Do Colored Overlays Improve Reading? A Test of the Irlen Effect

by

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(ABSTRACT)

The purpose of this study was to examine the use of colored overlays as an aid to individuals with reading problems; and, in particular, to assess the role visual contrast sensitivity may play in this treatment and in reading problems in general. Arguments both supporting and refuting the validity of the Irlen technique of using colored overlays and lenses as a treatment for reading problems are reviewed. While much of the criticism regarding the Irlen technique appears warranted, it seems that, for many reading disabled individuals, overlays and lenses do provide relief from symptoms and help to raise scores on reading tests. Tinted overlays may work by improving the contrast ratio of print for those with poorer contrast sensitivity. It was hypothesized that reading scores of many poor readers would improve with the addition of tinted overlays, that those who were helped would show poorer contrast sensitivity than those who were not, that contrast sensitivity would also improve with the addition of a tinted overlay, and that subjects would be equally helped by a neutral density gray overlay.

One-hundred-seventy-four undergraduate volunteers were screened for reading ability with the Nelson Denny Reading Comprehension Test. The top 46 and bottom 46 were divided into three groups who were tested again

using either a) one of four overlays deemed "optimal" for that subject by performance on the Tinker Speed of Reading test b) a gray overlay of the same density or c) no overlay. Contrast sensitivity was also tested under both conditions. The Irlen effect was not seen with this group of subjects. Results showed no significant effect of group or overlay color on reading performance. Scores in general increased significantly on the second trial, with low readers improving more than high readers. Contrast sensitivity showed no relationship to reading indices.

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Do Colored Overlays Improve Reading? A Test of the Irlen Effect

In recent years, the use of colored overlays or lenses as an aid to individuals with reading problems has attracted a lot of attention both in the media and in the research literature. The "Irlen technique" has appeared on the popular news magazine program 60 Minutes and the December, 1990 Journal of Learning Disabilities dedicated a special issue to this controversial approach. Little research has evaluated whether it is effective or not, and if effective, what perceptual processes may be underlying the effect.

The idea of using colored overlays originated with Helen Irlen, a California school psychologist interested in reading disabilities. Irlen (1983) also coined the term "Scotopic Sensitivity Syndrome" (SSS), which is described as a type of perceptual dyslexia with major symptoms such as slow, inefficient reading, poor comprehension, eye strain and fatigue, headaches, shimmering of text and word reversals. According to Irlen, about half of those labeled as reading disabled show signs of SSS and are helped by eliminating certain wavelengths of light using colored overlays or lenses.

Although it is not clear how Irlen associates both reading and color with the scotopic or rod system of the eye (which neither reads nor sees color), the term can be seen again and again without question in subsequent literature on the Irlen technique (Adler & Atwood, 1987; Blaskey, et al., 1990; Fricker, 1989; Irlen & Lass, 1989; Irlen, 1990; Miller, 1985; O'Connor, Sofo, Kendall, & Olsen, 1990; Robinson & Conway, 1990; Robinson & Miles, 1987; Whiting, 1988; Whiting & Robinson, 1988; Winter, 1987). The Irlen Differential Perceptual Schedule (IDPS; Irlen, 1983), which consists of questions regarding visual resolution, depth perception, sustained focus, span of focus, peripheral vision and eye strain symptoms, has also been widely accepted as a valid measure of SSS.

Studies Supporting Irlen

When the popularity of the Irlen technique began to grow, a controversy erupted. Many researchers and practitioners involved in the treatment of reading and visual problems expressed either support or disapproval for Irlen and her methods. While much of the criticism of the mysterious and costly Irlen lenses appears warranted, many researchers reported both experimental and anecdotal evidence indicating that the lenses work. These findings led to further studies of the Irlen effect and Scotopic Sensitivity Syndrome, as researchers searched for an explanation for the apparent success of the lenses.

Miller (1985) identified SSS in 65 college students grouped according to high or low reading ability using the Nelson Denny Reading Test and the Perceptual Speed cluster of the Woodcock Johnson Psycho-Educational Battery. Each was given the Irlen Differential Perceptual Schedule to assess "scotopic sensitivity syndrome." Although SSS was found in both groups, the incidence and severity were greater in the low reading group, as one would expect. The low group showed a statistically significant ($p<.01$) incidence of 73.68% while incidence of SSS in the high group was 14.8%. A total of 86% of the lows and 40.74% of the highs exhibited a wide range of SSS symptoms and severity.

Adler and Atwood (1987) conducted a study of 41 high school students identified as reading disabled through the IDPS. Twenty-three experimental subjects and 18 control subjects were matched on four types of learning ability:

general, verbal, numerical and spatial. The experimental group was then given spectrally modified lenses based on the Irlen Institute's testing procedure. They also received group counseling, enrollment in a regional occupational program, and an analysis of their learning/training problems; recommended strategies were given to their parents and teachers. Upon post testing with the IDPS four months later, significant improvements were seen in the experimental group's responses regarding visual efficiency, energy and effort to read, eye strain, length of sustained reading, photophobia, visual resolution, span of focus, and time to find place on a page (all $p<.01$). The researchers also provided more descriptive evidence in the form of quotes from the subjects and their parents (e.g. "The words are darker and easier to read; can read faster, comprehension has improved...", "The glasses help with reading; no longer get headaches...", "Everything is easier to look at...everything was too bright/harsh before."). Unfortunately, it is impossible to attribute such success to the tinted filters alone, since other interventions were done simultaneously. The fact that the lenses were never described in terms of color or spectral transmission makes the study impossible to replicate.

Robinson and Miles (1987) conducted a more specific study of 40 subjects aged 9-74 who had called inquiring about tinted lenses. They were given the IDPS and divided into three groups based on the severity of their reading problems. Subjects were given four visual processing tasks (word matching and identification of words, letters, and numbers) either with a clear plastic overlay, a tinted overlay chosen by the subject, or a random tinted overlay. The subjects with the highest degree of reading problems showed significantly better scores on the word matching and identification of letters and numbers with their chosen overlay than with the clear or random overlays. It is impossible to rule out a placebo effect here, however, since in one group, subjects chose their own overlays while in the other groups, they did not.

Australian researchers Whiting and Robinson (1988) surveyed those already fitted with Irlen lenses using the Irlen procedure, which is not available to the research community. A survey was conducted of individuals who had been using Irlen lenses for at least 12 months. Of the 213 responses, 57.4% found the lenses very helpful, while an additional 35.6% found them to be somewhat helpful. Reading fluency was the area most affected, with 90.7% reporting improvement in this category. Eyestrain, comprehension, and concentration were also rated by many as being improved substantially. Tiredness and handwriting were the least affected, however 55.6% and 57.7% still reported improvement on these measures. As with any survey research, the question of non-respondents must be addressed; the response rate was 48%, and in a telephone survey of 25 non-respondents, 87% indicated that the lenses had been a definite help.

Another longitudinal study on the effects of colored lenses was conducted by Fricker (1989). A total of 127 Tasmanian children aged 7-14 were fitted with Irlen lenses and evaluated for over 12 months. The children were given timed reading tests at set intervals, and questionnaires were given to parents, teachers and children. Stereopsis was tested with the Stereo Reindeer Test, and 75% exhibited less than optimal stereopsis without the lenses; but, when they were tested again with their chosen lenses, 80% of this group showed immediate improvement. No claims were made regarding statistical significance. On the Gray Oral Reading Test and the A.C.E.R. Silent Reading Test, most children showed similar improvement, demonstrating an immediate increase in speed and accuracy with the lenses. Finally, on the questionnaires, parents (95% response rate) and teachers (65% response rate) reported substantial improvements in the children's reading, as did the children themselves. In her concluding remarks, Fricker stated that while the placebo effect cannot be entirely ruled out, the sustained improvement exhibited by the subjects over 2 years suggests that at least some genuine improvement can be attributed directly to the effects of the lenses.

