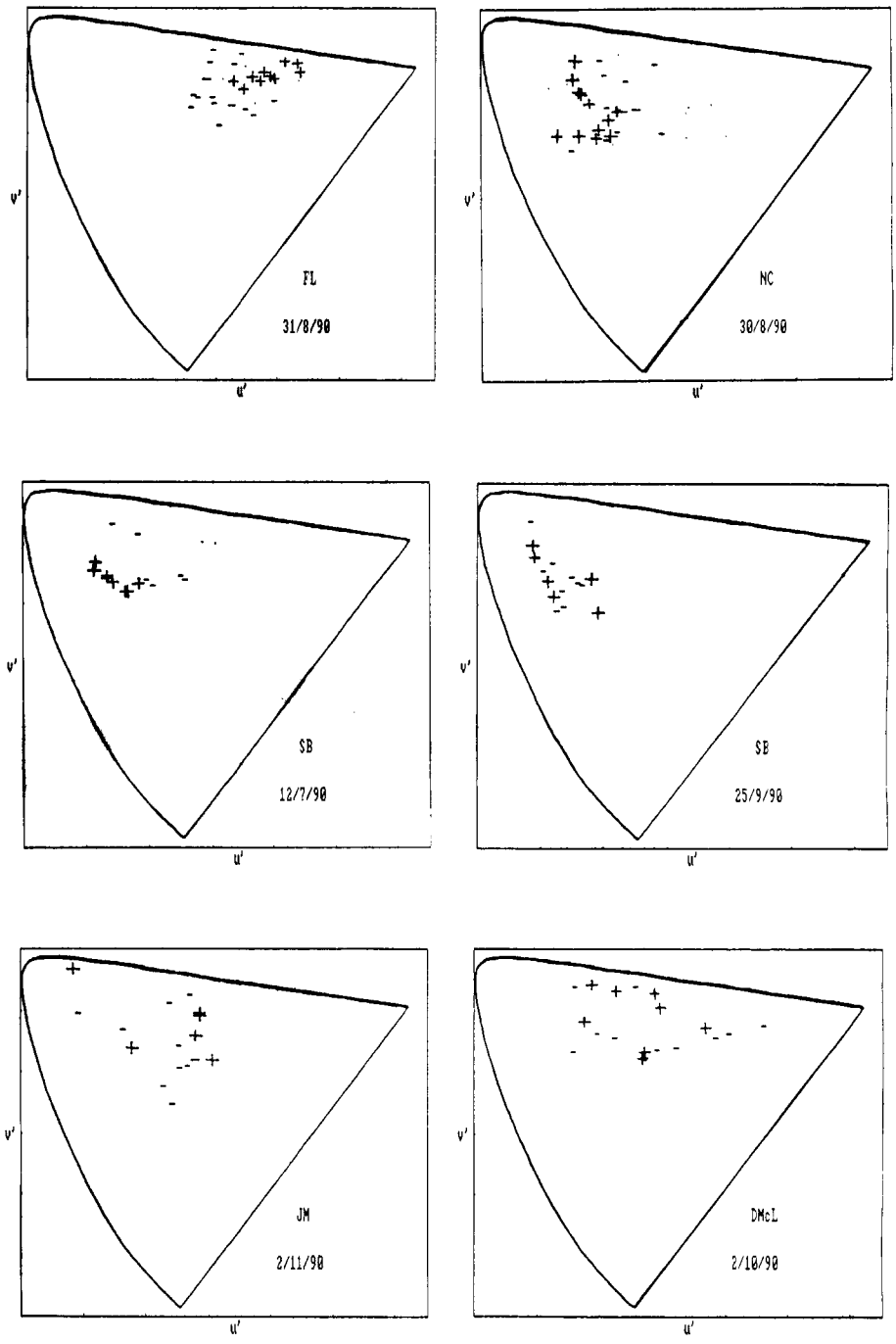
Coloured filters change brightness as well as colour, and when children compare one filter with another, they are comparing more than one thing. We have therefore developed an intuitive colorimeter (Wilkins, Nimmo-Smith and Jansons, in press). This is a simple optical device that enables a child to change the colour of light falling on a page of text by turning a wheel. By moving a lever the child can vary the saturation of the hue from near white to strongly coloured. None of these changes affect the brightness of light on the page: this can be changed using a separate control.

The intuitive colorimeter has three important advantages for studying the effects of colour on reading.

(1) The observer changes just one variable at a time: because the hue, saturation or brightness can be varied more-or-less independently, it is easier to separate their effects, and the child knows how to obtain a particular shade.
(2) Colour is varied continuously so that an infinite number of colours is available within the range (gamut) that can be obtained in the apparatus. The child is not restricted to a number of discrete colours.
(3) No surfaces in the apparatus reflect light of one colour more than that of any other colour. Therefore if brightness is held constant, only two variables (the hue and saturation of the illuminating light) are important. This simplifies matters considerably.

