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Use of eye movements measured during reading as an objective assessment of the benefits provided by irlen color filters

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Abstract
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Subjects: Twenty-nine subjects with different reading abilities were recruited. Ages ranged from 8 to 39 years, grades ranged from 3rd to post-graduate. Based on the IOPS, 7 had low SSS levels, 15 had moderate levels, and 3 had high levels.

Methods: A certified Irlen screener selected the best, next to best, next to worst, and worst colors from the Irlen overlay set. Eye movements were analyzed by an Ober2 system as subjects read through these filters. In addition they read through a clear filter and without a filter. Reading levels of the paragraphs were equated across subjects based on data from the Dyslexia Determination Test (DDT) or the Adult Dyslexia Test (ADT).

Results: Grouped data for all subjects showed no significant effects of the overlays. Data for the moderate and high SSS subjects also showed no significant overlay effects. One subject did seem to benefit significantly from the use of an overlay.

Discussion: For the majority of subjects considered in this study, the use of Irlen overlays could not be shown to have significant value. Reasons for the failure to show benefits include the possibility that effects of the filters take several months of use or significant fatigue to become manifest, or that the paragraphs used in the study were too "easy" for the subjects. It is also possible that any benefits were below the detection threshold for the Ober2 system, or that the Irlen filters simply did not have an effect on eye movements for the majority of subjects.

Degree Type
Dissertation

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USE OF EYE MOVEMENTS MEASURED DURING READING AS AN OBJECTIVE ASSESSMENT OF THE BENEFITS PROVIDED BY IRLEN COLOR FILTERS

A Thesis Presented To Pacific University College of Optometry for the Degree Master of Science in Clinical Optometry

by

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May 1995
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KEY WORDS
Irlen, scotopic sensitivity syndrome, reading, dyslexia, colored filters, eye movements, Ober2, vision, reading disability
INTRODUCTION

Often children who have reading problems are seen in optometric practices. Occasionally their problems are caused by eye focusing or teaming difficulties, but some children who seem normal visually, emotionally, and intellectually still have a hard time reading. It has been estimated that up to 15% of the school-age population have reading problems and that 2 to 3% have more serious learning disorders such as dyslexia.¹

The use of the term dyslexia is very controversial. Most authors agree that dyslexia is not a single entity but feel that it exists in several subtypes. The most common of these subtypes is an auditory-language disorder called dysphonesia characterized mainly by visual-spatial disorders. A less common type, dyseidesia, is characterized by visual-perceptual problems.²

Patients with dysphonesia often have speech defects, low verbal versus performance IQs, and delays in language development. Eye movements are usually normal and visual-spatial abilities are also typically normal in persons with this problem.²

Patients with dyseidesia have problems with visual perception, and often demonstrate left-right disorientation, performance IQs lower than verbal IQs, excessive reversals, transposition of letters and syllables, spatial difficulty, and poor eye movements during reading. They also have poor sight recognition of whole words during decoding and slow, labored reading because many of the words must be decoded phonetically.²
Irlen System

Several years ago, Helen Irlen suggested that colored filters could be used to help persons with reading problems. She found that when reading material was covered by colored acetate sheets, some individuals experienced an improvement in their reading ability. The reason for this improvement is uncertain, but Irlen has suggested that colored filters compensate for a condition called Scotopic Sensitive Syndrome that interferes with reading. A person with SSS can experience some or all of the following five symptoms: photophobia, poor print resolution, inadequate background accommodation, restricted span of recognition, and lack of sustained attention.

Research has shown that about 15% of the general population and 50% of people with learning disabilities suffer from SSS. It is often seen in combination with other problems such as poor handwriting, hyperactivity, auditory difficulties, eye muscle imbalances, allergies, and emotional overlays from feelings of educational or personal inadequacy. Children with SSS are frequently labeled stupid and/or lazy, and this can lead to low self-esteem.

The Irlen Differential Perceptual Schedule is administered to assess the level of a subject's SSS. It contains questions about the history of reading problems along with tests of visual resolution, sustained focus, span of focus, peripheral vision, and eye strain. During testing the subject is asked to perform several visual and perceptual tasks such as counting the number of squares in a three dimensional cube figure. At the end of testing, different color
filters are placed over a page of print and the subject chooses the overlay color that makes reading easiest and most comfortable.\textsuperscript{3,4} The subject is then instructed to use the filter whenever she/he reads. If positive results are found, the subject can be referred to the nearest Irlen Center for prescription of spectacle lenses with chromatic tints.

