The Effect of Colored Overlays on Reading Eye Movements in Adults

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Abstract

Irlen coined the term Scotopic Sensitivity Syndrome (SSS) to describe a number of conditions that interfere with reading. She suggested that close to 90% of individuals could be successfully treated with tints. However, few, if any studies have shown significant objective improvement in performance or symptoms.

Reading eye movements of 60 adult subjects were measured. Two test groups (symptomatic vs. asymptomatic) were identified via the use of a validated survey. Each subject was tested with each of 10 short reading passages and 10 colored overlays, in two separate visits.

Color filters were not found to have an effect on any of the variables measured. The two groups and two sessions were significantly different for all six dependent reading eye movement variables. Seventy-three percent of symptomatic patients and 27% of asymptomatic patients had an identifiable binocular disorder.

No significant change in the six dependent variables, as measured by the Visagraph, was found with any of the selected colored overlays. Significant findings were found for sessions, passages and groups, but were not related to tinted filters. The data supports the theory that many of those with SSS symptoms actually have an underlying binocular/accommodative vision disorder. Evidence of SSS is not supported by this study.

Key Words

colored filters, eye movements, Irlen, Irlen Syndrome, Meares-Irlen Syndrome, Scotopic Sensitivity Syndrome, Visagraph

Introduction

Irlen described six categories of visual symptoms of the Scotopic Sensitivity Syndrome (SSS) in 1983. These symptoms were acerbated by reading.[1-7] SSS is also referred to as the Meares-Irlen syndrome or Irlen lens syndrome.[1-12] These symptoms are more fully described in Table 1.

Irlen postulated that SSS was associated with an "excessive sensitivity of the retina to particular frequencies of the light spectrum."[6] She suggested that high contrast material such as black writing on white paper caused individuals with this condition to use more energy and effort when reading due to "inefficiency." Irlen claimed these individuals see the printed page differently from non-symptomatic readers. She also purported that luminance, intensity, wavelength and color contrast can all influence visual function.[6]

SSS treatment is based on prescribed tinted lenses. These lenses supposedly reduce specific wavelengths to modify "the random variation in responses to the photoreceptors."[2] Irlen suggested that close to 90% of symptomatic individuals could be successfully treated with tints. Substantial changes in visual resolution, depth perception and peripheral vision are claimed to be achieved with treatment.[13]

Theories to explain the reported reduction in symptoms include: a transient system (magnocellular) neural defect,[14] contrast-sensitivity-related changes, anomalous perceptual effects,[15] accommodative/binocular dysfunction[16] and pattern glare.[4,8,16,17] Both biological and genetic causes have also been investigated.[18-20]

Table 1. Visual Symptoms Associated with Irlen Syndrome

Photophobia	An increased sensitivity to glare, brightness and intensity in certain lighting conditions. Reading difficulty and trouble with night driving are common.
Background Distortion	The ability to accommodate high contrast material (black/white) such as textbooks and magazines.
Visual Resolution	The ability to see print clearly, without distortions. Complaints include moving/shifting words and text that disappears.
Scope of Focus	The ability to perceive groups of letters, notes, numerals or words at the same time.
Sustained Focus	The ability to keep focus on material for an extended time period. Complaints include blurring of vision when reading, blurred vision at distance following sustained reading, blinking and squinting while reading.
Depth Perception/Gross Motor Activities	The ability to judge distance accurately. Complaints include trouble walking up steps, poor sports performance and difficulty judging height and depth.

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Significant variations have been reported in blood lipids, urine amino acids and organic acids between a group purported to suffer from Irlen syndrome and a visually normal control group.[18] A second study found decreased total plasma cholesterol and an increase in the relative abundance of heptadecanoic acid, a fatty acid, in Irlen sufferers.[19] Another study found an 84% chance that either of the parents would exhibit symptoms similar to the child, but found no genetic model to substantiate the findings.[20]

Several studies have documented positive influences of tints on subjective complaints, reading speed and reading comprehension.[17,21-24] Few studies have shown a positive correlation in improvement when using objective measures.[14,25] The present study was designed to investigate the relationship between Irlen filters and objectively determined changes in eye movements of individuals with and without symptoms similar to Irlen syndrome. We also wanted to compare the optometric findings between the two groups.

