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COMPARISON OF IRLEN SCOTOPIC SENSITIVITY SYNDROME TEST RESULTS TO SCHOOL AND VISUAL PERFORMANCE DATA

A Thesis Presented to Pacific University College of Optometry For
The Degree Master of Science
In
Clinical Optometry

by
Rosalia Lopez, B. OPT

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December 1992
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Robert L. Yolton, PhD, OD (Chair)

Paul Kohl, OD

Dennis L. Smith, OD, MS
To my parents who make everything possible for me.

Rosalía
Abstract

Recently, Irlen developed the theory that many people with reading problems have a condition called scotopic sensitivity syndrome (SSS) which can be treated with colored overlays or lenses. To investigate this theory, 39 children with known reading and academic abilities were tested for SSS and were prescribed colored overlays. The children were also given complete optometric examinations. Results showed no clear associations between reading ability and SSS classification, nor between the color of overlay prescribed and SSS, academic, or optometric findings. There was, however, a relatively strong tendency for poor readers to have both SSS and optometric problems suggesting the simultaneous existence of both these problems can make reading very difficult.

Key Words
Reading problems, dyslexia, Irlen, school performance, vision, optometry, reading

Acknowledgment

We thank Kathlene Farber for testing our subjects with the IDPS.
INTRODUCTION

A very common presenting complaint for patients, especially those of grade school age, is poor reading ability. Dyslexia and other significant reading problems affect between 4 and 15% of the population. Even though these problems are relatively common, they can be very difficult to diagnose and manage. In some cases, reading problems involve neurological, sensory, or motor difficulties, whereas in other cases the problems can be psychological, perceptual, intellectual, or educational. It has even been suggested that dyslexia with phonological dysfunction can have a genetic etiology. In addition to patients for whom poor reading skills can be traced to specific causes such as reduced intelligence, educational deprivation, psychological difficulties, or deficient mechanical skills, there exists a group of patients for whom no specific cause of the reading problem can be identified.

Theoretical Approaches to Reading Problems

Many professions offer therapy for patients with reading problems, and the approaches of these professions are often very different. From one perspective, it is believed that there is no clear relation between dyslexia or other significant reading difficulties and vision problems such as refractive errors, accommodative abilities, binocular status, stereopsis, eye dominance, and fixation ability. However, others believe that the visual system is frequently and very significantly involved, and that subtle eye movement problems or refractive errors such as hyperopia and anisometropia can be associated with poor reading performance. Some also believe that a pattern of high exophorias and reduced
fusional vergence ranges at near causes many or most reading problems. This is supported by studies which report that more than 75% of reading disabled children have visual abnormalities.

**Etiology of Reading Problems**

Studies have shown that mid-range spatial frequency contrast sensitivity seems to be reduced in dyslexic readers, and this suggests a malfunction of the "transient" visual system. The transient, or M-cell, system is one of two visual pathways used to carry information into the brain. Some theories suggest that failures or abnormalities within this pathway can cause dyslexia.

Other theories suggest that dyslexics are better able to detect colors with their peripheral retina than normal readers. This supports the hypothesis that dyslexics' retinas have unusually high cone densities in the periphery, which might affect the balance between the M and P system.

Some theories associate dyslexia with poor eye movement skills. However, there is no firm experimental proof for any disturbances in dyslexia, but backward saccades or regressions are frequently found, not only in dyslexics, but in normal readers when comprehension is poor.

**Educational Testing**

Many tests have been developed to measure the ability of students to receive, manipulate, abstract, conceptualize, and express ideas. Other tests can evaluate short-term auditory and visual memory, grammar, syntax, the ability to deal with numbers, spatial orientation, visual auditory discrimination, and the ability to
solve problems. Examples of these tests include the Wechsler Intelligence Scale for Children (WISC), Stanford-Binet Intelligence Scale, Metropolitan Achievement Test, Survey of Basic Skills, and the Acer Primary Reading Survey Test. New ways of testing have been developed to diagnose not only reading difficulties, but also learning disabilities independent from IQ scores. Unfortunately, few of these traditional academic tests are able to reliably diagnose the causes of reading problems and/or dyslexia.

The Irlen Discovery

Researchers in many areas have been trying to find new ways to make reading easier and to diagnose the causes of reading problems. One of these researchers is Helen Irlen, a psychologist who has worked with children and adults with reading and learning disabilities. In the course of her work, Irlen accidentally discovered that a red gel overlay placed on top of a printed page helped an individual student to read. Following this discovery, another student used the colored overlay, and for the first time was able to read without having the words move back and forth. Another group of students with reading problems tried the overlay, but they didn't appreciate any benefit from it. This prompted Irlen to try different colored overlays (she used theater gels as overlays) for a variety of patients with reading problems. This experiment produced an interesting result; of 37 patients with visual perception/reading problems, 31 were helped by the colored overlays. Irlen also discovered there were certain colors that made reading easier for some patients, and others that made reading more difficult. She
also tried the colored overlays with normal readers, and found the overlays had little effect on their reading ability.\textsuperscript{10}

**Scotopic Sensitivity Syndrome**

Based on her findings, Irlen developed the theory that many poor readers have a possibly hereditary condition called Scotopic Sensitivity Syndrome (SSS).\textsuperscript{11} Not only can SSS affect reading, it can also affect mathematical ability, art, composition, visual perceptual tasks, motor skills, energy level, motivation, and work production.\textsuperscript{11} SSS is not in itself a learning difficulty, but it can be found in association with dyslexia, dyscalculia, attention deficit disorder, and many other learning problems. Some feel that it involves a structural brain deficit.