A study of two reading disabled brothers was carried out by Hannell, et al., (1989). They were given an ophthalmic assessment, the Neale Analysis of Reading, and tests of copywriting, pattern copying, perceptions of spaces between words, and figure-ground discrimination. Improvement was seen on all measures for both boys with the addition of the overlays, which the subjects chose themselves for superior readability. Interestingly, the researchers mentioned that the density of a color is also important and could be modified by using either single or double sheets of the overlay. This study is one of few that addresses the apparent misnomer of "Scotopic Sensitivity Syndrome", as the word "scotopic" refers to the dark adapted phase of vision (or the rods of the retina) and they pointed out that no one reads in the dark. Hannell et al. also criticized Irlen's technique because the assessment for and prescription of Irlen lenses is a commercial secret and not open to scientific scrutiny. This study was also one of few that attempted to speculate on reasons for the success of the lenses; one possible explanation they put forth resembles the familiar Pulfrich phenomenon:

> Tinted lenses are known to slow transmission of impulses along the primary visual pathway from the retina to the occipital cortex...tinted lenses may therefore act by modulating the transmission of information from the environment to the visual cortex, allowing a better match of visual input with information from the language channel (p. 176).

This explanation does not, of course, explain why different subjects prefer different colors, and the authors acknowledged that more research must be done on this and other aspects of the phenomenon.

Robinson and Conway (1990) conducted a study of 44 reading disabled subjects aged 9-15. They were given the Student's Perception of Ability Scale after 6 and 12 months of wearing Irlen lenses and the Neale Analysis of Reading at 3, 6, and 12 months. Subjects demonstrated a significant improvement in the attitude scale and in comprehension and reading accuracy, but not in rate of reading. This study was limited, however, by its lack of a control group and inability to rule out any placebo effect.

O'Connor, Sofo, Kendall, and Olsen (1990) used colored overlays to study 92 children with reading disabilities. Subjects were classified "scotopic" or "nonscotopic" using the IDPS and were assigned to six treatment groups using colored or clear overlays. The "scotopic" subjects were split into four groups: one was given a preferred colored overlay, two were given a clear transparency, and one was given a nonpreferred colored overlay. The "nonscotopic" children were divided into two groups: one was given a clear transparency and one was given a randomly selected overlay. Reading performance was measured by the Neale Analysis of Reading Ability and the Formal Reading Inventory. The "scotopic" children who were given their preferred colored overlay improved significantly in all reading scores, while the other groups showed either no change or a drop in scores. The researchers concluded that the changes in reading performance were due to actual effects of the colored overlays and not a placebo effect because, had it been a placebo effect at work, the "scotopic" group given the wrong overlays and the "nonscotopic" group given random overlays would have shown improvement. The problem with this argument is that, if there is a placebo effect at work, it is most likely due to the fact that the subject's chosen color worked best, not one they were given without their consent.

Studies Refuting Irlen

Several researchers have shown skepticism regarding the Irlen effect, attributing the positive results reported above to placebo effects and methodological problems, perhaps due to a lack of impartiality of researchers (like Irlen and her colleagues) who stand to gain from the success of the overlays. One such study by Winter (1987) demonstrated this skepticism. Fifteen students aged 7-11 years who already had been fitted with Irlen lenses were split into four groups and given a four minute letter identification task either with their own lenses, no lenses, plain or gray lenses. They were asked to read for 10 minutes with no lenses before performing the task so that they would be sufficiently adapted. Results showed no difference in performance levels across all conditions other than a substantial practice effect shown across the four trials . Several of the children reported reading better with the plain and gray lenses than with none at all. However, because only one four minute letter identification task was used and only 15 children were tested with only one condition each, this study must be viewed with caution.

Winter argued that the results offer no evidence to support the use of Irlen lenses to improve visual performance, and claims in favor of the treatment should be viewed with caution.

Cole, et al., (1989), in a study of 24 dyslexic children aged 9-12, found no significant change in Neale Analysis of Reading scores after they had been reading with tinted lenses for one school term. What was interesting about this study is that, of the 381 suitable subjects, 208 were excluded because they were also diagnosed asthma sufferers. This was done so that they might avoid the effects of asthma medication on cerebral function in the subjects. One asthmatic child was inadvertently included in the study; he did respond positively to the tinted lenses. If such a large proportion of dyslexics have asthma (in this sample, 55%) and are taking medication that could be affecting their cognitive functioning, such a variable needs to be taken into account in studies involving dyslexics and others with reading problems. Another problem with this study was that only 7 of the 13 experimental subjects and 4 of the 11 control subjects consistently wore their lenses for the duration of the study. One beneficial aspect of this study not seen in any others was the detailed information regarding the type and colors of the lenses used (most subjects chose either blue or pink). The researchers concluded by stating that in their experience with over 1200 lens users, there does appear to exist a subgroup which benefits considerably from the lenses and that further research should be conducted by others not commercially associated with the lenses and their success.

Blaskey et al. (1990) studied 30 subjects who had requested information about the colored lenses. Optometric testing revealed that 38 of the 40 original subjects showed specific vision anomalies. Subjects were randomly divided into 3 groups: an Irlen filter group, a vision therapy group, and a control group. The Irlen group (n=11) was fitted with Irlen lenses by the Irlen clinic and given placebo lenses of a randomly selected tint. After trying each set for 2 weeks, they were asked to choose the lenses they felt improved their reading most. They wore this set for 2 more weeks, and post testing was conducted with these lenses. The vision therapy group (n=8) received treatment aimed at correcting the accommodative or binocular dysfunction they seemed to be having. They were treated with 45 minute sessions once or twice a week in the office and were also given exercises to do at home. Two of these subjects were later given Irlen lenses to determine any additive effects of the two treatments. The control group received no treatment, and only three of the original eight returned for post-testing. Three of the Irlen group chose the placebo lenses. A significant reduction in symptom scores was found for the Irlen lens subjects, but not for the placebo subjects. Pre and post scores on a letter reading task, the Gray Oral Reading Passage test, the Stanford Reading Test, and the Woodcock Reading Test were compared for the groups. For the Irlen group, significant improvement was found only on the letter reading task and the Woodcock Reading Test. Optometric evaluations revealed the same visual problems these subjects began with. The vision therapy group showed significant improvement on the symptom measures and on the Gray Oral Reading Test. Seven of the eight subjects showed improvement in their originally diagnosed vision problems. The control group showed no change. The researchers suggest that undetected vision problems may be the largest factor for those who are seeking to use Irlen lenses.

Hypotheses

Although many of the studies done in this area suffer from various methodological problems and some of the results cast doubt on the Irlen technique, of the studies reviewed, eight supported further use of Irlen's procedure, indicating that there may be something to the treatment.

Several hypotheses as to why the overlays work exist. The first hypothesis, which originated with Irlen, states that the receptors of the eye are hypersensitive to certain wavelengths of light and by filtering out these disturbing wavelengths, subjects are better able to read (Irlen, 1990). The neuropsychological implications of Irlen's overly simplistic hypothesis have not been addressed by Irlen or her colleagues at this point, but subsequent research by others directed at the effectiveness of overlays has generated several hypotheses. One, put forth by Hannell et al. (1989) states that the tinted lenses are slowing the transmission of impulses along the primary visual pathway and allowing a better match of visual input and information from the verbal channel.

The most programmatic work on the underlying mechanisms of the overlay treatment is that of Australian researchers Lovegrove, Williams and their colleagues who have studied various visual correlates to reading disabilities. Lovegrove, Heddle, and Slaghuis (1980) found that, compared with normal controls, disabled readers have significantly longer visual information store (VIS) durations for low spatial frequencies and shorter VIS durations for high spatial frequencies. This suggests that normal readers are better able to make use of multiple fixations and of information in the periphery of the visual field when reading, while disabled readers cannot. Lovegrove, Martin, Bowling, Blackwood, Badcock, and Paxton (1982) found differences in contrast sensitivity functions of reading disabled subjects and normals, although the nature of the difference varied across experiments. Lovegrove, Slaghuis, Bowling, Nelson, and Geeves (1986) went on to demonstrate that contrast sensitivity (2 and 4 cy/deg) was a moderate predictor of reading ability 2 years later. They suggest that a transient system deficit may play a part in their subjects' reading disabilities and that more direct measures of transient system functioning such as flicker sensitivity should be utilized. Lovegrove, Martin and Slaghuis (1986) described in more detail the characteristics of the transient system: it is most sensitive to low spatial frequencies and high temporal frequencies, has fast transmission times, responds at stimulus onset and offset, predominates in peripheral vision, and may inhibit the sustained system. Therefore, the transient system is a flicker or motion system which transmits information about stimulus change, while the sustained system is a pattern system which transmits information about stationary stimuli. Good reading is a result of the proper balance between the two. They report that a number of studies which compared the contrast sensitivity functions of reading disabled and controls show small but consistent differences between the two groups, with reading disabled subjects being less sensitive at low spatial frequencies, but often more sensitive than controls at high frequencies. Contrast sensitivity is one way of assessing transient system functioning, but flicker sensitivity has been more commonly used (Martin & Lovegrove, 1987, 1988). Lovegrove et al. (1986) suggested that reading disabled subjects might perform better in tasks when the stimuli are presented singly rather than under normal reading situations and that they make less use of parafoveal information while reading. This second hypothesis was supported by Brannan and Williams (1987).