METHODS

Subjects

This study consisted of 60 adult optometry students (mean age: 26 yrs, range: 20-30 yrs, M/F: 22/38) from a professional optometry program. Participation was on a voluntary basis, and the subjects were compensated for their time. An optometric examination was administered to each subject. (Table 2) Exclusion criteria were strabismus, amblyopia, and systemic/ocular disease.

This study was approved by the Nova Southeastern University Institutional Review Board, and Health Professions Review Board and consent forms were signed by all participants.

DESIGN AND PROCEDURE

Apparatus

Eye movements were measured using the Visagraph II,[a] a computerized instrument that measures several aspects of ocular motilty. Infrared emitters and detectors are mounted in safety-like goggles. The eye position is determined by sensing the differential reflections from the cornea, sclera and other anterior ocular surfaces. This information is then converted into digital values by computer software and is analyzed to determine when certain eye movements occur.[26] Investigations involved with the use and reliability of this technology in recording eye movements have been documented.[26,27] Recorded numeric data includes fixations made per 100 words, regression eye movements, and reading speed. From that data three other variables are determined. (Table 3)

Ten different 8.5 x 11" tinted overlays[b] were used in this investigation: Rose, Orange, Yellow, Green, Turquoise, Aquamarine, Blue, Purple, Lavender and Neutral Gray. A clear overlay was used as a baseline control stimulus.

Subject Groups and Procedures

Determination into one of two testing group (symptomatic vs. asymptomatic) was made via the use of a validated symptoms survey,[28] consisting of 15 questions. (Appendix A) Each question was given a score according to the frequency/severity of the symptoms. Each question score was added to give a total score. As in previous studies, a score of 16 served as a separation point between the two groups. Sixteen and above was considered symptomatic, while 15 and below was considered asymptomatic. This survey was administered by one author (MT) to determine group status prior to testing.

In this manner, two groups of 30 subjects were created. The average survey score was 30.0 for the symptomatic group and 8.1 for the asymptomatic group. The average age and M/F ratios were as follows: symptomatic group 25.2 years old, 10M/20F, asymptomatic group 25.7 years old, 12M/18F.

Subjects were shown the Visagraph II and a "test run" was performed to eliminate a

Table 2. Optometric Procedures Performed

1) Visual acuity at distance and near
2) Cover test at distance and near
3) Positive and negative fusional ranges at distance and near
4) Negative and positive relative accommodation
5) Nearpoint of convergence
6) Monocular Estimate Method Retinoscopy (MEM)
7) Fused cross cylinder
8) Lateral phoria at distance and near
9) Accommodative amplitude
10) Monocular and binocular accommodative facility

Table 3. Names and Definitions of Data Produced by the Visagraph

Name	Measurement or calculation
Fixation	Number of eye pauses per 100 words
Regression	Number of significant right-to-left eye movements (excluding return sweeps) per 100 words
Span of Recognition	Number of words divided by the number of fixations made
Duration of Fixation	Total reading time (in seconds) divided by the number and fixations made
Comprehension Rate	Reading rate (words per minute)
Directional Attack	Number of regressions divided by the number of fixations made

Table 4. ANOVA Analysis of Group Effects

Number of Fixations	Asymptomatic: 87.911 +/- 22.6789 Symptomatic: 103.930 +/- 22.9316	Significant (p<0.0001)
Regressions	Asymptomatic: 7.9108 +/- 6.8480 Symptomatic: 14.2083 +/- 10.3348	Significant (p<0.0001)
Span of Recognition	Asymptomatic: 1.21237 +/- 0.302992 Symptomatic: 1.01105 +/- 0.235059	Significant (p<0.0001)
Duration of Fixation	Asymptomatic: 0.249783 +/- 0.031368 Symptomatic: 0.268883 +/- 0.035961	Significant (p<0.0001)
Comprehension Rate	Asymptomatic: 291.277 +/- 86.6232 Symptomatic: 227.275 +/- 66.7402	Significant (p<0.0001)
Directional Attack	Asymptomatic: 8.5233 +/- 5.85731 Symptomatic: 12.6345 +/- 7.18617	Significant (p<0.0001)

learning curve during actual testing. Each subject was tested with each of 10 passages and ten colored overlays during two separate visits. The passage used for the "test run" was not used a second time as familiarity would alter the results. Testing was performed consecutively with a 1 minute rest between reading passages.