An SSS patient can experience any or all of the following: light sensitivity, inadequate background accommodation, poor print resolution, restricted span of recognition, and/or lack of sustained attention.\textsuperscript{12} Light sensitivity problems are related to glare, brightness, and certain lighting conditions like fluorescent illumination. According to Irlen, inadequate background accommodation occurs when there is insufficient contrast between the black letters and the white background on a printed page.\textsuperscript{13} The white background can be more "powerful" than the black letters, so that the letters are less readable.\textsuperscript{12}

In poor print resolution, the letters seem to move or disappear; some of the letters or words can be stable, but the rest of the words on the page might appear to be changing. Restricted span of recognition involves difficulty in reading groups of letters or words at the same time. It might be accompanied by a lack of sustained
attention, and the need for frequent breaks while reading, writing, or working on a computer. Complaints associated with these problems can include fatigue, headaches, burning or watering eyes, strain, and skipped words. Using a finger or a marker during reading can make the activity easier for SSS patients.

SSS isn't a problem only for patients who have difficulty reading; it can also be present in good readers. Irlen notes that not all people with reading difficulties have SSS. According to her, 12% of the population suffers from signs or symptoms of SSS, and approximately 46% of those with SSS have reading problems or learning difficulties.13

Irlen believes that SSS is a perceptual dysfunction rather than a vision problem, and that it can be helped by modifying the light entering the eye through the use of colored filters.14 She also believes that SSS is not easy to detect by vision specialists such as optometrists or ophthalmologists, and that it is not easy to detect by the use of traditional educational tests.11, 15

Even though some investigators have shown a high rate (90%) of undetected visual problems in patients with SSS,16,17 Irlen still believes that SSS is a separate condition unrelated to vision. In opposition to this, some researchers have suggested that the use of visual therapy (VT) could eliminate most of the problems reported by SSS patients, or that the use of overlays in conjunction with VT could give good results.16

How to Assess SSS

Irlen designed a test to diagnose SSS that is called the Irlen Differential Perceptual Schedule (IDPS). The test has three
sections. The first is concerned with gathering information about problems of strain and fatigue after reading for an extended period. As part of this section, some questions deal with specific visual symptoms. The second section of the IDPS involves performance tasks, such as counting boxes within a cube or on a three dimension figure, counting Xs in a figure, and looking at lines of musical notes. It is scored according to the difficulty the patient has with the tasks. The third section involves the comparison of six different overlays and requires the patient to choose the easiest and most comfortable filter to read through. The total SSS score is determined from the three sections and is used to classify the patient as having low, moderate or high SSS. The IDPS is used for children and adults which can be a problem because it relies only on subjective judgments that can be difficult for a child to make.

This part of the Irlen system is called a "first level" screening. If it is shown that the patient can benefit from a colored overlay, one is dispensed and the patient uses it for a few weeks. If the overlay continues to be helpful, the patient can be referred to the nearest Irlen Institute where over 150 different colors filters are evaluated. Based on this evaluation, a prescribed color is given in CR-39 tinted lenses along with the patient's refractive correction.

Even if the overlay helps with reading, it doesn't mean that an SSS patient might not need other training. For example, patients with significant reading difficulties can also have comprehension problems. For this reason, some have suggested that it is
desirable to support the patient's use of colored filters with phonetic or linguistic training.

**Effectiveness of Color Overlays**

Even though more than 20,000 people wear Irlen lenses or use the overlays,\(^{19,20}\) the validity of colored filters for treatment of reading problems remains controversial. Studies have shown that short wavelength (e.g. blue) light increases the rate of visual processing of the transient system (M-pathway) in normal subjects, and one study has shown that a blue overlay has a beneficial effect on reading comprehension for specific reading disabled children, whereas a red overlay makes reading harder for them.\(^{21}\) It has also been shown that using a gray background color affects the ease with which some patients can read. This suggests that decreasing the contrast of printed material increases the ability of the transient system to respond which results in easier reading.\(^{21}\) One study found that 80% of SSS subjects reported improvements in stereopsis. This might be due to increased stability and clarity of the image on the retina produced by the use of an overlay.\(^{22}\)

O'Connor, et al., found improved reading for those subjects who were given a correct overlay, but those who were given clear overlays regressed in their reading ability, accuracy, and comprehension. Another group was given the wrong overlay or one that wasn't the preferred overlay; some of the non-preferred overlays made an improvement, but many of them did not.\(^{23,24}\)

The improvement produced by prescribing the proper overlays was also found in a study by Whiting, et al. They reported that after 12 months of using Irlen filters, 90% of the total population tested
reported at least some improvement in reading. The most often
noted improvements were in the areas of reading difficulty, fluency,
concentration, comprehension, and fatigue.\textsuperscript{25,26}

A curious report in this area is that a small group of children
who had left eye dominance were helped more by the colored filters
than those with right eye or crossed dominance.\textsuperscript{27}

Other studies also describe the value of Irlen filters. One
study found that the restriction in span of vision, poor clarity,
difficulty in reading, and visual distortions can be reduced by the
use of these filters. However, even with these improvements, Irlen
patients don't quite reach the reading level of normal readers with
the same chronological age.\textsuperscript{28}

Controversy

It has been suggested that the placebo effect of colored filters
on an Irlen patient's attitude toward school and homework can not be
separated from any true effects of the filters on reading
performance. It is also possible that patients receiving colored
filters commit themselves to more effort, and as a result have
better reading speed and comprehension.\textsuperscript{22,29} Children receiving
Irlen filters did show a more positive attitude in school during a 12
month study, along with decreased anxiety and increased reading
motivation. The gain was greatest during the first three months of
filter use.\textsuperscript{14,24}

Irlen filters might increase reading speed and comfort, but
changes in comprehension are less certain.\textsuperscript{14} Significant
improvement can be obtained in visual processing of easy verbal
material, but failures remain in word identification.\textsuperscript{13} However,
even the processing improvements are not long-lasting in many patients, and this casts some doubt on the value of colored overlays.29