Williams, Brannan, and Lartigue (1986) conducted a study of 8-10 year old children who were classified as good or poor readers, and adults' performance on a visual search task. They found that the poor readers' visual search time improved dramatically when the arrays were presented slightly out of focus (the contrast of high spatial frequencies was reduced). They suggest that this blurring, which seems to slow the sustained system response, may reestablish the temporal precedence of the information from the transient system. More recently, in a study conducted by Williams, LeCluysa, and Rock (1992), reading comprehension scores of 80 % of 30 specifically reading disabled children (ages 8-12) showed significant improvement when text appeared on a blue or light gray background as opposed to red, green or white. Although they were unable to describe the reason blue overlays or backgrounds help, they again suggested a possible speeding of the slow transient system by affecting contrast levels. Lovegrove pointed out in an interview with Science News that this technique is not the same as the "Irlen Technique", in which Irlen specialists charge hundreds of dollars to help patients choose from a range of colored lenses in order to treat the vaguely defined and controversial scotopic sensitivity syndrome (Weiss, 1990).

The research described above lends support to the hypothesis of the present study, which states that placing an overlay, regardless of its color, over reading material should alter the contrast ratio of the print, thus facilitating easier reading, as shown in Figure 1. (H. Snyder, personal communication,

Insert Figure 1 about here

fall, 1992). In order to determine whether there might be a valid phenomenon taking place, a small pilot study was conducted.

<u>Pilot Study</u>

Sixty-four undergraduate subjects were recruited from sign up sheets in the psychology department. They were given the Nelson Denny comprehension test (Brown, Bennett & Hanna, 1981) in several groups without an overlay, then three subjects were selected at random from each of the low, middle and high portions of the distribution of both reading and comprehension scores and were tested again individually with an Edmund Scientific overlay of their choice.

Far and near acuity were verified as 20/20 natural or corrected using a Bausch & Lomb Orthorater. Subjects' contrast sensitivity was tested using slides of sine wave gratings. Spatial frequencies measured were .4, .8, 1, 1.7, 2.3, 3.7, 5.7, 7.5, 11.4, 13.5, 16, and 20.5 cycles per degree. Spatial frequencies were presented in mixed order and contrast levels were mixed within each spatial frequency.

Forms E and F of the Nelson Denny Reading Test were used to measure reading ability and improvement. Reading speed scores are out of 622 possible points. Comprehension scores are out of a possible 36. Means and standard deviations are presented in Table 1. The average change score between the first and second test was 60.88 for speed and 2.66 for comprehension, with a range of 26-149 points for reading rate and 0-5 points for comprehension.

Insert Table 1 about here

The subjects whose Nelson Denny scores improved at least 1 comprehension point and 25 reading rate points with the overlay actually showed better contrast sensitivity for all spatial frequencies except 7.5 cy/deg when compared to those who were not helped or were hindered by the overlays. (Although the sensitivity scores differed numerically, they were not tested statistically.) This may indicate that those individuals who suffer from symptoms which are relieved by overlays may also experience better than normal contrast sensitivity. To find out if an overlay affects contrast sensitivity for these individuals, one subject who reported the most

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Insert Figure 2 about here

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severe reading problems and was helped the most by the overlay was invited back to have her contrast sensitivity tested with an overlay in front of the lens of the projector. Her contrast sensitivity scores dropped slightly at .8, 1, 2.3, and 13.5 cy/deg with the addition of the overlay.

One interesting finding was that this individual, who scored the lowest in both reading and comprehension in the group of 64, also showed the best contrast sensitivity of the group. From this result, it would appear that the overlays are affecting contrast sensitivity by reducing contrast levels. It became apparent, however, that this could not be the case, since overlays actually enhance contrast.

A combination of data from these 9 subjects and 19 others from a related pilot study from our lab, which assessed changes in Tinker speed of reading scores with two overlays which the subjects chose themselves, showed that 63% of the overlays chosen as either a first or second choice were either Edmund Scientific filter no. 802 "bastard amber" (16%), no. 805 "light straw" (12%), no. 834 "salmon pink" (19%) or no. 849 "pale blue" (16%). Therefore, these were the four overlays chosen for use in the current study, described below. Spectral curves of these overlays are shown in Figure 3.

Insert Figure 3 about here

The Current Study

The hypothesis put forth in the current study centered on contrast sensitivity. Our ability to discern the differences in brightness of adjacent areas, or contrast, determines our ability to perceive visual information (Campbell & Maffei, 1974). Placing an overlay, regardless of its color, on top of reading material should actually improve the contrast ratio of light to dark elements of the print, making it easier to read (H. Snyder, personal communication, fall 1992) previously shown in Figure 1. Because only two small n studies (n=11 & n=2) make any mention of the type of overlays used and their densities (Cole et al., 1989, Hannell et al., 1989), it is impossible to tell from existing research whether individual differences are due to the color of the overlay or merely the density.

The current study proposed to test the following hypotheses:

1. A population of poor readers whose reading is helped by overlays exists among VA Tech Psychology students.
2. Differences exist in the contrast sensitivity of subjects who are helped by the overlays and subjects who are not.
3. A shift in subjects' contrast sensitivity scores will occur with placement of an overlay.
4. The color or the luminosity of the overlay will determine its effectiveness in aiding individuals with reading problems.

Subjects were divided into two extreme groups based upon their reading level as determined by a screening done with the Nelson Denny comprehension test. Subjects returned for further reading and contrast sensitivity testing. After being split into three groups (within the level groups) they were given an alternate form of the Nelson Denny and were tested again for contrast sensitivity. Group A performed these second tests with their "optimal" overlay in place. Group B was tested with a neutral density gray overlay matched to their "optimal" for light transmittance. Group C received no overlay.

If the colored overlays are, as Irlen states, useful because they are filtering out a wavelength of light the individual's eye has difficulty with, we would expect that the subjects would perform better with the optimal colored overlay than with the matching gray, and there would be no differences between contrast sensitivity scores of those who are helped and those who are not, or between the upper and lower levels of reading ability. If it is the contrast of the material being affected regardless of color, the subjects should perform equally well using either colored or neutral gray overlays, and subjects who are helped (or subjects in the lower reading level) should yield poorer contrast sensitivity scores than those who are not helped.

Method

Subjects:

A total of 174 undergraduate volunteers was recruited via sign up sheets in the psychology department. They were given extra credit for their participation. Sign up sheets specified the need for both normal and reading disabled subjects. Several initial screenings took place where up to 26 students at one time took the comprehension section of the Nelson Denny Reading Test Form E and F (Brown et al., 1981), the general indicators, eyestrain and photophobia portions of the Irlen Differential Perceptual Schedule (IDPS; Irlen, 1983) and an additional survey regarding their reading habits and any problems they might have. Out of these 174 students, the top 46 scorers and the bottom 46 scorers on the comprehension test who were available were chosen to come back for individual testing. Descriptive statistics regarding the reading scores of these individuals are given in the Results section. Of these 92, 55 were women and 37 were men. Twenty-seven women and 19 men fell in the higher group, while 28 women and 18 men fell in the lower group. All were within the ages of 18 to 23.

Materials:

The comprehension section of the Nelson Denny Reading test, forms E and F (Brown et al., 1981), was used to compare subjects' reading with and without an overlay. The Nelson Denny (see Appendix A) has been established as a valid test of reading speed and comprehension and is widely used in this type of research . Subjects must read 8 paragraphs and answer comprehension questions regarding each. Reading rate is also measured for the first minute of the 20 minute test as provided by the Nelson Denny.

Only part of the IDPS was used, and only in a relative, descriptive way. This was because much skepticism still surrounds the IDPS, and it would take a trained Irlen screener to correctly administer much of the one-on-one testing. The General Indicators, Eyestrain and Photophobia sections of the IDPS (see Appendix B) were administered. In addition, a questionnaire that asked about handedness, eye color, age, asthma and medications, diagnosis of dyslexia or other reading or learning problems (see Appendix C), was also administered.