The two visits were separated by a minimum of 30 days to eliminate passage remembrance. Both the passage and the overlay sequence were randomized within and between visits. The randomization of the passage order accounted for possible fatigue as testing progressed within each session. Prior to testing, each subject read material for 15 minutes.

Age-appropriate standardized passages, 100 words in length, were used during testing. These passages were provided by Taylor Associates[a] to be specifically used during testing with the Visagraph. The passage was presented 40 cm from the patient and was placed at eye level. The overlay was placed on top of the passage and was held in place by a clip during testing.

Passage and overlay randomization occurred between each session with each patient. The same passage and overlay were not used in conjunction with each other between patient sessions. Likewise, passage and overlay order were randomized between sessions. Lighting conditions did not vary during testing, which was completed in the same room throughout the study. Ambient lighting consisted of two overhead fluorescent fixtures.

Statistical Methods

The data were initially analyzed with a one-way Analysis of Variance (ANOVA). We examined each dependent variable as a function of each of the independent variables. No interactions between independent variables were considered. ANOVA analysis examined all of the dependent variables together, along with their within-subject and between-subject interactions. The data were then analyzed using a repeated-measures Multivariate Analysis of Variance, (MANOVA) of the means. Multivariate models are an extension of standard ANOVA methods to fit several simultaneous dependent variables. Repeated measures (or within-subjects) techniques are used when all members of a random sample are measured for each of a number of different conditions. The dependent variables in the present study are found in Table 3. The independent variables were the filter color, reading passage, session, group (symptomatic versus asymptomatic), and color by group interaction effects.

RESULTS

ANOVA analysis indicates that color filters for both test days were not found to have a significant effect on any of the variables measured by the Visagraph. The two groups (symptomatic and asymptomatic) were found to be significantly different, for all the Visagraph variables ($p=<.0001$). The symptomatic group always scored poorer than the asymptomatic group with every variable, except for span of recognition. (Table 4)

Significantly fewer regressions and a larger span of recognition were measured during the second session. Reading rate with comprehension was slower and fixations were greater during the second session. The individual passages read were significantly different when compared to their fellow passages for four out of the six variables. (Appendix B)

The repeated measures MANOVA provides similar findings to ANOVA (Table 5). The color considered alone ($p=0.4227$) and filter color by group interaction ($p=9714$) had no significant effect even within subjects. Again, the only variables that had significant effects were group ($p<0.0001$), session ($p<0.0001$) and passage, ($p<0.0001$) plus the interactions between them, session by group interaction ($p<0.0001$) and passage by group interaction. ($p=0.0023$)

When we compared those who exhibited a recognized vision problem (Table 6), we found that 25 of 30 (73.3%) subjects with symptoms showed objective measures of a binocular problem, an accommodative problem, or both. This is compared to only 8 of 30 (26.7%) subjects in the asymptomatic group. Chi-square analysis showed these two groups to be significantly different ($Z= 7.5$; $p=<.001$).

Discussion

In contrast to Solan et al,[29] colored overlays were not found, in the present study, to have a significant effect on eye movements. Solan showed a change in fixations, regressions, reading rate and comprehension using a blue filter. In comparison, the current study evaluated reading eye movements with each of nine filters. A blue filter, as well as others previously described, did not have any effect as measured by the Visagraph.

The official Irlen evaluation is a two-part process that is given by an Irlen trained associate at an Irlen center.[30] The first part evaluates if the patient has the syndrome and if filters, in the form of overlays, will be of benefit. If the patient subjectively reports improvements, the overlay is used for several weeks. Upon returning, a subjective process of choosing the correct tint that will be incorporated in a spectacle prescription is used. The color selected for the overlay and the glasses is often different for patients. This has been explained by color adaptation. When patients look through the colored lenses, they fully adapt to the color, but when they look at the colored sheet on the page, they only partially adapt to the color.[31] The subjects in the present study did not have the opportunity to select a color that they felt caused subjective improvement, prior to testing, and therefore color bias was controlled.