A problem with testing for SSS and recording the amount of improvement produced by an overlay is that all answers from the patient are subjective. Therefore, SSS scores and improvements are hard to quantify, and it is difficult to replicate studies showing the benefits of the filters. Another problem in the SSS literature is that several studies report that Irlen filter subjects can read for longer periods of time, but the length of the period of time is not well specified.30

It has been found that specific visual problems were detected in 90% of SSS patients. The most common problem was binocular dysfunction, followed by accommodative anomalies. Some SSS subjects who also had visual problems reported only temporary relief from the color filters, whereas those who received visual training obtained more long-lasting relief.15

Other important issues associated with the use of Irlen filters involve the reasons why the optometric community can not have access to SSS testing and overlays, and why the filters are only distributed by Irlen-controlled labs. To answer these questions, Irlen suggests that there is a danger of misuse and abuse of her technology. However, it is also possible that optometrists might discover that SSS is really only a form of visual system malfunction previously not detected because some vision care specialists don't perform accommodative, binocular, or eye movements tests during a regular examination.20 This idea is supported by the findings from a
study done in California in which 42% of the problem readers had visual problems that weren't detected by previous vision exams.\textsuperscript{31}

There is not yet overwhelming evidence demonstrating the efficacy of Irlen filters. Those research projects that do support Irlen typically suffer from inadequate control data and/or objective evidence. It is also not clear if there is something special about the Irlen filters, or if, as Gregg reported in 1988, broad-band theatrical gelatin filters are equally effective.\textsuperscript{32}

The most important point in the literature seems to be that Irlen filters can help some patients to read better, but it is unclear how they do this. The best current evidence suggests that there is a transient system deficit in some reading disabled patients, and this affects their reading by causing distortion, movement of letters, etc. This is what Irlen calls SSS, and it is what she treats with her colored filters.\textsuperscript{33}

**Project Goals**

Even though many papers have been written about Irlen filters and their ability to help reading disabled patients, the use of these filters remains controversial. To further investigate this topic, three project goals were established. The first goal was to determine if there was a significant agreement between SSS scores and diagnoses of reading or general academic problems based on school tests. The second goal was to determine if there was a preference for certain colored overlays based on school or SSS test results, and the third goal was to determine if there was a relationship between SSS levels, optometric test data, and overlay color preference. To answer these questions, 39 children were
studied. Each child received a complete optometric examination which included determinations of monocular and binocular acuity, refractive status, accommodative ability, ocular posture, etc. Contrast sensitivity and saccadic ability were also tested, and information on reading and general academic ability were obtained from school records. Each child was also given the Irlen Differential Perceptual Schedule by a person trained at the Irlen Institute in California.

SUBJECTS AND METHODS

Subjects

Thirty-nine subjects participated in this project. All were students at local schools, and had participated in other studies of reading ability. Subjects were initially recruited through contacts with special education teachers, by news releases in local papers, and by word of mouth. Prior to participation in the project, informed consent was obtained from each subject’s parents. To compensate subjects for their participation in this project, they were given a certificate redeemable for a complete vision examination.

Data obtained from subjects prior to this project included age, school grade, optometric examination findings, contrast sensitivity curves, and performance on a task which simulated the saccadic eye movements required in reading (Rolodex test).

Mean age of the subjects was 11.2 years (sd = 1.5). Of the 39 subjects, 22 were female (mean age = 11.5; sd = 1.4), and 17 were male (mean age = 10.7; sd = 1.5). Five subjects were about to start
the 4th grade, 11 the 5th grade, 8 the 6th grade, 7 the 7th grade, 4 the 8th grade, and 4 the 9th grade.

Within one year prior to participation in this project, all subjects had taken a standardized school achievement test; most of them had taken the Metropolitan Achievement Test, but a few had taken the Survey of Basic Skills or the Woodcock Johnson. On the basis of their test performances, 24 subjects were classified as normal (no score below the 40th percentile), 9 were classified as having an isolated reading problem (a score below the 40th percentile on reading and/or language, and scores above of the 40th percentile on math and general ability), and 6 were classified as having general problems (a score below 40th percentile on reading and/or language, and a score below the 40th percentile on math and/or general ability). Ages, gender distributions, school grades, and test scores of the subjects in the three groups are shown in Table 1. These data show that although the mean ages of the three groups were similar, their ability levels were quite different.

Methods

Testing was conducted by a special education teacher who was trained and certified by the Irlen Institute in California to conduct first level Scotopic Sensitivity Syndrome screenings. After introducing herself to the subject, the examiner determined eye preference using an aperture sighting task, as well as writing hand and kicking foot preferences.
The examiner then administered the Irlen Differential Perceptual Schedule by using materials supplied by the Irlen Institute according to instructions from the Institute. Normally, SSS testing starts with a review of the subject's reading problems, however in this project the review was delayed until after other testing to keep the examiner masked as to the reading ability of the subject.

SSS testing was started by determining the subject's preferred reading distance, and all further testing was done at this distance. The subject then sequentially viewed figures of two cubes, a pumpkin, and a penguin. The first cube was approximately 3 cm by 4 cm and had evenly spaced straight lines forming squares on each face. The subject's task was to count the squares along the second row from the upper left corner along the top and front faces of the cube. The next cube was similar to the first, but the lines on the faces of the cube were not evenly spaced; they formed rectangles rather than squares. Again, the subject's task was to count the rectangles on the second row from the upper left corner along the top and front faces of the cube.

The pumpkin shown to the subject depended on age; for subjects younger than 9, the pumpkin was about 15 cm in diameter and was formed from a set of "X"s each about 3 mm high. The eyes were formed by triangles; between the eyes were two small squares, and between the squares were twelve 3 mm "X"s. The task of the subject was to count the 12 "X"s. For subjects over 9 years of age, the pumpkin was formed by "%"s instead of "X"s.
The penguin figure was about 20 cm high by 11 cm wide and was formed from a set of "X"s. The subject’s task was to count the number of "X"s (there were 26) in a double row along the left edge of the figure.