The Tinker Speed of Reading test (Tinker, 1947) was used to determine the overlay that each subject was most comfortable reading with (see Appendix D). The test consists of pairs of sentences arranged in paragraph form. The second sentence of each pair contains a word which does not belong, given the meaning of the first sentence (e.g. "On the trip he took abroad, Gary went into an ancient castle over two thousand years old. He was thrilled as he could be to enter such a modern building.") The subject must read the test silently, but verbally report the incorrect word while the experimenter counts the number of sentences the subject reads in a 3 minute period. Although the Tinker is a test of reading speed, it is clear that a comprehension element is also present, as the subject must understand the meaning of the sentences in order to pick out the word that does not belong. Most importantly, the Tinker can be used again and again without overlap, as each of the two forms consists of over 400 pairs (about 40 minutes of reading each). Different sections of the test were chosen for each trial, leaving at least a paragraph between passages in case subjects had looked ahead.

Subjects read from the Tinker with Edmund Scientific transparent colored overlays placed on top. Overlay numbers 802 ("bastard amber"), 805 ("light straw"), 834("salmon pink") and 849 ("pale blue"), were used, as these were the 4 most commonly chosen overlays from the pilot study. The "optimal" overlay for each individual was the overlay the individual scored best with on the Tinker (see figure 3 for spectral curves of the overlays).

Subjects' vision was tested on a Bausch & Lomb Orthorater vision tester for acuity, stereopsis and phoria. Subjects looked into the viewfinder and answered questions regarding the orientation of a checkerboard pattern and other icons while the experimenter verified the responses.

Static contrast sensitivity was tested using sine wave grating patterns generated using a VAX 11-785 computer with a Perceptics 9200 color image processor and photographed with a Matrix graphic image recorder camera. At a viewing distance of 63.5 cm, the 3.8 cm projected circular test targets subtended 3.5 degrees of visual angle. The contrast values of the test targets were assessed using a Gamma Scientific scanning photometer. The targets were presented on a testing device built to test both static and dynamic contrast sensitivity (Olesko, 1992). This device consisted of a Kodak 850 H slide projector which had been modified to reduce the size of the image and produce a circular test target. The targets were then projected through a right angle prism onto a mirror which projected the image onto a ground glass screen. A large wooden box contained all but the projector, for which a hole had been cut in the back . The front of the box contained the ground glass screen. The spatial frequencies of the targets were as follows: .04, .08, 1.0, 1.7, 2.3, 3.7, 5.7, 7.5, 11.4, 13.5, 16.0, and 20.5 cycles per degree. Spatial frequencies were again presented in mixed order and contrast levels were mixed within each spatial frequency (see Appendix E). Subjects were seated at a chin rest positioned 63.5 cm from the apparatus. In the darkened room, they were asked to respond "yes" or "no"' to indicate whether they could see each pattern of bars or not. Instructions emphasized speed and accuracy, and subjects viewed the target until they responded; approximately .5 - 3 seconds.

Procedure

Subjects were screened in several groups of up to 26 in a classroom illuminated by fluorescent tubes. The average illumination was about 50 footcandles as measured by a Shurlite footcandle meter. After reading and signing the consent form, portions of the IDPS, an additional survey regarding reading habits, eye color, handedness, and illnesses (including asthma), and either form E or F of the Nelson Denny reading comprehension test were administered. The top 46 and the bottom 46 scorers available on the Nelson Denny were called back and scheduled for an individual session. The Nelson Denny manual places the high readers' mean score of 30.65 correct in the 68th percentile while the low readers' mean of 20.23 fell in the 13th percentile for end-of-the-year college juniors. High readers' mean speed score of 261.98 was at the 44th percentile while low readers' mean score of 187.83 was at the 12th percentile. Although the scores of the high readers do appear low for their academic and age group, numerically, there was little room for improvement, as the average comprehension score was 30 out of 35. Groups were assigned so that each of the "optimal" overlays was represented as equally as possible using the assignment chart pictured in Table 2.

Individual sessions were conducted in a lab that was also lit with fluorescent fixtures, but was brighter than the classroom, with an illumination of about 75 foot-candles. This arrangement made it possible to manipulate the contrast enhancing effects of the overlays while holding brightness constant, since when the subject was reading with any of the overlays, the illumination of the page was reduced by about 25 foot-candles.

Each subject's vision was tested with the Orthorater, then his or her contrast sensitivity was tested. Next, the subject was asked to read for 3 minutes from different passages of the Tinker Speed of Reading test with each of the four most commonly chosen overlays (from the pilot study) presented in random order following a three minute practice trial with no overlay. Reading material was placed on a surface slanted approximately 45 degrees to reduce glare from the direct overhead lights and was at a comfortable arm's length from the reader's eyes.

Subjects within the upper and lower reading levels were assigned to one of three groups according to the assignment scheme depicted in Table 2. Groups were assigned so that each "optimal" overlay was represented as equally as possible. For example, group A contained the first, fourth and seventh person to do best with blue, the third, sixth and ninth for pink, the second, fifth and eighth for amber and the first, fourth and seventh for straw.

Insert Table 2 about here

All three groups were given the alternate form of the Nelson Denny (i.e. subjects who received E first now received F and vice versa) and a second measure of contrast sensitivity. Group A was tested with their optimal overlay placed over the printed material and inserted in front of the projector lens in the contrast sensitivity apparatus. Group B was tested similarly, but with a neutral density gray overlay matching the light transmittance of their optimal overlay. Group C was tested with no overlay and under light conditions similar to those of the pretest, providing them with the same illumination level as groups A and B, but without the overlay. Due to the limitation of having only two equivalent forms of the Nelson Denny, it was impossible to test each subject with no overlay, a colored overlay, and a gray overlay.

After testing, the subjects were debriefed and were shown their reading scores if requested.

Analysis

A 2 x 3 x 4 x 2 (Reading Level x Group x "Optimal Color" x Trial) analysis of variance (ANOVA) was performed for each reading score (number correct, number completed and reading rate) and for each of the 12 spatial frequencies with repeated measures for the last factor (trial). Other analyses included a 2 x 3 x 4 (Reading Level x Group x "Optimal Color") ANOVA for the change scores between the pre and post trials, looking at which subjects' Nelson Denny scores improved with an overlay vs. those whose did not, which overlays were chosen most often and by whom, how the portions of the IDPS administered were related to the other variables, and the incidence of asthma and other demographic variables in each group.

Results

Reading Scores

A 2 x 3 x 4 x 2 (Reading Level x Group x "Optimal Color" x Trial) ANOVA was performed on the Nelson Denny reading indices of a) how many completed correctly (out of 36), b) number completed, and c) reading rate (out of 622 words) with repeated measures for the last factor. For number correct, which is the main indicator of reading comprehension, significant main effects were found for level $F(1,68) = 104.25$, $p < .0001$, trial $F(1,68) = 24.29$, $p < .0001$, and a significant interaction effect was found for level by trial $F(1,68) = 41.3$, $p < .0001$. To determine the sources of the interaction, one-tailed t tests were performed. Differences between the pre and post low means were significant $t(45) = 4.93$, $p < .001$. Differences between the pre and post high means were not significant; $t(45) = 1.083$, $p < .25$. Differences between the low and high pretest means were significant, $t(45) = 16.37$, $p < .001$ as were differences between the low and high posttest means, $t(45) = 5.31$, $p < .001$.

Similar results were found for number completed: level $F(1,68) = 74.65$, $p < .0001$, trial $F(1,68) = 50.46$, $p < .0001$, and level by trial $F(1,68) = 26.42$, $p < .0001$. Only the level factor was significant for reading rate $F(1,68) = 20.57$, $p < .0001$. Means and standard deviations for the two levels of readers on these indices are given in Table 3.

Insert Table 3 about here

The group $\underline{F}(2,68) = .05$, $\underline{p} < .951$ and color $\underline{F}(3,68) = .76$, $\underline{p} < .523$ factors were not significant for number correct or any other measure, indicating that any changes in reading scores across trials were not due to the manipulations of group (colored, gray or no overlay) or "optimal color" (amber, pink, blue, straw). More likely, what was seen, as evidenced by the significant level x trial interaction, was a simple practice effect with the scores of the lower level increasing more than those of the upper group. This probably due to the fact that most of the upper level scored in the 30's (out of 36) on the pretest and did not have as much room for improvement as the low group (see page 21).

Insert Table 4 about here

Level and group means are given in Tables 4 and 5, respectively.