The effects of colour on perceptual distortion

The apparatus was used to examine a second series of people referred by teachers, educational psychologists, and optometrists. They all found reading difficult, and complained of distortions of the page of text when reading. All had been examined by an optometrist and none needed glasses. Figure 4a shows data from an 18-year-old girl. She was asked to rotate the wheel of the colorimeter, varying hue, to see if she could find a setting in which the distortions on a page of text disappeared. The settings are shown with the symbol '+'. She was then asked to turn the wheel slowly until the distortions reappeared, and the settings are shown with the symbol '−'. She did this repeatedly with hues of different saturation. There is a very small area of colour space in which her distortions disappeared. It is so small that it might



Figures 4–6 Chromaticity diagrams in which the symbol '–' indicates a hue at which perceptual distortions occur, and '+' indicates the absence of distortions.

be missed by a limited range of tinted glasses or overlays. Figure 4b shows data from a 15-year-old boy. Note that the distortions disappear when the light is an unsaturated blue or a saturated green.

These data would seem to substantiate Irlen's claims that the choices of colour are idiosyncratic and can be very specific. The colour choices can also be stable and reliable from one test to the next. Figures 5a and 5b show data from a 10-year-old girl obtained on two occasions one week apart.

The technique does not necessarily result in patches in colour space. It is quite possible for children to report distortions that are inconsistent and may relate to tiredness or other factors. Figures 6a and 6b present data for two boys, one aged nine and the other ten, showing an inconsistent scatter in colour space using the same technique as that used to obtain the settings shown in the previous figures.

From the above observations it would seem that certain children are subject to distortions of text, and that for some children but not others the distortion can disappear when the text has a particular colour. The colour is sometimes (but not always) specific, consistent, and yet different from one person to another.

In order to arrange for tinted glasses to give this appropriate colour is quite difficult. It is necessary to take into account (1) the influence of coloured surfaces and (2) the colour of the illuminating source, be it fluorescent light or daylight or some combination of the two. The MRC have developed a tinting system in collaboration with Cerium Optical Products, and it is currently undergoing clinical trials at a variety of centres including the Institute of Optometry, London.

Why do the lenses work for some children?

Placebo effects play a large role in medical treatment, and tinted glasses are certainly no exception. Nevertheless, there do appear to be beneficial effects that are difficult to attribute only to placebo mechanisms. It is impossible to say at present why these occur, but it may be worth considering a few possibilities.

(1) It is impossible for the lens of the eye to focus all the colours of the rainbow on to the light-sensitive retina, so the brain makes a compromise. It usually focusses yellow light correctly, allowing blue light to focus in front and red light behind the retina. The brain is always hunting for the best compromise, and it is possible that the

colour filters act on this mechanism in some way.

(2) The lens of the eye fluoresces. In response to ultraviolet and blue light it emits light of longer wavelength, and it is remotely possible that this scattered light is sufficient to reduce the visibility of the image slightly. If so, it is possible that the coloured filters affect the fluorescence of the lens and other structures inside the eye.

(3) As mentioned earlier, text can form a pattern that is unpleasant to look at. People with migraine are particularly affected, and 17 of the 20 children in our initial study had parents with migraine. It is not known why coloured glasses affect the glare from patterns, but it is interesting that most colour choices avoid green: green light is that to which the visual system is most sensitive. Perhaps the patterns overload the visual system, giving a sensation of glare. By providing filters that absorb green light we may be overcoming the effects of that overload in some way.

(4) Many of the filters chosen have a red or rose colour. This may be for yet another reason. The rapid imperceptible flicker from fluorescent lighting is resolved by the retina affecting the firing of nerve cells in the human eye. In the cat the flicker affects the firing of cells in the lateral geniculate nucleus, part of the brain closely linked with areas that control movements of the eyes. The flicker has a small effect on human eye movements and causes eye-strain and headaches (Wilkins, *et al.*, 1989). In most fluorescent lamps the flicker comes mainly from light at the blue end of the spectrum (Wilkins and Clark, 1990). By cutting out light with these short wavelengths it is possible to reduce the flicker by a small amount. We have developed glasses for this purpose. They have a rose-red appearance and are called Comfort 41. They are available from opticians, but it is important to try them out before purchase because some people find the colour uncomfortable on the eyes (Wilkins and Wilkinson, 1991).