For each figure, the subject was asked 16 questions about perceived blur, jiggle, float, brightness, movement, confusion, etc. while they were doing the counting task. The number of positive responses was totaled for each figure and recorded on the IDPS form. The examiner added extra points if the subject squinted, blinked excessively, didn’t pay attention, moved the page closer or farther away, or did other things that indicated significant difficulty with the task.

The subject was then shown three short musical score segments arranged horizontally on a page. The specific segments were selected on the basis of the subject’s age and differed in terms of the number of lines and the width between the lines. While fixating a 4 mm dot in the center of the central score segment, the subject was asked to respond to 11 questions about the straightness, flicker, float, changes in the white spaces between the lines, etc. in the central score segment. She or he was then asked to answer 12 questions about the appearance of the musical score segments to the left and right of the central score. The number of responses indicating perceptual distortions was recorded on the IDPS form.

In the next part of the IDPS, subjects were asked to fixate a central star from which radiated eight lines of symbols (Greek letters, circles, and squares). While maintaining fixation on the
star, the subject reported how many of the circles located on the lines radiating out from the star were clear and sharp. (The circles were the third symbol from the star on each radiating line and were about 20 mm from the center of the star.) The test was then repeated by having the subject report how many squares could be seen as clear and sharp. (The squares were the 6th symbol from the star on each line and were about 40 mm from the center of the star.) The numerical score for this part of the test was calculated by multiplying the number of missed circles by 2 and adding the number of missed squares.

The next phase of the test involved determining the color of an overlay that produced the most improvement in the subject's reading ability. Available overlay colors were blue-gray, turquoise, green, yellow, goldenrod, peach, and rose; each overlay had a glossy and a mat finish side. (During this phase of testing only the mat sides were presented to the subject.)

To determine overlay color preference, different overlays were placed on the left and right halves of a full page of closely spaced, low contrast, Dutch words. Starting with the yellow and turquoise, the subject then chose between the two overlays on the basis of which made the words more sharp, clear, and comfortable to read. The preferred overlay was then changed to the other side of the page and the comparison process repeated with a new overlay until the subject determined which single overlay made the words maximally clear, sharp, and comfortable. Then the glossy and mat finish sides of the preferred overlay were shown to determine the subject's preference.
The choice of overlay was next refined by asking the subject to fixate on a word in the middle of the page and to indicate whether the fixation word, along with the surrounding words, looked clear and sharp through the preferred overlay. Overlays of either the same or different colors were then added on top of the first overlay. For most subjects, only a single overlay was needed to achieve maximum clarity and sharpness, but some subjects required two.

At this point, the screener changed to another page written in Dutch, but printed with higher contrast than the previously used page. A word in the middle of the page that did not start with a capitol letter and was not close to a word containing a capitol letter was chosen for the subject to fixate. After a brief fixation (about 5 sec), the subject was asked to look away from the page for about 5 sec, and then was asked to look back to the page and locate the fixation word. The time to locate the word (with a maximum search time of 10 sec) was recorded with and without the preferred overlay. The word search was repeated 6 times with different target words, and the difference in total search times with and without the overlay was recorded.

The examiner then returned to the low contrast page of Dutch words, selected a line and asked the subject to call out the individual letters with and without the preferred overlay. To accomplish this, the first third of the line was covered with the overlay while the subject read it, the overlay was removed while the subject read the middle third, and the overlay was replaced while the final portion of the line was read. The subject was then asked if the overlay made the letters more comfortable to read.
In the final phase of SSS testing, the subject was asked to read aloud from a page of text selected according to their grade level (with an upper limit of grade 8). The first paragraph was read with the preferred overlay, the second without the overlay, and the third again with the overlay. The subject was then asked to describe as none, slight, moderate, or considerable the amount of improvement that was produced by the overlay in 10 specific areas such as letter brightness, comfort, blur, strain, and fatigue.

Based on the results from the IDPS, the examiner classified each of the subjects as having a low, moderate, or high degree of SSS. These determinations were made according to criteria from the Irlen Institute and involved summarizing the results from individual tests. The examiner also provided a subjective rating (none, low, moderate, high) with respect to the benefit provided to each subject by the preferred overlay.

Normally, the examiner would have started the IDPS by reviewing the subject's history, but in this study the history was taken last so as to avoid biasing the examiner. In the IDPS history, the first 16 questions cover general reading problems such as skipping lines, losing one's place when reading, missing words, etc. Another set of 16 questions cover the symptoms that the subject experiences after reading to the point of wanting to stop. They deal with strain and fatigue, headaches, red or tired eyes, burning or itching of the eyes, etc. The responses to the questions in the two history sections were coded as: "often," "sometimes," "never," or "unable to answer." To calculate a score for the subject on each history section, the "often" responses were counted as one point.
each, and the "sometimes" responses were worth 0.5 point. At the completion of all testing, the examiner used the sum of the history points along with the results from the remainder of the IDPS and again classified each of the subjects as having a low, moderate, or a high degree of SSS.

RESULTS

IDPS Results

As noted above, prior to obtaining history information from the subjects, the examiner followed Irlen procedures to rate each as having a low, moderate, or high degree of SSS. These ratings were based on the composite pattern of performance the subject showed on the figures, musical lines, span of recognition, and word search tests. After this rating was made, the examiner asked the history questions, and again rated the subjects. These ratings turned out to be identical for each subject; the history information did not affect the subject's SSS classification.

Table 2 shows the IDPS performances for the low, moderate, and high SSS groups. Within the cells of this Table, means for the subjects divided on the basis of their school achievement tests into normal (NOR), reading problem only (REA), and general problem (GP) groups are also shown. There is some association of the IDPS history scores to the school test classifications, but the other IDPS results show no clear pattern of association with these classifications.