Insert Table 5 about here

A 2 x 3 x 4 (Reading Level x Group x "Optimal Color") analysis of variance (ANOVA) was performed for the change scores across trials for the number correct on the Nelson Denny, as this is the most telling indicator of reading performance. Significant differences due to level were found, with the low readers improving more than the high readers, whose average actually dropped slightly $\underline{F}(1,91) = 40.691$, $\underline{p}<.0001$, but again, this was most likely due to the lack of room the high group had to improve. This effect is shown in Figure 4. Group and color had no significant effect on the change scores.

Insert Figure 4 about here

<u>Contrast Sensitivity</u>

A 2 x 3 x 4 x 2 (Reading Level x Group x "Optimal Color" x Trial) ANOVA was performed separately on threshold scores for each of the 12 spatial frequencies with repeated measures for the last factor.

Insert Figure 5 about here

Significant main effects of trial were found for .4 cy/deg ($\underline{p}<.002$), 2.3 cy/deg ($\underline{p}<.036$), and 20.5 cy/deg ($\underline{p}<.018$). In each case, scores improved on the second trial regardless of which manipulation subjects received, again suggesting a practice effect. Results of pre and post contrast sensitivity measures are pictured in Figure 5. Because some of the spatial frequencies (especially the highest and lowest) are often ambiguous at first, it is reasonable that many subjects would perform better the second time around once they know what to look for. In contrast to the results of the pilot study, subjects whose reading scores improved with an overlay (N=53) showed only slightly different contrast sensitivity functions than those whose scores went down (N=39), as seen in Figure 6.

Insert Figure 6 about here

Contrary to our expectations, differences in contrast sensitivity between high and low readers were minimal and are pictured in Figure 7.

Insert Figure 7 about here

The other statistically significant findings were beyond explanation: a color x group x trial interaction for .8 cy/deg ($\underline{p}<.042$), a group x trial interaction for 3.7 cy/deg ($\underline{p}<.017$), a color x trial interaction for 5.7 cy/deg ($\underline{p}<.046$), and a level x color interaction for 16 cy/deg ($\underline{p}<.030$).

Correlation

Pearson product moment correlation was performed on all baseline or trial 1 variables, including the three reading indices, the change score, and the 12 spatial frequencies. While the reading indices were all intercorrelated, and while some of the spatial frequencies were intercorrelated, the reading scores were in no way significantly correlated with any spatial frequency.

IDPS

Although the IDPS was not used in the form in which it was originally intended, a 2 x 3 x 4 (level x group x color) ANOVA was performed to assess its relationship to the other variables involved. No significant effects were found, although it approached significance for reading level. As would be anticipated, the low reading group showed a tendency to report more visual complaints on the IDPS than did the high reading group $F(1,91) = 3.51$, $p<.065$. Scores were split at the median (15 out of 43 "yes" answers), and the data were

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Insert Figure 8 about here

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analyzed again by looking at the high scorers (more complaints) versus the low scorers (fewer complaints). For reading level, high readers reported fewer complaints and low readers reported more X (1, $N = 92) = 4.35$, $p<.037$, and those reporting more complaints chose amber less and blue, straw, and pink as their "optimal color" more than those who reported fewer complaints X

(1, N = 92) = 7.12, p<.068. The results of these chi square analyses are depicted in Figures 8 and 9.

Insert Figure 9 about here

Individual Cases

An examination of all individual subjects from the poor reader group who improved 6 points or more on the post-test was performed. Seven of these subjects were in the color group, six were in the grey group, and nine were in the control group. The average improvement did not differ significantly between groups. Within the color group, three improved with straw, three with blue, one with pink, and none with amber. Of the three who improved with straw, two had asthma and reported reading or comprehension problems and one reported slow reading and photophobia. Of those who improved with blue, one reported slow reading, and one reported mild dyslexia. In the grey and control groups, five reported photophobia and two reported slow reading. Contrast sensitivity scores of these subjects did not differ from the experimental subjects in general.

Demographics

As reported earlier, 55 women and 37 men participated in the study. They fell evenly between the low and high groups, with a female/male ratio of 27/19 in the low group and 28/18 in the high group. Men and women did not differ in their color choices of overlays.

Self-reports of any learning or reading disability revealed 27.3% of women and 54.1% of men in the study felt they currently had some form of reading or learning disability. Of these, 33.3% of the women and 35% of the men chose blue as their "optimal color". Of men who reported no disability, 41% had blue also.

Discussion

The goals of this study were, first to determine whether the Irlen effect could be demonstrated in a population of high and low college readers and, assuming that it could, to determine whether contrast sensitivity plays a role in the effect. The presence of a significant level by trial interaction for reading scores indicates that subjects who scored lower to begin with were able to improve more on the second trial than those in the group of higher readers, whose average score did not go up on the second trial at all. Because this interaction occurred regardless of which group the readers were in (color, grey, or nothing), the experimental manipulations were not the cause. Because the majority of the high readers scored in the thirties and the high twenties (out of 35), it is possible that they were already doing their best and did not have much room to improve. The low readers, on the other hand, might have benefited more from practice provided by the first test, or perhaps they were in the low group because they had not done their best the first time, but were actually capable of more.

The lack of a significant group x trial interaction for the reading scores indicated that the overlays had no significant impact on reading performance; therefore, the Irlen effect was not demonstrated in this population of high and low college readers. These results correspond with Winter (1987) who also found no difference in reading performance (other than a practice effect) in a population of young reading disabled Irlen lens wearers tested with colored, gray, or no lenses. This correspondence may indicate that it is the technique and not the population which needs to be questioned. However, since Winter's study was small and problematic to begin with, this evidence alone is not enough to dismiss the technique as a whole.

On the other hand, Williams, et al. (1986) found that blurring letters, thereby reducing the contrast of high spatial frequency information, helped reading disabled subjects in a visual search task. If the overlays do work, perhaps it is due to a reduction of this high spatial frequency contrast. The results of the pilot study would support this hypothesis, as the subjects who were helped by an overlay were actually more sensitive to contrast at several spatial frequencies. This was not, however, substantiated in the main study, where good and poor readers did not differ significantly in their contrast sensitivity. The pilot study included at least one severely reading disabled individual (out of 9), although it was unfortunately much less thorough than the main experiment, which had few, if any, severely reading disabled subjects. Since no evidence of the Irlen effect was found, it was impossible to test the hypothesis that contrast sensitivity plays a part in the effect. No significant correlations were found between the spatial frequencies and the reading measures, and reading level had no significant effect on contrast sensitivity. In contrast with the findings of Lovegrove, et al. (1982) and Lovegrove, et al. (1986), contrast sensitivity did not play a significant role in the reading ability of the subjects. This could, of course, be accounted for by methodological differences in assessing contrast sensitivity. This is not to say that contrast sensitivity plays no part in the Irlen effect; it still may, but it must be tested on subjects for whom the Irlen effect is demonstrated before any conclusions can be drawn.

This study was meant to extend and improve upon previous work in this area. By testing a large body of subjects consisting of both good and poor readers, splitting the subjects into color, gray and control groups, and giving each group equal treatment, the methodological problems of many of the preceding studies in this area were overcome. The fact that subjects did not actually choose the overlay they wanted and that each subject only received one type of treatment (color, gray or none) also reduced the chance of a placebo or Hawthorne effect being a significant factor. Allowing the subjects to choose their own "optimal overlay" was the most commonly criticized aspect of other studies of the Irlen effect, and many have dismissed Irlen's technique as resulting completely from the placebo effect. It is, therefore, extremely important for future studies to be aware of this possibility and to set up appropriate control groups.

Although this study was proposed as the first step in a program of research designed to uncover the mechanism behind the Irlen effect, the results reported here indicate that a reading disabled population is needed to evaluate the effect of overlays on reading performance. Few dyslexics were found for this study, and according to Irlen, only about 50% of diagnosed dyslexics respond to the lenses and filters. Improvements on this study would include testing truly reading disabled subjects, as it is they for whom the miraculous claims often reported are about. Use of a test that provides several equivalent forms would allow measurement of each subject with several colors and grays, which also might help clarify mechanisms involved in the Irlen effect. Future research should also include several indices of visual functioning, including eye movements, dynamic contrast sensitivity, dark adaptation, and, as shown by Martin and Lovegrove (1987, 1988), flicker sensitivity. Overall, this may still be an extremely important and valid area of research, but it is recommended that future studies focus on diagnosed reading disabled subjects.