Significance for the classroom

It is important to identify the children who might benefit from coloured overlays and tinted glasses. Children have no way of comparing their vision with that of others except by talking about what they see, and they may be unaware that they see text as distorted. If the distortions occur mainly with text, they may be aware that the letters of text do something that other objects do not do, such as move

around, wobble, or show coloured halos. Table 1 shows a list of questions derived partly from those suggested by Helen Irlen to which affected children are likely to reply 'yes'. Not all the children who report perceptual distortion can be helped by coloured overlays. Some may find greater benefit from a reading mask that reveals only one line of text at a time covering not only lines below but also lines above. To assess the possible benefit of coloured overlays it is necessary to try a wide range of colours such as red-rose, gold, yellow, turquoise, and blue overlays, and combinations of these that include purple. Suitable overlays can be obtained from the Irlen Institute. Alternatively, overlays similar to those provided by the Institute can be obtained by combining theatrical filters, obtainable from theatre lighting companies. Table 2 shows the filters necessary. It may be preferable to obtain a swatch of filters and try a larger range. Sheets of the appropriate filter can then be purchased. Unfortunately theatre filters have a tendency to crease, and need to be laminated in plastic or kept in a clear plastic wallet if they are to survive the classroom. Other overlays such as coloured polythene sheets may be just as suitable, provided an appropriate tint is available. Children who persistently

Table 1 Questions for children with visual discomfort (adapted from Irlen and Lass, 1989).

(1)	Do you find that reading makes you restless?
(2)	Do you screw up your eyes when you are reading?
(3)	Does reading leave you feeling tired?
(4)	Do you read either near or far away from the page?
(5)	Do you often suffer from headaches or migraines?
(6)	Does reading leave your eyes sore, tired etc.?
(7)	Do you miss out words/lines?
(8)	Do you need to read words/lines twice to understand them?
(9)	Do you need a marker to keep your place?
(10)	Do you miss out words like *in, of, at,* etc?
(11)	Do you need a break from reading after 20 minutes or less?
(12)	Does it get harder the longer you read?
(13)	Does fluorescent lighting upset you?
(14)	Do words ever look strange on the page?
(15)	Do words or letters move about (wobble or shimmer)?

Table 2 Filters similar to the Irlen overlays produced by superimposing theatre filters.[a]

Rose: Lee 218 + Rosco 04
Peach: Rosco 602
Gold: Rosco 06 + Rosco 07 + Rosco 11
Yellow: Rosco 10 + Rosco 96
Green: Lee 218 + Rosco 671
Turquoise: Rosco 66 + Rosco 669
Blue: Lee 218

[a] Obtained from theatre lighting companies such as Ancient Lights, Ditton Walk, Cambridge CB5 8QD, tel 0223 410249

use their overlays and derive obvious benefit from them may find tinted glasses useful for written work. Tinted glasses can be obtained by contacting the Irlen Institute, the charity Reading Through Colours, or the Institute of Optometry.

Teachers who have a light-sensitive child in their classroom may find the following steps of help.

(1) Minimize the effects of any fluroescent lighting by using daylight where possible (avoiding direct sunlight). The amount of flicker from fluorescent lighting varies considerably from one type of lamp to another: warm white lamps flicker less than white or cool white, so it may help to change the lamp (Wilkins and Clark, 1990). Any new lighting installation should use high-frequency circuitry rather than conventional. It operates the lamps at frequencies that are too high to affect the brain. High frequency circuitry is cheaper to run, but unfortunately costs more to install.

(2) Coloured paper can be used for class tests and assignments. A buff colour may provide a suitable alternative to white. It is possible to photocopy an individual's work onto coloured paper. Bear in mind that photocopying can increase the contrast of the material. It may sometimes be helpful to enlarge material when it is photocopied. Avoid photocopying at reduced size if the material is conventionally printed text or music manuscript, because this can make it very much more difficult to read.

(3) When using blackboards, whiteboards, or overheads, experiment with the colour of the chalk or pen, so as to reduce the contrast, or glare. As an alternative, photocopy work onto coloured paper.

(4) It is often helpful to cover not only the lines below those being read but also the lines above, since they also contribute to visual confusion. An adjustable plastic reading mask, the Cambridge Easy Reader, is obtainable from Engineering and Design Plastics, 84 High Street, Cherry Hinton, Cambridge CB1 4HZ, tel. 0223 249431. An alternative mask, the Dexframe, does not adjust, but incorporates coloured filters. It is obtainable from Learning Development Aids, Duke Street, Wisbech, Cambridge PE13 2AE, tel. 0945 63441. In mathematical work, particularly with material that is tabulated, highlighters can be used to decrease the similarity between neighbouring columns, and increase the conspicuousness of the relevant cells in the table.

(5) Place reading materials directly in front of light-sensitive pupils, so that they can choose their viewing position with respect to the

material. It may be necessary to avoid shared reading for this reason. Book stands may sometimes be useful to avoid reflected glare.

(6) Written work may sometimes be easier for the child to write and subsequently to read if it is written on alternative lines.

(7) In extreme cases a peaked cap or visor may be helpful in avoiding glare from sunlight etc.

Conclusion

We are far from understanding the mechanisms underlying the use of colour in preventing perceptual distortion. There is increasing evidence that coloured filters (overlays or tinted lenses) can have beneficial effects for a few children. These effects are best judged by the pupils themselves. Pupils should be left free to use or discard any therapy offered, and given support necessary to combat any ridicule from peers.

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