**Success of SSS Therapy**

The exact mechanism by which color filters help subjects with SSS is not fully understood. Robinson and Miles investigated the effect of colored overlays on 40 subjects ages 9 to 74.\textsuperscript{5} All subjects had reading difficulties, and all but two had received an optometric examination within the previous two years. By using the lOPS, subjects were divided into three groups depending on the severity of their SSS. The three groups were tested on letter and number recognition, word matching, and word identification using the "correct," clear, and randomly chosen overlays. Results indicated that the correct overlay improved some test performances significantly (word, letter, and number reading).

Robinson and Conway did a study on 44 subjects ages 9 to 15 who had reading disabilities and high SSS levels.\textsuperscript{6} All subjects wore Irlen lenses for a 12 month period and experienced a significant improvement in reading accuracy and comprehension.

O'Connor et al. also investigated the effects of colored filters on 92 children with learning disabilities.\textsuperscript{7} By using the lOPS, children were classified as being either scotopic (67 children) or non-scotopic (25 children). The scotopic subjects were randomly assigned to one of four treatments groups labeled A, B, C, and D.
Group A subjects were given their best colored filters, subjects in groups B and D were given clear filters, and subjects in group C were given a randomly selected filter with a color other than the one they preferred.

The non-scotopic children were randomly assigned to groups E and F. Group E subjects were given clear filters, and group F subjects received a randomly selected colored filter. After one week of using the filters for all reading tasks, SSS subjects using their correct filters (group A) had significantly greater improvements in reading rate, reading accuracy, and comprehension than did subjects in the other groups.

Blaskey et al. conducted a pilot study comparing the effectiveness of Irlen filters to vision therapy as methods for improving performance on reading tasks. Thirty subjects ages 9 to 51 were randomly divided into three groups: an Irlen filter treatment group, a vision therapy treatment group, and a no treatment control group. In both treatment groups, there was a significant reduction in symptoms associated with reading problems.

In spite of the improvements found in some studies, not all researchers have concluded that colored filters provide an effective therapy for reading problems. For example, Cotton and Evans found that for 60 subjects, 38 of whom were diagnosed as having SSS, there was no significant effect on reading rate, accuracy, or comprehension produced by Irlen lenses.
Eye Movements of Poor Readers

As compared to skilled readers, many people with reading problems have poor eye movements. Typically, poor readers have more fixations per line, longer fixation durations, shorter saccades, and higher frequencies of regression. However, it is unclear whether the poor eye movements cause the reading difficulties or occur as a result of them.

During reading, the eyes move in small jerky steps called saccades, with intervening fixational pauses. Saccades occur about every 250 to 300 msec. with the length of a typical saccade being about seven or eight characters. During a saccade, suppression occurs to prevent what would otherwise be the perception of a blurred image caused by movement of the eyes. It is believed that suppression starts about 50 msec. before and ends 50 msec. after each saccade.\textsuperscript{10}

Perceptual span of recognition is defined as "...the area within which visual information is processed for each fixation."\textsuperscript{10} The area is approximately three or four characters to the left of the fixation point and about 15 characters to the right. Spatial information extending to the right is used to determine where to fixate next. Of this 15 character range, a span of up to 8 characters gives information on word and letter identification.\textsuperscript{10}

It has been suggested that regressions are a normal part of the reading process. Among skilled readers, about 5 to 20\% of all reading eye movements are leftward saccades or regressions. A regression can occur to correct misread words, to look back at interesting details, to help in understanding the meaning of words,
and/or to correct oculomotor inaccuracies. As reading material becomes more difficult, an increasing number regressions will occur.10

Reading rate is defined as how many words per minute (wpm) the subject reads. The rate is affected by eye movements and is related to span of recognition, duration of fixation, and number of regressions. A skilled reader has a rate of between 200 and 400 wpm depending on the difficulty of the material being read.10

Some researchers have suggested that poor eye movements result from the frustration associated with trying to understand text.11 Others believe that subjects with reading disabilities have poor eye movements because of a deficiency in basic spatial processing which leads to a difficulty in word recognition and sequencing of eye movements.10 It is important to remember that there are many different types of reading/learning problems, and that both possibilities could be correct depending on the etiology of the particular patient's difficulty.