Irlen argued that every SSS individual is helped with a specific colored filter.[6] In the present study, each subject's Visagraph recording with each of the ten filters was examined. None of the colored filters were found to improve more than one of the dependent variables in either the symptomatic or asymptomatic group. For example, when tested with a yellow filter, patient A might have had reduced regressions, but the fixations worsened, and the remaining variables showed no change.

The difference in the eye movements between the symptomatic and asymptomatic groups, as measured by the Visagraph, indicated that patients with an accommodative or binocular vision disorder had less accurate eye movements when reading. For each of the dependent variables, the asymptomatic group scored significantly poorer than the symptomatic group.

One unexpected finding concerns the standardization of the passages. (Appendix B) It appears that some passages are significantly easier or harder than others. For the six dependent variables, significant differences were found in four. Scores on passages 87 (Amundsen), 91 (Dorothea Dix) and 92 (Clarence Darrow) showed the best results (better reading skill), while passages 88 (Houdini), 94 (Frank Lloyd Wright) and 95 (Sir Earnest Shackleton) consistently provided the worst results (poorer reading skills). This could be an important consideration when using the Visagraph as a measure of change following a reading or vision therapy program. The clinician might think improvement or

Table 5. Repeated MANOVA by Tint, Group, Session and Passage

Variable	Result
Filter color	p=0.4227
Group	p<0.0001*
Filter color by group interaction	p=0.9714
Session	p<0.0001*
Passage	p<0.0001*
Session by group interaction	p<0.0001*
Passage by group interaction	p=0.0023*

** statistically significant*

lack of improvement had occurred while an easier or harder passage was used during retesting. One method to account for the discrepancy might be to apply our above findings of relative paragraph difficulty for pre- and post-testing. However, further research is indicated in this regard.

One question that has been investigated by Scheiman et al[2] was whether patients who Irlen identified as candidates for the filters simply have unidentified visual disorders. Few articles in the literature address the need to rule out an underlying visual concern in their research design.[30] Scheiman et al found that 95 % of the subjects who qualified for Irlen lenses also had underlying vision anomalies.[2] The most common findings included binocular vision problems (57%), accommodative anomalies (34%), and ocular motor dysfunction (26%). Each of the study's 39 patients in the study had undergone the Irlen screening battery by a certified Irlen screener, as specified in the SSS protocol. The screening revealed that 37 out of the 39 met the criteria for SSS. Of these 37 patients, 35 were found to have underlying vision problems.

The symptomatic group in the present study had a significantly greater percentage of binocular vision disorders. It was found that 25 out of 30 (73.3%) symptomatic patients and 8 out of 30 (26.7%) asymptomatic patients had an identifiable binocular disorder. These findings support the use of the survey to separate the groups. The breakdown of conditions for both groups can be found in Table 7. Determination of the diagnosis was made based upon the classification of clinical findings from Scheiman and Wick.[32] While these numbers differ from Scheiman et al[2], the number of underlying binocular and/or accommodative issues potentially mistaken for SSS is disturbing.

In view of the Scheiman et al[2] and this present study's findings of a high percentage of binocular disorders with potential Irlen clients, it is telling that in some other studies the possibility of such disorders was not adequately considered. For example, Robinson and Foreman,[14] authors of one of two double-masked randomized placebo controlled trials, claim "an optical or ophthalmologic examination within the year prior to being screened was performed. It was assumed that identified symptoms were unlikely to be confused with problems of a refractive or accommodative nature." Unfortunately, there are many different levels of examinations. Some eye care providers do not routinely perform the tests required to diagnose accommodative and/or binocular disorders. Eye care providers and technicians providing care may not fully evaluate for proper refractive correction and not perform visual skills testing to identify such cases.