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Appendix A

Excerpt from the Nelson Denny Reading Comprehension Test

PASSAGE SIX

The convention finally completed the task of drawing up a new constitution for France in 1795. The Directory, which thus came into existence, governed the country for the next four years. In 1799, a *coup d'état* brought a successful young general, Napoleon Bonaparte (1769-1821), to power. He engineered a series of constitutions, each of which gave him greater and more absolute authority than its predecessor. Nevertheless, Napoleon continued to claim that his power rested on the will of the people and he took considerable pains to prove his popularity by holding plebiscites to ratify each of his successive constitutions.

In fact, Napoleon was in many respects a true heir to the revolution. He completed the reorganization of the laws of France (*Code Napoléon*) which translated into everyday legal practice many of the principles enunciated in general terms by revolutionary orators, e.g., freedom of contract, civil marriage and divorce, and abolition of legal discrimination between classes. The *Code Napoléon* offered a convenient model for other lands as they were brought under French influence by the victories of Napoleon's armies. Once such changes had simplified the daily routines of a region or country it proved practically impossible to restore the multiplicities and complications of the Old Regime.

25. In what year did Napoleon come to power?
- **A.** 1795
- **B.** 1799
- **C.** 1802
- **D.** 1805
- **E.** Date not mentioned

26. Napoleon was spoken of as
- **A.** a true heir to the revolution.
- **B.** a revolutionary upstart.
- **C.** the Savior of France.
- **D.** France's greatest general.
- **E.** the soldier-emperor.

27. Judging from this passage, the Old Regime would be most accurately described as
- **A.** orderly.
- **B.** fair.
- **C.** simple.
- **D.** reasonable.
- **E.** complex.

28. You would assume that Napoleon's most lasting contribution would be in the area of
- **A.** economic advances.
- **B.** public monuments.
- **C.** military strategy.
- **D.** technological development.
- **E.** legal reform.

PASSAGE SEVEN

In primitive rural societies water use was probably about 5 gallons per day per person; in the modern industrial society of the United States, household use has climbed to 60 or 70 gallons per person per day. This generous allowance is made possible by municipal water prices averaging 35 cents per 1000 gallons. Much water is wasted by excessive washing, rinsing, flushing, and sprinkling. At prevailing prices, there is little incentive for more conservative practices. Per capita use in United States cities ranges from the household average in nonindustrial communities to 175 gallons per person per day in cities where big water-using industries are located. In the United States about 340 billion gallons of water per day are drawn from all of the various sources. Divided by a population of 192 million, the total withdrawal is 1770 gallons per person per day. This does not include the water necessary to produce food, fibers, timber, etc. Maxwell estimated total per capita daily use in these terms as in excess of 15,000 gallons per day. Slightly more than half of the total withdrawn for consumption is used by industry, about 40 percent is used in agriculture (irrigation) and about 9 percent is used for municipal and rural supply.

29. Daily per capita use of water in U.S. cities is as high as
- **A.** 110 gallons.
- **B.** 125 gallons.
- **C.** 150 gallons.
- **D.** 175 gallons.
- **E.** 200 gallons.

30. In the U.S. we draw a total of about how many gallons of water a day?
- **A.** 245 billion
- **B.** 275 billion
- **C.** 290 billion
- **D.** 305 billion
- **E.** 340 billion

31. The author contrasts primitive rural society with our modern industrial society to point up
- **A.** our increasing use of water.
- **B.** the need for conservation.
- **C.** the danger of industrialization.
- **D.** the reasons for increased use of water.
- **E.** our current waste of water.

32. The author develops his point largely through
- **A.** examples.
- **B.** details.
- **C.** general statements.
- **D.** cause-effect reasoning.
- **E.** definition.

Do not stop here. Turn to page 9.

Appendix B

Portion of IDPS Used (General Indicators, Eyestrain, Photophobia)

PLEASE DO NOT WRITE ON THIS FORM!!!! Record answers on opscan.

	1 yes	2 no	3 d/k
1) While reading do you skip lines?	___	___	___
2) While reading do you use or wish you could use your fingers or any other marker to keep your place?	___	___	___
3) Do you skip words unintentionally while reading?	___	___	___
4) Do you avoid reading textbooks whenever possible?	___	___	___
5) Do other people generally read faster than you?	___	___	___
6) While reading, do you catch yourself repeating lines you have already read?	___	___	___
7) While reading do you move closer OR further from the page to see better?	___	___	___
8) Do you feel you read word by word as opposed to reading by grouping words?	___	___	___
9) When you are tired do you feel like there is a thin line between keeping the page in focus and letting it blur?	___	___	___
10) Do you feel fidgety, tired of sitting, or restless when reading?	___	___	___
11) Do you consider reading work rather than relaxing?	___	___	___
12) When taking a test that uses a "bubble in" or Scan-tron multiple choice answer sheet, do you often mark the wrong answer space if you don't constantly re-check?	___	___	___
13) Does time of day make a difference? e.g., Can you read better in the morning?	___	___	___
14) Are you unable to skim with comprehension?	___	___	___
15) Did you make significant improvement in a speed reading course?	___	___	___

	yes	no	d/k
16) While reading do your eyes feel tired or strained?	___	___	___
17) Whenever you read do you get sleepy?	___	___	___
18) While reading do you move closer to the page? blink, squint or frequently open your eyes wide?	___	___	___
19) When reading, does it take energy and effort to see the words?	___	___	___
20) Do you have difficulty reading for longer than an hour without taking breaks?	___	___	___

21) How long can you read before experiencing a sense of strain and frustration and find you must look away from the page or rest your eyes?
1 = 1 hour or more
2 = 30 - 60 minutes
3 = 16 - 30 minutes
4 = 6 - 15 minutes
5 = 1 - 5 minutes
Number _____

22) Approximate number of headaches you get per week? Number _____

23) When reading do your eyes feel dry?	___	___	___
24) While reading do your eyes become red and watery? (Not related to allergies)	___	___	___
25) While reading do your eyes feel sandy, scratchy or itchy?	___	___	___
26) While reading do your eyes hurt or ache?	___	___	___
27) While reading do you find yourself rubbing your eyes?	___	___	___
28) Do you get headaches after reading for a few hours or do you stop reading just before you sense the onset of a headache?	___	___	___

29) Number of times per week you take medication due to these headaches? Number ______

30) After watching TV, do your eyes feel tired or strained?	___	___	___

31) When copying from a blackboard do your eyes hurt, water, feel strained or tired? ___ ___ ___

32) After watching a movie in a theater do your eyes hurt, water, feel strained or tired? ___ ___ ___

33) Must you strain to read road and street signs, etc.? ___ ___ ___

34) Is reading comfortable and relaxing? ___ ___ ___

35) Do you find sunlight "too bright"? ___ ___ ___

36) Does flourescent lighting seem "too bright" or uncomfortable to read or work under? ___ ___ ___

37) Do you squint outside because the light bothers you? ___ ___ ___

38) When reading do you often adjust the lighting to make it brighter or dimmer and still feel it isn't quite right? ___ ___ ___

39) Do sunglasses feel like they reduce your vision? ___ ___ ___

40) When driving or riding in a car at night, do the lights (headlights, streetlights, etc.) bother you? ___ ___ ___

41) When riding or driving in a car at night, do the streetlights have halos around them? ___ ___ ___

42) Do you have difficulty adjusting from bright light to darkness or from darkness to bright light? ___ ___ ___

43) While reading magazines or textbooks with shiny, glossy pages, do you move the books around in order to eliminate glare? ___ ___ ___

44) Can you read comfortably in sunlight? ___ ___ ___

45) Is it difficult to see the dots on top of "i's", periods, and commas? ___ ___ ___

46) When growing up, did your parents tell you not to read in the dark and to turn the lights up? ___ ___ ___

Appendix C

General Information Questionnaire Used

SS#________________________________ Date______________

The following information is necessary for us to understand what factors are involved in reading problems and what your reading habits are. All information will be kept coded for confidentiality and will be seen only by the experimenters.

Male/Female ____ Eye color __________

Date of Birth _________ Left or Right handed? __________

Do you wear glasses or contacts? ____________________________

If yes, what problems do you wear them for?_____________________
____

When you were younger, did you ever take special classes in reading or other subjects? _______________________________________
____
____

Have you ever been diagnosed with dyslexia or other reading or learning problems? ____
____

Do you suffer from asthma? ________ Take asthma medication?_____

If yes, what and how often? ____________________________________

Are you taking any other medication? ____________

If yes, describe. ____

Do you feel you have problems with reading? ____________

If yes, describe. ____
____
____

What kind of lighting do you typically read with?