Insert Table 2 About Here
Relationship of IDPS Results to School Test Performance

Table 3 shows the relationship of standardized school test scores to IDPS level. It is interesting to note that although the number of males and females was about even for the low SSS subjects, all of the high SSS subjects were females. This is somewhat contrary to the concept that more males than females have reading problems (or that there is no gender difference for reading problems). It is also interesting to note that there was no clear relationship between SSS level and standardized test performance; although language scores were somewhat different, reading scores for low and high SSS subjects were almost identical.

Insert Table 3 Around Here

Overlay Benefits

To determine the degree of benefit provided by the color overlays, data from the word search portion of the IDPS can be used. As Table 2 shows, low SSS subjects actually spent somewhat more time finding the word with the overlay than without (23% more time), the moderate SSS subjects were faster by about 2% with the overlay, and the high SSS subjects were 30% faster. Care must be taken in interpreting these data, however, because the SSS classifications made by the examiner were based, in part, on the degree of word search improvement produced by the overlay.
**Relationship of SSS and Academic Classifications to Optometric Test Results**

Either before or after Irlen screening, 36 of the 39 subjects received a complete optometric evaluation by an examiner who was blind to the subject's academic and SSS status. (Three subjects could not be scheduled for examinations). On the basis of these examinations, subjects were classified into one of several groups.

To be classified as normal, a subject had to have 20/20 acuity along with an age-appropriate range of accommodation, near point of convergence, phorias, ductions, and refractive status. Subjects classified as having accommodative problems had an accommodative facility of less than minus 2.00 or plano at distance, and plus or minus 2.00 at near. Binocularity problem subjects were those defined as having a near point of convergence less than 8.0 cm; distance phorias of more than 2.0 prism diopters of exophoria, or any amount of esophoria; near phorias of more than 6 prism diopters of exophoria, or any amount of esophoria; base in distance ductions of less than 6 diopters to break and plano to recover; base out distance ductions of less than 12/plano; near base in ductions of less than 12/plano; or near base out ductions of more than 14/plano. Refractive problem subjects were classified as those who had at least one eye more than 1.00 D hyperopic, any habitual correction for myopia, or more than 0.50 D of astigmatism. Based on this classification system, 18 subjects were normal, 1 had an accommodative problem, 6 had binocular problems, 5 had refractive problems, and 6 had both accommodative and binocular problems.
Table 4 shows the distribution of the subjects on the basis of SSS, academic, and optometric test results. Based on these data, there is some suggestion that accommodative and/or binocular optometric problems might be associated with SSS test results, however, as with other comparisons, care should be taken because of the relatively small number of subjects in each group.

Insert Table 4 About Here

Relationship of IDPS Results to Eye, Hand, and Foot Dominance

To evaluate the possibility that children with crossed dominance were more likely to have reading or learning problems, the percentages of subjects in the low, moderate, and high SSS groups with homonymous and crossed dominances were calculated. In the low SSS group, 11 of the 17 subjects (65%) had crossed dominance of either eyes, hands, or feet (10 of the 17 had crossed hand-eye dominance). In the moderate SSS group, 9 of 15 subjects (60%) had crossed dominance, all of whom had crossed hand-eye dominance. In the high SSS group, 3 of 7 subjects (43%) had crossed dominance, all of whom had crossed hand-eye dominance.

Dividing the subjects on the basis of school performance shows a similar pattern of dominances. In the normal academic group, 16 of the 24 subjects (67%) had crossed dominance; in the group with reading problems only, 3 of the 9 subjects (33%) had crossed dominance; and in the general problem group, 4 of 6 subjects (67%) had crossed dominance. The number of subjects in the groups is too small to allow meaningful statistical analysis, but they
certainly do not suggest that there is a greater probability of crossed dominance in children with high SSS or academic reading problems as compared to normal children.

**Overlay Color Preferences**

To measure the transmission spectra of the Irlen overlays, a small piece of each overlay (and the overlay combinations that were chosen by some subjects) was placed in a Varian DMS 200 UV-Visible Light Spectrophotometer. Spectra from 400 from 800 nm are shown as Figures 1 to 15.

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Insert Figures 1 to 15 About Here

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To determine if there was a preference for a particular color of overlay based on school test or IDPS classification, frequency histograms were constructed (Figures 16 and 17). In Figure 16, the percentages of preferred overlay colors for subjects divided on the basis of school test scores are shown. Percentages are used because there are different numbers of subjects in the three groups. While there is some hint that subjects with general problems tend to select the goldenrod filter, that normal subjects tend to select blue-gray or goldenrod, and that reading problem subjects tend to select either a turquoise or rose filter, there is no obvious and outstanding overall pattern in the data.

Figure 17 shows the filter preferences of the subjects divided on the basis of SSS rating. Low SSS subjects seem to prefer blue-gray or goldenrod, while moderate SSS subjects prefer goldenrod or rose, and high SSS subjects tend to select blue-gray or turquoise.
Again, however there is no obvious and outstanding pattern in the data, except for the tendency of normal and low SSS subjects to prefer blue-gray or goldenrod filters.

Insert Figures 16 and 17 About Here

To continue the search for a pattern in color preferences, data from subjects who reported a high degree of benefit from their overlays were considered. Again, no obvious pattern in color preference was detected (2 subjects selected blue-gray, 3 selected turquoise, 1 green, zero yellow, 2 goldenrod, 1 peach, and 2 selected rose). However, it is interesting to note that 5 of the 11 subjects (45%) received maximum benefit from double overlays.

Relationship of Overlay Color Preference to Optometric Diagnosis

To determine if there was a relationship between overlay color preference and the results of optometric testing, another frequency histogram was constructed. (Figure 18) Although there was a tendency for subjects with binocular and refractive problems to select either blue-gray or turquoise filters (67% and 60%, respectively), and for normal subjects to chose goldenrod or blue-gray (59%), the small number of subjects in the different groups makes it difficult to establish any definite patterns.