In a study by Evans and Joseph, they contradict themselves concerning colored filter therapy.[12] They state that 80% of 113 subjects had received professional eye care "at some time" and that 40% received an eye examination in the previous year. In the following sentence, they state that "uncorrected optometric problems seem unlikely." It is unclear how they can assume that there is no underlying visual disorder if 20% of the subjects that have never had any eye care and over half have not been examined within the last year. In addition, there is no indication as to the type of examination or how long it had been since the last exam for the remaining 40% not seen in the previous year.

Several years later, Evans wrote "it is a cause for concern that all of the systems for treating this syndrome do not stress the need for an exam."[33] Evans presented three cases of suspected SSS. Each case had an underlying refractive, accommodative/binocular dysfunction. It should be considered a fatal flaw if a study concerning a visually based condition does not properly rule out refractive and/or visual efficiency deficiencies.

Most interestingly, Evans et al[16] attempted to show that placebo effects are not the root cause of improvements with colored overlays, but appears to prove that underlying binocular vision problems should be suspected in cases of SSS. The vergence reserves of the experimental group were compared with those of the control group. The divergent and convergent vergence reserves, amplitude of accommodation and stereo acuity were significantly lower for the experimental group. The authors advocated treating binocular and accommodative anomalies prior to tinted lens treatment. They concluded that the visual skills dysfunctions are not an underlying cause of Irlen syndrome, but a correlate. No explanation or evidence of this statement was made or supported in their paper.

Some studies performed with colored overlays have shown a positive effect on reduction of symptoms.[3,4,11,12] However, Solan and Richman[1] pointed out many inconsistencies in procedures and methods among the various studies performed. The homogeneity of the groups studied, the nature of the optometric/ophthalmologic examination performed and the utilization of either colored overlays versus colored lenses are questioned.[1]

Several tinted filter studies claimed to have positive effects on optometric findings and accuracy of eye movements. We found confounding data and the interpretation of data confusing. Of 10 subjects wearing their Irlen correction for at least one year, only two showed a reduction in muscle imbalance at near using the Maddox wing.[17] One subject "improved" from orthophoria to 4.4 exophoria with the Irlen lens. Robinson and Foreman[14] used the Developmental Eye Movement test and Groffman Visual Tracking Test in their study. Their subjects were placed in a control group and three experimental groups that included a group using a placebo tint, a blue tint or an optimal tint. Compared to baseline findings, the experimental groups without any tinted filters exhibited an improvement in correct tracking for the control group. There was improved speed of tracking for the experimental groups on the Groffman Test. With the Developmental Eye Movement test, they found significant changes in the horizontal time and time ratio for the control group, vertical time and time ratio

Table 6. Visual Diagnosis Between Symptomatic and Asymptomatic Groups

Symptomatic Group	Count	Asymptomatic Group	Count
Normal Binocular Vision	5	Normal Binocular Vision	22
Convergence Insufficiency	3	Convergence Insufficiency	3
Accommodative Insufficiency	7	Unspecified Accommodation Dysfunction	2
Accommodative Excess	3	Accommodative Infacility	1
Unspecified Accommodation Dysfunction	3	Combined Accommodative/Binocular Dysfunction	2
Accommodative Infacility	4		
Exotropia	1		
Combined Accommodative/Binocular Dysfunction	4		

changes for both the blue and placebo tint groups, but only vertical time improvements for the optimal tint group. They attributed the failure to find improvements in all eye movement tasks to "established habits of guessing when reading."

CONCLUSION

The rationale for undertaking this quantitative study was to investigate the effect of reading characteristics with colored overlays using objectively measured outcomes. This study found no significant change in the six dependent variables (fixation, regressions, duration of fixation, span of recognition, directional attack and comprehension rate) as measured by the Visagraph with any the selected colored overlays. Significant findings were found between the two sessions the and symptomatic and asymptomatic groups as well as among the individual passages, but were not related to tinted filters. Our data supports the theory that many of those with SSS type symptoms had an underlying binocular /accommodative vision disorder.