Flourescent ____________________
Incandescent __________________
Sunlight ______________________
Other (describe) _________________________

Do you find reading with any of these uncomfortable? _________

If yes, describe. ____

Do you read with a filter or overlay? ______ Describe _________
____

Appendix D

Excerpt from the Tinker Speed of Reading Test

1. Jim is shooting off his firecrackers now, as you can hear. I wish that he had done so at his own home, for it is too much music for me. 2. On his way to work one morning, Mr. Smith slipped on the ice and broke his leg. Several months went by before he was completely well and could see again. 3. The doctor told Mr. Jones that if he had more exercise he would feel better, so he went to the gymnasium where he could get all the food he needed. 4. Marcella took her mischievous and noisy little brother to the theater with her and then was ashamed of him, for he was so quiet she had to take him home. 5. The Smiths' house was so cold and drafty during the winter that it was difficult to keep warm. In order to remedy the situation, Mr. Smith bought a new refrigerator.

6. John delivered his newspapers promptly and faithfully throughout the cold winter months no matter how cold it was or how deep the snow-drifts. Few people are as lazy as this. 7. The redwoods in California with their huge trunks are among the largest trees in the world. One of them when cut down will provide a very large amount of hay. 8. Our office force is working hard this week to get some important reports ready for publication. However, none of us minds because this light work will be over very soon. 9. Bees sting only when they are bothered as they gather honey from the flowers, so when you go to pick flowers make sure first there are no ants around them. 10. The light bulb in the living room burned out, and as a party was going on, Mr. Hicks called the janitor to ask him to put a new furnace in.

11. Helen has been counting the days until her tenth birthday, and she is as delighted as can be now when she looks ahead and realizes it's only one mile away. 12. When we saw curtains at the windows and children playing in the yard of the house which had been vacant for years, we realized someone had finally burned the place. 13. Caroline could not finish writing her English examination because she forgot to fill her pen and it ran dry. Now she will remember to fill her pitcher before she begins. 14. This morning Junior was playing with his daddy's razor, and he cut himself badly with it. Now he knows that he must be careful to leave his sister's things alone. 15. Chester always envies the grown folks because they drink coffee and he must not, and he can hardly wait until he has grown up so he can drink milk too.

16. If that lively puppy does not quit chasing cars, he will get hit. This would make the children very sad because he is the nicest kitten they have ever had. 17. Jerry got a sliver in his finger and because it was not removed, it became so infected that the doctors thought they might have to cut off his whole ear. 18. We opened all of the windows to get rid of the paint smell, but for a week it bothered us for never had we smelled such a strong onion odor. 19. On the trip he took abroad, Gary went into an ancient castle over two thousand years old. He was thrilled as he could be to enter such a modern building. 20. We must be sure to teach all of the children to turn off the lights whenever they are not using them, because no one should waste water in these times.

21. Because he was ill, Carl was not elected to the class team this year. He is going to be more careful hereafter because he doesn't want to get dirty again. 22. Mark wanted to build a birdhouse for the robins, and asked Earl to show him how, but Earl could not, for he had never learned how a chair was made. 23. Eleanor was very busy each morning as she had to dress her little sister for school, but she didn't mind because she thought taking care of her flowers was fun. 24. If you want to borrow costumes for the party, you will have to ask my sister as she used them last and remembers where the dishes have been packed away. 25. We saw a big nest in the treetops when we were walking through the woods on our way home from the lake. We knew a bear must have built it.

26. While Mrs. Glass was ironing her husband's shirts, to her surprise the iron cooled off. She called the electrician immediately because her husband had to wear his shoes that evening. 27. Freight boats carry coal from the mines to distant ports where it is loaded onto trains and carried to all western cities so you and I can paint our homes. 28. The little country girl was so shy that she blushed every time she was spoken to. I felt sorry for her because everyone laughed to see how white she became. 29. If father had known I was going swimming, he would have forbidden it. He found out after I returned, and made me promise never to skate again without telling him. 30. Living on a lake in the summertime with fishing and swimming is the perfect way to spend vacations. We go out each year because we enjoy the painting so much.

31. Please be careful not to disturb the baby for he has just fallen asleep after crying steadily for four hours. The poor little thing must have sung himself to sleep. 32. "Your dress feels wet," said mother to Corrinne. "You must have fallen into the pond. Don't you know that I always expect you to stay far away from the dogs?" 33. The fountain pen I got as a graduation gift is leaking badly and I get ink all over my hands.

Appendix E

Contrast Sensitivity Data Sheet

Subject ________________ Age _____ N Acuity _____ Corr?_______

Speed _____ Comp ____ OL Speed ____ Comp ___ LD?____ EC ___

Date ________ Experimenter ___________________ OL ________

Period	Cy/Deg	Contrast Levels
25.0	2.3cy/deg	30 2 7 12 U 15 .6 3 9 4
13.5	5.7cy/deg	24 .7 2 11 3 14 U 1 5 16 .4
3.0	20.5cy/deg	8 3 6 U .5 5 2.8 5 .9 1.5 .3
17.0	3.7cy/deg	34 1 13 U 10 28 5 22 1 .9 8
165.0	0.4cy/deg	70 17 30 43 66 7 61 21 50 U 5 9 50
8.5	11.4cy/deg	33 8 11 U .8 15 3 1.4 5 20
33.5	1.7cy/deg	36 3 1 4 11 2 22 29 U 15 7
65.0	1.0cy/deg	45 9 2 23 13 U 7 4 6 31 16 11
5.0	13.5cy/deg	19 12 10 U 3 .7 2 8 5 6
100.0	0.8cy/deg	54 40 18 12 U 44 27 33 14 11
4.0	16.0cy/deg	14 5 6 .8 2 U 1 11 2
10.0	7.5cy/deg	34 20 4 6 14 U 1 9

Observed Thresholds (w/o, w/ overlay)

2.3 __________ 5.7 __________ 20.5 __________ 3.7 ___________

.4 ___________ 11.4 _________ 1.7 ___________ 1 ____________

13.5__________ .8___________ 16 ___________ 7.5 ___________

False Alarms _________________

Appendix F
Informed Consent

This study will investigate the visual abilities which are related to good and poor reading. It may require returning for an individual session to complete the study. You will receive one experimental credit for each hour you participate. You may terminate your participation in this study at any time and you will receive experimental credit for your participation to that time. There is no physical or psychological discomfort involved and, though we cannot promise any benefits, the understanding of the visual mechanisms involved in good and poor reading will play an important part in the development of corrective measures. We will fully inform you about the purpose and results of this study when you have completed your participation.

The information accumulated by this research may be used for scientific or educational purposes. It may be presented at scientific meetings and/or published and republished in professional journals or books, or used for any other purpose which Virginia Tech's Department of Psychology considers proper in the interest of education, knowledge, or research. Individual data will be coded to guarantee anonymity and will be viewed only by researchers and, if requested, the individual subject.

This project has been approved by the Virginia Tech Human Subjects Research Committee and the Instructional Review Board. If you have any questions about this research project please call:

Kathleen Thomas - Principal Investigator 552-4662
Dr. Albert M. Prestrude - Faculty Advisor 231-5673
Dr. Joseph J. Franchina - Chair, Human Subjects Committee, Psychology 231-5664
Dr. Janet Johnson - Chair, IRB 231-6077

I hearby agree to voluntarily participate in the research project described above and under the conditions described above.