Insert Figure 18 About Here
Relationship Between SSS, Academic, and Optometric Test Classifications and Performance on a Reading Simulation Task

Prior to SSS testing, subjects' reading abilities were evaluated by using a simulation test. This test, designated the Rolodex, was patterned after a procedure devised by Sperling. In the Rolodex test, the subject fixates a spot in the center of a video display screen on which a series of letters is sequentially presented. When the subject detects a target letter in the sequence, she or he shifts fixation to a location on the right or left, where another series of letters is being presented sequentially. The task of the subject is to report the first letter that can be seen. This provides an indication of the time required to interpret the meaning of the target letter, plan and execute a saccade to the location of the second set of letters, erase the persistence of the target letter, and finally detect a letter in the new set. Table 5 shows the Rolodex times for the subjects divided on the bases of SSS, academic, and optometric testing.

Insert Table 5 About Here

Rolodex position 1 corresponds to a shift of 2.0 degrees to the right, position 2 corresponds to a 7.0 degree right shift, and positions 3 and 4 correspond to 2.0 and 7.0 degree shifts to the left, respectively. Although there is a tendency for subjects with general academic problems to take longer to move to either the left or the right, and for those with reading problems to have more trouble with
saccades to the left, the variability of the Rolodex data makes it difficult to draw more specific conclusions from these data.

**Relationship Between SSS, Academic, and Optometric Test Classifications and Contrast Sensitivity Test Results**

Contrast sensitivity was measured with a Vistech 6000 near-point test unit under binocular viewing conditions. Contrast sensitivity curves for the subjects divided on the bases of academic, SSS, and optometric tests are shown as Figures 19, 20, and 21. The high SSS subjects show no evidence of contrast sensitivity loss for either high or low spatial frequencies; in fact the high SSS subjects showed increased contrast sensitivity for these spatial frequencies. For the subjects grouped on the basis of academic ability, those with general problems showed some contrast sensitivity loss across most of the spatial frequency spectrum. When subjects were divided on the basis of optometric data, no differences were seen between contrast sensitivity curves for those who were normal and those who had visual problems. Again, however the small numbers of subjects and the significant variability in the data make general conclusions difficult to reach.

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**DISCUSSION**

The goals of this project included an evaluation of the relationship between academic abilities and SSS levels; an assessment of the overlay colors preferred by subjects with different SSS and academic classifications; and a determination of
the relationship between SSS level, overlay preference, and optometric/vision classification.

Relationship Between Academic Performance and SSS Level

Results of this project did not demonstrate a strong association between SSS and academic classifications. This is not too surprising because Irlen herself has suggested that some subjects with high SSS scores can overcome this problem and read well, while other subjects who cannot read well might have problems other than SSS. Based on these data, it is interesting to ask why some with high SSS levels can read well and others cannot. Perhaps it is the case that high SSS alone is not enough to cause a reading problem, but SSS only affects reading when combined with a visual problem. This would explain why some studies have demonstrated that there are many high SSS patients who have visual difficulties.

Relationship Between Overlay Color and SSS or Academic Classification

Based on the data presented in Figures 16, 17, and 18, there was a slight tendency for normal and general academic problem patients to select either a goldenrod or blue-gray filter, and for high SSS, optometric problem, and poor reading subjects to select turquoise. These relationships are very weak, however, and no definite conclusions can be drawn about overlay color and reading ability.

There was a significant relationship between the degree of benefit an overlay provided and the subject's SSS level with high SSS subjects receiving the most benefit (Table 2). This strength of
this relationship might be taken to support the existence of SSS as a real clinical entity, but the relationship might also be an artifact because each subject's SSS classification depends partially on the degree of benefit that the overlay provides.

**Relationship Between Optometric Data, Overlay Color Preference, SSS, and Academic Ability**

Although there was not a clear relationship between overlay color preference and optometric classification (normal, accommodative, binocular, or refractive problem), Table 4 demonstrates that there was an apparent correlation between SSS level and visual problems. The number of subjects in the high SSS category is too small to allow definite conclusions to be made, but the relationship is strongly suggestive. In support of the possibility that poor reading might require both high SSS and an accompanying vision problem, only those subjects who had both conditions were considered. On the basis of academic testing, every one of these subjects was a poor reader. This strongly suggests that SSS and vision problems need to be present together to cause a reading problem in many patients, and it explains why some patients with high SSS seem to read well in spite of their SSS. It might also explain why therapy designed to treat either the SSS or the vision problems can increase reading ability.

**Vision Therapy, Colored Overlays, and the Etiology of Reading Problems**

It is reasonably clear why vision therapy would help patients with visually related reading problems, but why should the use of a colored overlay help patients with SSS? This question is hard to
answer because it is not yet really clear what SSS is. Irlen has defined its signs and symptoms and has developed a test to diagnose it. She has also provided a method to treat it, but its etiology remains a mystery. Several current theories have linked dyslexia with problems in the M-pathway of the visual system.\textsuperscript{1,2,3,4,5,6} This pathway is responsible for carrying information about low spatial frequencies and rapid movement; it is also thought to be involved in the control of eye movements. (The other pathway, called the P-pathway, is responsible for carrying information about color, fine detail, and slow stimulus movement.) If the M-pathway is defective in patients with reading problems, and if it is not sensitive to the color of a stimulus, how can the use of a colored filter help poor readers? Some have suggested that the most important effect of the filter is not to alter the color of the letters or the page, but to change their contrast. It is possible that the effect of the contrast change (or perhaps of the color change) is to somehow re-balance the relationship between the M- and P-pathways in the visual system so as to re-synchronize the arrival time of information at a central location in the brain, or perhaps the overlay affects the M-pathway to make eye movements or erasure of the previous fixation more efficient. Further experimentation will be needed to evaluate these possibilities.