Fletcher and Martinez showed that eye movements were affected by the use of colored filters in 22 subjects who had SSS.12 They found that fixation durations, saccade accuracies, and regressions all improved as a result of wearing colored filters. However, these results are difficult to interpret because no improvements were found in the subjects' reading comprehension scores, i.e., their eye movements improved but they did not learn more as they read.
M and P Visual Pathways

There are at least two relatively independent neural pathways that carry visual information: the M-pathway and the P-pathway. M-pathway axons synapse in the magnocellular layers of the lateral geniculate nuclei, whereas P-pathway axons synapse in the parvocellular layers. Cells in the M-pathway respond best to low contrast and high temporal frequency stimuli; cells in the P-pathway respond best to high contrast, high spatial frequency, and low temporal frequency stimuli (e.g., small objects that do not move or move slowly). P-pathway cells also carry information used for color perception.13

The interaction of cells in the M- and P-pathways during reading is not yet completely defined, but it has been suggested that during saccades the M-pathway erases the image of the previous fixation still persistent in the P-pathway. This makes the P-pathway ready to receive new information. If the M-pathway does not function as it should, the images of successive fixations superimpose, and reading problems can result.13-16

The mechanism by which colored filters help poor readers is unknown, but recent studies have shown that short wavelength stimuli make the M-pathway more effective in erasing P-pathway persistence.17

Additionally, several studies have shown that blurring images can slow the response times of cells in the P-pathway. Colored filters might act in a similar manner by changing the response times of M- or P-pathway cells. In this way the filters could "re-
synchronize" the information carried by the two pathways and facilitate its processing at higher brain centers.\textsuperscript{11}

It is possible that the poor eye movements often seen in patients with reading problems are caused by M-pathway defects. For this reason, changes in eye movement patterns might give an indication of the benefit provided by Irlen filters. This possibility has been strengthened by the results of an investigation in which it was found that the use of colored filters produced positive changes in the eye movements of subjects with reading problems.\textsuperscript{12}

\textbf{Purpose of Study}

The purpose of this study was to assess the effects of colored filters on eye movements made during reading. To measure these effects, an objective system was used to monitor eye movements while 29 subjects read paragraphs through Irlen acetate filters.

\textbf{SUBJECTS}

Subjects were recruited from the local community. An attempt was made to find subjects with reading problems, but normal subjects were also recruited. All subjects (or their parents) gave informed consent for participation in the project.

A total of 29 subjects were found; 22 were males and 7 were female. Ages ranged from 8 to 39 (mean = 13.7, sd = 7.0); school grades ranged from 3rd grade to graduate school. Fourteen of the subjects were in lower school grades (3rd through 6th grade), 9 were in middle school (7th through 9th grade), 2 were in high school, 3 were in optometry school, and one (age 39) was not a student.
METHODS

Preliminary Testing

Prior to eye movement evaluations, all subjects were tested using the Dyslexia Determination Test or the Adult Dyslexia Test, depending on age. These tests were used to determine the level and type of any dyslexia present and the subject's reading/decoding level. Subjects were also tested by a certified Irlen screener using the Irlen Differential Perceptual Schedule. The screener determined each subject's SSS level and selected the best, next to best, next to worst, and worst filters for the subject.

Eye Movement Testing

Eye movements made during reading were assessed with an Ober2 Model B120 computer device. The Ober2 uses an infrared recording system mounted in a pair of goggles to monitor the positions of the eyes. Data from the goggles is analyzed by an IBM compatible computer that provides information on the number of fixations and regressions made per 100 words, the average duration of fixations, and the overall reading rate.

Eye movements were analyzed while subjects read paragraphs consisting of 12 double-spaced sentences. (Paragraphs were supplied with the Ober2 system by Taylor Associates.) At the end of each paragraph, 10 comprehension questions were asked to insure that the subject was processing the informational content of the paragraph.

To induce reading stress and to reduce any learning effects associated with the use of the Ober2 system, three paragraphs were read without a filter prior to the start of actual data gathering.
During data gathering, paragraphs were read using 6 different conditions: four Irlen colored overlays, a clear overlay, and no filter. The four overlay colors were the ones that the Irlen screener had determined to be best, next to best, next to worst, and worst for each subject. The examiner was masked with respect to which filter was which, and the order of presentation for the 6 conditions was randomized.