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Appendix A[27]
The Convergence Insufficiency Symptoms Survey

		Never	Infrequently	Sometimes	Fairly Often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you ever feel a “pulling” feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place when reading or doing close work?					
15.	Do you have to re-read the same line of words when reading or doing close work?					
	Multiply by the column value	x0	x1	x2	x3	x4
	Sum 5 values					

Score:_____

Appendix B.
Analysis of Different Passages by Visagraph Variables

The results were analyzed based on the passage for each variable. The results are displayed with the worst performance at the top for each variable. For example, regressions lists passage 88 first as it was found on average to produce the greatest number of regressions.

Regressions	Passage 88: 13.1422 +/- 11.0058 Passage 94: 11.9717 +/- 9.8731 Passage 95: 11.6634 +/- 9.6468 Passage 87: 11.2568 +/- 9.3456 Passage 96: 11.0708 +/- 8.5679 Passage 92: 10.7525 +/- 8.9012 Passage 89: 10.7018 +/- 8.4644 Passage 91: 10.6964 +/- 11.7487 Passage 97: 10.4387 +/- 7.9077 Passage 90: 10.1126 +/- 7.9045 Passage 93: 9.9871 +/- 8.0327 Significant (p=0.0202)
Span of Recognition	Passage 94: 1.03061 +/- 0.277919 Passage 95: 1.05738 +/- 0.261864 Passage 88: 1.07294 +/- 0.299172 Passage 96: 1.10712 +/- 0.288108 Passage 97: 1.10906 +/- 0.290236 Passage 93: 1.12409 +/- 0.259802 Passage 90: 1.12856 +/- 0.281807 Passage 89: 1.13763 +/- 0.277540 Passage 92: 1.14535 +/- 0.308542 Passage 87: 1.14689 +/- 0.307403 Passage 91: 1.16121 +/- 0.302526 Significant (p<0.0001)
Duration of Fixation	Passage 90: 0.255360 +/- 0.034413 Passage 92: 0.255495 +/- 0.034899 Passage 87: 0.257703 +/- 0.036568 Passage 94: 0.258208 +/- 0.036514 Passage 95: 0.258515 +/- 0.032960 Passage 88: 0.259083 +/- 0.035196 Passage 89: 0.259912 +/- 0.033726 Passage 97: 0.260802 +/- 0.033568 Passage 93: 0.261164 +/- 0.038047 Passage 96: 0.262257 +/- 0.032927 Passage 91: 0.263571 +/- 0.036033 Not Significant (p=0.2849)

Comprehension Rate	Passage 94: 242.406 +/- 84.2414 Passage 95: 247.248 +/- 76.6995 Passage 88: 251.188 +/- 85.7117 Passage 96: 255.752 +/- 84.1244 Passage 97: 257.047 +/- 81.3967 Passage 93: 261.371 +/- 80.3173 Passage 89: 265.211 +/- 83.6060 Passage 90: 265.482 +/- 81.7474 Passage 91: 266.054 +/- 84.4916 Passage 87: 268.477 +/- 86.3279 Passage 92: 270.465 +/- 88.0558 Significant (Prob < 0.0041)
Directional Attack	Passage 88: 11.6615 +/- 7.63217 Passage 87: 11.2703 +/- 7.49413 Passage 96: 10.8584 +/- 6.77494 Passage 94: 10.8026 +/- 7.03891 Passage 95: 10.6050 +/- 6.65874 Passage 89: 10.5361 +/- 6.61001 Passage 92: 10.4118 +/- 6.83530 Passage 91: 10.2817 +/- 7.03720 Passage 97: 10.2170 +/- 6.15288 Passage 93: 10.0783 +/- 6.82287 Passage 90: 9.6675 +/- 6.26268 Not Significant (p=0.1493)
Number of Fixations	Passage 94: 103.665 +/- 25.9665 Passage 88: 100.615 +/- 28.6198 Passage 95: 100.233 +/- 24.0923 Passage 97: 96.198 +/- 24.587 Passage 96: 95.779 +/- 22.4207 Passage 90: 94.324 +/- 22.9503 Passage 89: 93.149 +/- 22.5376 Passage 92: 93.297 +/- 23.5664 Passage 87: 93.306 +/- 24.2246 Passage 93: 93.647 +/- 20.9876 Passage 91: 91.728 +/- 22.9424 Significant (p<0.0001)