From this study it is clear, however, that there is not a strong relationship between overlay color and any of the SSS, academic, or optometric classifications considered. The strength of the relationship between overlay benefit and degree of SSS is interesting (but may be artifactual), and the possibility that high
SSS and visual problems can combine to make reading difficult is certainly worthy of follow-up.
Table 1- Academic Classification.

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>NUMBER</th>
<th>AGE av(sdv)</th>
<th>M/F</th>
<th>GRADE</th>
<th>GRADE</th>
<th>GRADE</th>
<th>GRADE</th>
<th>GRADE</th>
<th>READING SCORE av(sdv)</th>
<th>LANG SCORE av(sdv)</th>
<th>MATH SCORE av(sdv)</th>
<th>GENERAL SCORE av(sdv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORMAL</td>
<td>24</td>
<td>11(1.6)</td>
<td>10/14</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>76(14)</td>
<td>76(16)</td>
<td>72(25)</td>
</tr>
<tr>
<td>READING ONLY</td>
<td>9</td>
<td>11(1.6)</td>
<td>4/5</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>40(23)</td>
<td>34(15)</td>
<td>57(22)</td>
</tr>
<tr>
<td>GENERAL DYSFUNCTION</td>
<td>6</td>
<td>11(0.8)</td>
<td>3/3</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>24(24)</td>
<td>20(12)</td>
<td>28(14)</td>
</tr>
</tbody>
</table>
Table 2- IDPS Scores and Academic Classification Versus SSS Level.

<table>
<thead>
<tr>
<th>SSS LEVEL</th>
<th>IDPS HISTORY SCORES (first part/ second part)</th>
<th>IDPS FIGURE TASK (With the overlay)</th>
<th>IDPS WORDS SEARCH TIME DIFFERENCE</th>
<th>DEGREE OF IMPROVEMENT WITH OVERLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low SSS</td>
<td>Avrg=3.5\2.04 / Avrg=6</td>
<td>Avrg=6</td>
<td>Avrg=-1.4</td>
<td>None=7</td>
</tr>
<tr>
<td></td>
<td>Nor=3.37\2.12 / Nor=5.71</td>
<td>Nor=5.71</td>
<td>Nor=-1.99</td>
<td>Low=6</td>
</tr>
<tr>
<td></td>
<td>Rea=3.6\2.04 / Rea=4.8</td>
<td>Rea=4.8</td>
<td>Rea=0.56</td>
<td>Moderate=3</td>
</tr>
<tr>
<td></td>
<td>GD=4.25\1.5 / GD=6.6</td>
<td>GD=6.6</td>
<td>GD=-0.45</td>
<td>High=1</td>
</tr>
<tr>
<td>Mod SSS</td>
<td>Avrg=5.2\4.73 / Avrg=8</td>
<td>Avrg=8</td>
<td>Avrg=0.22</td>
<td>None=1</td>
</tr>
<tr>
<td></td>
<td>Nor=5.06\4.55 / Nor=5.46</td>
<td>Nor=5.46</td>
<td>Nor=-0.21</td>
<td>Low=4</td>
</tr>
<tr>
<td></td>
<td>Rea=7.5\6.11 / Rea=8</td>
<td>Rea=8</td>
<td>Rea=2</td>
<td>Moderate=5</td>
</tr>
<tr>
<td></td>
<td>GD=4.25\4.64 / GD=5.62</td>
<td>GD=5.62</td>
<td>GD=0.45</td>
<td>High=5</td>
</tr>
<tr>
<td>High SSS</td>
<td>Avrg=8.1\8.82 / Avrg=5</td>
<td>Avrg=5</td>
<td>Avrg=1.51</td>
<td>None=1</td>
</tr>
<tr>
<td></td>
<td>Nor=6.62\8.60 / Nor=4.55</td>
<td>Nor=4.55</td>
<td>Nor=2.05</td>
<td>Low=0</td>
</tr>
<tr>
<td></td>
<td>Rea=10\9.09 / Rea=5.8</td>
<td>Rea=5.8</td>
<td>Rea=0.8</td>
<td>Moderate=1</td>
</tr>
<tr>
<td></td>
<td>Gd=none</td>
<td>Gd=none</td>
<td>GD=none</td>
<td>High=5</td>
</tr>
<tr>
<td>CLASSIFICATION</td>
<td>NUMBER</td>
<td>AGE</td>
<td>M/F</td>
<td>GRADE 4</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>LOW SSS</td>
<td>17</td>
<td>11(1.6)</td>
<td>9/8</td>
<td>2</td>
</tr>
<tr>
<td>MODERATE SSS</td>
<td>15</td>
<td>11(1.4)</td>
<td>8/7</td>
<td>2</td>
</tr>
<tr>
<td>HIGH SSS</td>
<td>7</td>
<td>11(1.3)</td>
<td>0/7</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4- Visual Status Versus SSS Level and Academic Classification

<table>
<thead>
<tr>
<th>LEVEL OF SSS OR READING</th>
<th>NUMBER OF SUBJECTS ON EACH GROUP</th>
<th>WITH VISUAL PROBLEM (refractive, accommodation and/or binocular)</th>
<th>NO VISUAL PROBLEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low SSS</td>
<td>16</td>
<td>38%</td>
<td>63%</td>
</tr>
<tr>
<td>Moderate SSS</td>
<td>14</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>High SSS</td>
<td>6</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>Normal Readers</td>
<td>22</td>
<td>59%</td>
<td>41%</td>
</tr>
<tr>
<td>Reading Problems</td>
<td>9</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>General Difficulties</td>
<td>5</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Total</td>
<td>36 (100%)</td>
<td>18 (50%)</td>
<td>18 (50%)</td>
</tr>
</tbody>
</table>
Table 5- Rolodex Times Versus SSS Level, Academic Classification, and Visual Status.