Obviously the level of paragraph difficulty can affect reading rate and other data from the Ober2. In this project, the difficulty level for all paragraphs was set two grades below each subject's reading/decoding grade level as determined by the DDT or ADT. The paragraphs themselves were printed on white paper by a laser writer using 12 point Times Bold font and were viewed from a distance of 40 cm. Subjects who required refractive error correction to achieve a minimum of 6/6 (20/20) near Snellen acuity had trial lenses inserted into the cells of the Ober2 goggles. A chin rest was used to reduce head movements and to increase the reliability of the Ober2 data.

RESULTS

Data from 4 of the 29 subjects could not be analyzed by the Ober2 system, so these subjects were excluded from the study. Data from the remaining 25 subjects are presented below.

Effects of Filters on Eye Movements

For each paragraph, the Ober2 determined the mean number of fixations per 100 words (also sometimes referred to as decoding), the mean span of recognition (defined as the inverse of the mean number of fixations per 100 words), the mean number of regressions
per 100 words, the mean duration of fixations, and the overall reading rate. The level of comprehension was also determined by asking 10 questions about the informational content of the paragraph. If overlays improved the subject's reading ability, rate, span of recognition, and/or comprehension scores would be expected to increase, whereas scores for fixations, regressions, and duration of fixations should decrease.

Table 1 shows mean Ober2 scores for all 25 subjects including the 7 with low SSS levels, the 15 with moderate levels, and the 3 with high levels. Repeated measures analyses of variance (ANOVA) showed no significant benefits or decrements produced by the Irlen overlays (p>0.05).

Because analyzing data from all subjects as a group could obscure any effects that might occur only for those subjects with moderate and high SSS levels, data from these subjects were analyzed separately. Table 2 shows mean Ober2 scores for the 18 subjects with moderate and high SSS levels. Repeated measures ANOVAs for these subjects showed no significant differences between the Ober2 scores for any of the reading conditions; there was no indication that Irlen filters significantly affected the subjects' eye movement abilities.
Post-hoc Search for Subjects Who Were Helped by Overlays

Because the analyses of grouped data did not show significant effects of the overlays, a post-hoc search was made for any individuals who seemed to derive significant benefits from their best filters. One such individual was identified: an 8 year old male, in grade 4, with a moderate SSS level, low levels of dysphonesia and dyseidesia, and a turquoise filter preference. As compared to the no filter condition, use of the turquoise filter resulted in a decrease of 38% in his mean number of fixations per 100 words, an increase of 58% in recognition span, a decrease of 63% in regressions, an increase of 54% in reading rate, and an increase in comprehension of 40%. Actual Ober2 data for this subject are shown on Table 3.

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DISCUSSION

The purpose of this project was to assess the effects of colored filters on eye movements made during reading. When data from all subjects were combined, and when only moderate and high SSS level subjects were considered, the results were the same: Irlen colored filters could not be shown to have a significant effect on reading eye movements. There was no significant improvement in fixations or regressions per 100 words, mean duration of fixations, mean span of recognition, or reading rates produced by the use of any of the filters. In addition, there was no significant effect on comprehension. These results are similar to those found in other studies.1,8,18-20
Why was it not possible to demonstrate significant filter benefits? Perhaps the filters did help, but their effects were obscured by other factors. For example, it is possible that the benefits of the overlays were relatively minor and were not detected because of the variability inherent in using the Ober2 system.

Another possibility might be related to the fact that the lines in the paragraphs used in this study were printed double spaced using a relatively large, bold font. This might have reduced symptoms such as words running together and loosing one's place that subjects with high SSS levels experience. If high SSS subjects found it easy to read the paragraphs, the degree to which the filters could improve their reading levels would be limited.

It is also possible that overlay benefits take some time to become manifest so that they would not be detected during the relatively short testing session used in this study. Some have suggested that the benefits of the filters take several months to develop,\(^6,7,21\) and others have suggested that fatigue is necessary to show benefits. (Fletcher and Martinez had their subjects read for 5 minutes before testing so as to “induce scotopic distortions through strain.”\(^{12}\) If significant fatigue or strain are required to elicit SSS symptoms, it is possible that the benefits of the overlays might not have been detectable when subjects were reading the short paragraphs used in this project.

Still another possibility for the lack of benefits produced by the colored filters is that they might work best only for dyseidetic subjects who have poor eye movements.\(^2\) There was only one
subject in this sample with a severe level of dyseidesia. This possibility is, however, not supported by the results of the study. The subject who experienced significant benefits from overlay use had a low level of dyseidesia, and the subject who had a severe level of dyseidesia did not derive any benefits from his best or next to best filters.