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>ROLODEX 1 Avrg(stdv)</th>
<th>ROLODEX 2 Avrg(stdv)</th>
<th>ROLODEX 3 Avrg(stdv)</th>
<th>ROLODEX 4 Avrg(stdv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low SSS</td>
<td>17</td>
<td>539.21 (137.05)</td>
<td>599.99 (153.20)</td>
<td>507.85 (137.21)</td>
</tr>
<tr>
<td>Moderate SSS</td>
<td>15</td>
<td>588.89 (273.03)</td>
<td>577.79 (186.72)</td>
<td>504.45 (133.86)</td>
</tr>
<tr>
<td>High SSS</td>
<td>7</td>
<td>576.19 (118.18)</td>
<td>561.90 (129.71)</td>
<td>585.71 (137.24)</td>
</tr>
<tr>
<td>Normal Reader</td>
<td>24</td>
<td>522.22 (140.62)</td>
<td>591.67 (147.85)</td>
<td>502.78 (131.12)</td>
</tr>
<tr>
<td>Reading Problem</td>
<td>9</td>
<td>574.07 (134.15)</td>
<td>544.45 (146.23)</td>
<td>577.79 (108.02)</td>
</tr>
<tr>
<td>General Problems</td>
<td>6</td>
<td>722.22 (362.49)</td>
<td>616.66 (235.47)</td>
<td>505.55 (186.69)</td>
</tr>
<tr>
<td>Normal vision</td>
<td>18</td>
<td>596.29 (252.28)</td>
<td>579.63 (211.48)</td>
<td>525.93 (164.33)</td>
</tr>
<tr>
<td>Accommodative problem</td>
<td>1</td>
<td>700.0 (0)</td>
<td>666.67 (0)</td>
<td>400.0 (0)</td>
</tr>
<tr>
<td>Binocular problem</td>
<td>6</td>
<td>600.01 (81.64)</td>
<td>522.23 (80.73)</td>
<td>533.33 (113.52)</td>
</tr>
<tr>
<td>Acc and Binoc problem</td>
<td>6</td>
<td>477.78 (45.54)</td>
<td>633.33 (94.29)</td>
<td>472.22 (102.03)</td>
</tr>
<tr>
<td>Refractive Problem</td>
<td>5</td>
<td>533.34 (113.04)</td>
<td>613.31 (138.63)</td>
<td>580.0 (138.65)</td>
</tr>
<tr>
<td>Mean Rolodex</td>
<td>39</td>
<td>564.95 (195.26)</td>
<td>584.61 (160.01)</td>
<td>520.52 (135.87)</td>
</tr>
</tbody>
</table>
Figure 16- Overlay Color Versus Academic Classification

COLOR

PERCENTAGE

<table>
<thead>
<tr>
<th>COLOR</th>
<th>Percentage</th>
<th>READ PROB</th>
<th>GEN PROBLEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue-gray</td>
<td>33.33</td>
<td>4.16</td>
<td>16.66</td>
</tr>
<tr>
<td>Turquoise</td>
<td>33.33</td>
<td>4.16</td>
<td>16.66</td>
</tr>
<tr>
<td>Green</td>
<td>11.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>20.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goldenrod</td>
<td>25</td>
<td>4.16</td>
<td>16.66</td>
</tr>
<tr>
<td>Peach</td>
<td>16.66</td>
<td>4.16</td>
<td>16.66</td>
</tr>
<tr>
<td>Rose</td>
<td>33.33</td>
<td>8.33</td>
<td>16.66</td>
</tr>
</tbody>
</table>
Figure 17- Overlay Color Versus SSS Level

COLOR

PERCENTAGE

Blue-gray
Turquoise
Green
Yellow
Goldenrod
Peach
Rose

% Low SSS
% Mod SSS
% High SSS
Figure 18- Overlay Color Versus Visual Status
Figure 19 - Contrast Sensitivity Curves Versus Academic Classification

- AVG OF NORMAL
- AVG OF READ PR
- AVG OF GD
- AVG OF ALL
Figure 20- Contrast Sensitivity Versus SSS Level

- Low SSS
- Mod SSS
- High SSS
- Avg Threshold
Figure 21- Contrast Sensitivity Curves Versus Visual Status

- Normal
- Binocular
- Binoc and ACC
- Refractive
- AVRG OF ALL
Table Captions

1- Academic Classification.
2- IDPS Scores and Academic Classification Versus SSS Level.
3- SSS Level Versus Academic Classification.
4- Visual Status Versus SSS Level and Academic Classification.
5- Rolodex Times Versus SSS Level, Academic Classification, and Visual Status.
**Figure Captions**

1- Transmission Curve for Blue-gray overlay.
2- Transmission Curve for Turquoise overlay.
3- Transmission Curve for Green overlay.
4- Transmission Curve for Yellow overlay.
5- Transmission Curve for Goldenrod overlay.
6- Transmission Curve for Peach overlay.
7- Transmission Curve for Rose overlay.
8- Transmission Curve for Double Blue-gray overlays.
9- Transmission Curve for Double Turquoise overlays.
10- Transmission Curve for Double Yellow overlays.
11- Transmission Curve for Double Goldenrod overlays.
12- Transmission Curve for Double Peach overlays.
13- Transmission Curve for Double Rose overlays.
14- Transmission Curve for Turquoise and Blue-gray overlays.
15- Transmission Curve for Green and Yellow overlays.
16- Overlay Color Versus Academic Classification.
17- Overlay Color Versus SSS Level.
18- Overlay Color Versus Visual Status.
19- Contrast Sensitivity Curves Versus Academic Classification.
20- Contrast Sensitivity Curves Versus SSS Level.
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