Although the Irlen overlays did not produce significant benefits for the majority of subjects in this study, one subject did seem to be helped by a filter. If the filters have no value, why did this subject's reading performance increase so dramatically? It remains unclear whether or not this subject represents the portion of the population that can be helped by Irlen filters or whether his data were simply a random variation.

Is SSS a real condition that affects reading ability? And, if it is, can colored filters help people who have SSS? The answers to these questions remain "perhaps." Certainly not all of the high or moderate level SSS subjects in this project derived significant help from the filters, but the fact that one subject was helped, poses a challenge for further research.
REFERENCES


TABLE 1. MEAN OBER2 SCORES FOR ALL SUBJECTS
(Numbers in parenthesis show standard deviations)

<table>
<thead>
<tr>
<th></th>
<th>No Filter</th>
<th>Clear</th>
<th>Best</th>
<th>Next to Best</th>
<th>Next to Worst</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixations</strong></td>
<td>166.0</td>
<td>166.7</td>
<td>166.7</td>
<td>165.5</td>
<td>184.7</td>
<td>167.0</td>
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<td>(99.7)</td>
<td>(66.6)</td>
<td>(73.8)</td>
<td>(76.6)</td>
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<td><strong>Recogn.</strong></td>
<td>0.68</td>
<td>0.71</td>
<td>0.64</td>
<td>0.69</td>
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<td>(0.25)</td>
<td>(0.24)</td>
<td>(0.22)</td>
<td>(0.28)</td>
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<td><strong>Regression</strong></td>
<td>48.3</td>
<td>48.0</td>
<td>48.8</td>
<td>47.7</td>
<td>53.6</td>
<td>47.4</td>
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<td>(30.0)</td>
<td>(25.9)</td>
<td>(26.7)</td>
<td>(25.5)</td>
<td>(30.9)</td>
<td>(31.0)</td>
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<tr>
<td><strong>Duration</strong></td>
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<td>0.30</td>
<td>0.30</td>
<td>0.28</td>
<td>0.30</td>
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<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.05)</td>
<td>(0.04)</td>
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<tr>
<td><strong>Read rate</strong></td>
<td>141.0</td>
<td>149.1</td>
<td>132.3</td>
<td>146.9</td>
<td>129.8</td>
<td>147.0</td>
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<td>(59.2)</td>
<td>(76.6)</td>
<td>(58.8)</td>
<td>(59.0)</td>
<td>(56.4)</td>
<td>(67.4)</td>
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<td><strong>Compreh.</strong></td>
<td>81.2%</td>
<td>78.0%</td>
<td>80.8%</td>
<td>77.6%</td>
<td>82.4%</td>
<td>79.20%</td>
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<td>(31.3)</td>
<td>(31.3)</td>
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<td>(0.05)</td>
<td>(0.04)</td>
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<td>Read rate</td>
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<td>146.9</td>
<td>159.1</td>
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<td>158.3</td>
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<td>81.1%</td>
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<td>(14.2)</td>
<td>(14.3)</td>
<td>(16.7)</td>
</tr>
</tbody>
</table>
### TABLE 3. OBER2 SCORES SUBJECT WHO SHOWED SIGNIFICANT BENEFITS FROM OVERLAY USE

<table>
<thead>
<tr>
<th></th>
<th>No Filter</th>
<th>Clear</th>
<th>Best</th>
<th>Next to Best</th>
<th>Next to Worst</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixations</td>
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<td>182</td>
<td>153</td>
<td>185</td>
<td>194</td>
<td>189</td>
</tr>
<tr>
<td>Recogn.</td>
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<td>0.55</td>
<td>0.65</td>
<td>0.54</td>
<td>0.52</td>
<td>0.53</td>
</tr>
<tr>
<td>Regression</td>
<td>84</td>
<td>51</td>
<td>32</td>
<td>52</td>
<td>61</td>
<td>52</td>
</tr>
<tr>
<td>Duration</td>
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<td>0.30</td>
<td>0.30</td>
<td>0.28</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
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<td>94</td>
<td>122</td>
<td>107</td>
<td>101</td>
<td>97</td>
</tr>
<tr>
<td>Compreh.</td>
<td>50%</td>
<td>80%</td>
<td>70%</td>
<td>60%</td>
<td>40%</td>
<td>50%</td>
</tr>
</tbody>
</table>