____

(Signature) (Date)

________________________ ____________________

(Student number) (Experimenter)

Appendix G
ANOVA Tables

Number Correct on the Nelson Denny : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	1581.08	68	23.25		
Constant	122407.64	1	122407.64	5264.57	.000
Level	2423.94	1	2423.94	104.25	.000
Color	52.67	3	17.56	.76	.523
Group	2.32	2	1.16	.05	.951
Level by Color	25.53	3	8.51	.37	.778
Level by Group	5.78	2	2.89	.12	.883
Color by Group	92.23	6	15.37	.66	.681
Level by Color by Group	117.55	6	19.59	.84	.542

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	595.62	68	8.76		
Trial	212.80	1	212.80	24.29	.000
Level by Trial	361.71	1	361.71	41.30	.000
Color by Trial	53.80	3	17.93	2.05	.115
Group by Trial	3.39	2	1.69	.19	.825
Level by Color by Trial	7.46	3	2.49	.28	.837
Level by Group by Trial	42.38	2	21.19	2.42	.097
Color by Group by Trial	51.50	6	15.37	.66	.681
Level by Color by Group by Trial	27.90	6	4.65	.53	.783

Number Completed on the Nelson Denny : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	1384.43	68	20.36		
Constant	178541.90	1	178541.90	8769.54	.000
Level	1519.88	1	1519.88	74.65	.000
Color	90.42	3	30.14	1.48	.228
Group	21.35	2	10.67	.52	.594
Level by Color	61.81	3	20.60	1.01	.393
Level by Group	1.88	2	.94	.05	.955
Color by Group	204.51	6	34.09	1.67	.141
Level by Color by Group	254.33	6	42.39	2.08	.067

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	481.43	68	7.08		
Trial	357.22	1	357.22	50.46	.000
Level by Trial	187.03	1	187.03	26.42	.000
Color by Trial	26.89	3	8.96	1.27	.293
Group by Trial	14.67	2	7.33	1.04	.360
Level by Color by Trial	.77	3	.26	.04	.991
Level by Group by Trial	29.70	2	14.85	2.10	.131
Color by Group by Trial	90.18	6	15.03	2.12	.062
Level by Color by Group by Trial	49.09	6	8.18	1.16	.340

Reading Rate on the Nelson Denny : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	840609.72	68	12361.91		
Constant	11233648.23	1	11233648.23	908.73	.000
Level	254251.23	1	254251.29	20.57	.000
Color	30282.30	3	10094.10	.82	.489
Group	4706.90	2	2353.45	.19	.827
Level by Color	19658.06	3	6552.69	.53	.663
Level by Group	21719.07	2	10859.53	.88	.420
Color by Group	89300.68	6	14883.45	1.20	.315
Level by Color by Group	23110.09	6	3851.68	.31	.929

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	148478.05	68	2183.50		
Trial	127812.21	1	127812.21	58.54	.000
Level by Trial	45.27	1	45.27	.02	.886
Color by Trial	4986.44	3	1662.15	.76	.520
Group by Trial	1644.81	2	822.40	.38	.688
Level by Color by Trial	3740.52	3	1246.84	.57	.636
Level by Group by Trial	7589.37	2	3794.68	1.74	.184
Color by Group by Trial	8902.71	6	1483.78	.68	.667
Level by Color by Group by Trial	9502.67	6	1583.78	.73	.631

Contrast Sensitivity (0.4 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	18898.99	68	277.93		
Constant	409896.85	1	409896.85	1474.84	.000
Level	172.01	1	172.01	.62	.434
Color	670.78	3	223.59	.80	.496
Group	112.83	2	56.41	.20	.817
Level by Color	1037.66	3	345.89	1.24	.300
Level by Group	190.15	2	95.08	.34	.711
Color by Group	641.65	6	106.94	.38	.886
Level by Color by Group	1651.42	6	275.24	.99	.439

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	4485.69	68	65.97		
Trial	722.17	1	722.17	10.95	.002
Level by Trial	12.55	1	12.55	.19	.664
Color by Trial	262.83	3	87.61	1.33	.272
Group by Trial	76.37	2	38.18	.58	.563
Level by Color by Trial	243.67	3	81.22	1.23	.305
Level by Group by Trial	39.46	2	19.73	.30	.742
Color by Group by Trial	217.48	6	36.25	.55	.769
Level by Color by Group by Trial	128.75	6	21.46	.33	.922

Contrast Sensitivity (0.8 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	5569.11	68	81.90		
Constant	76324.26	1	76324.26	931.94	.000
Level	47.70	1	47.70	.58	.448
Color	109.39	3	36.46	.45	.721
Group	439.61	2	219.81	2.68	.076
Level by Color	127.50	3	42.50	.52	.671
Level by Group	298.34	2	149.17	1.82	.170
Color by Group	864.16	6	144.03	1.76	.212
Level by Color by Group	797.60	6	132.93	1.62	.154

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	1634.64	68	24.04		
Trial	31.90	1	31.90	1.33	.253
Level by Trial	5.60	1	5.60	.23	.631
Color by Trial	132.69	3	44.23	1.84	.148
Group by Trial	10.40	2	5.20	.22	.806
Level by Color by Trial	146.24	3	48.75	2.03	.118
Level by Group by Trial	110.11	2	55.05	2.29	.109
Color by Group by Trial	335.26	6	55.88	2.32	.042
Level by Color by Group by Trial	104.46	6	17.41	.72	.632

Contrast Sensitivity (1 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	1500.59	68	22.07		
Constant	17059.01	1	17059.01	773.04	.000
Level	34.42	1	34.42	1.56	.216
Color	56.68	3	18.89	.86	.468
Group	92.04	2	46.02	2.09	.132
Level by Color	44.82	3	14.94	.68	.569
Level by Group	99.37	2	49.68	2.25	.113
Color by Group	103.96	6	17.33	.79	.585
Level by Color by Group	137.84	6	22.97	1.04	.407

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	241.96	68	3.56		
Trial	.54	1	.54	.15	.698
Level by Trial	1.86	1	1.86	.52	.472
Color by Trial	23.29	3	7.76	2.18	.098
Group by Trial	5.05	2	2.53	.71	.495
Level by Color by Trial	12.27	3	4.09	1.15	.336
Level by Group by Trial	4.40	2	2.20	.62	.542
Color by Group by Trial	14.82	6	2.47	.69	.655
Level by Color by Group by Trial	6.46	6	1.08	.30	.933

Contrast Sensitivity (1.7 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	277.37	68	4.08		
Constant	1244.64	1	1244.64	305.13	.000
Level	.46	1	.46	.11	.738
Color	5.03	3	1.68	.41	.746
Group	5.81	2	2.91	.71	.494
Level by Color	8.65	3	2.88	.71	.551
Level by Group	18.21	2	9.10	2.23	.115
Color by Group	38.68	6	6.45	1.58	.166
Level by Color by Group	7.11	6	1.18	.29	.940

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	111.11	68	1.63		
Trial	.01	1	.01	.00	.952
Level by Trial	.79	1	.79	.48	.489
Color by Trial	.97	3	.32	.20	.898
Group by Trial	4.30	2	2.15	1.32	.275
Level by Color by Trial	8.79	3	2.93	1.79	.157
Level by Group by Trial	.07	2	.04	.02	.978
Color by Group by Trial	3.49	6	.58	.36	.904
Level by Color by Group by Trial	12.75	6	2.12	1.30	.269

Contrast Sensitivity (2.3 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	179.75	68	2.64		
Constant	1630.67	1	1630.67	616.90	.000
Level	.01	1	.01	.01	.943
Color	6.03	3	2.01	.76	.520
Group	.34	2	.17	.07	.937
Level by Color	.33	3	.11	.04	.989
Level by Group	5.28	2	2.64	1.00	.374
Color by Group	9.79	6	1.63	.62	.716
Level by Color by Group	15.14	6	2.52	.95	.463

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	65.08	68	.96		
Trial	4.40	1	4.40	4.60	.036
Level by Trial	.04	1	.04	.04	.837
Color by Trial	3.07	3	1.02	1.07	.367
Group by Trial	4.78	2	2.39	2.50	.090
Level by Color by Trial	.85	3	.28	.30	.828
Level by Group by Trial	.46	2	.23	.24	.785
Color by Group by Trial	4.50	6	.75	.78	.585
Level by Color by Group by Trial	2.87	6	.48	.50	.807

Contrast Sensitivity (3.7 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	265.82	68	3.91		
Constant	405.46	1	405.46	103.72	.000
Level	.01	1	.01	.00	.969
Color	2.11	3	.70	.18	.910
Group	1.92	2	.96	.25	.782
Level by Color	4.79	3	1.60	.41	.747
Level by Group	16.62	2	8.31	2.13	.127
Color by Group	38.51	6	6.42	1.64	.149
Level by Color by Group	10.73	6	1.79	.46	.837

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	76.14	68	1.12		
Trial	.72	1	.72	.65	.425
Level by Trial	1.07	1	1.07	.95	.333
Color by Trial	7.37	3	2.46	2.20	.097
Group by Trial	9.70	2	4.85	4.33	.017
Level by Color by Trial	9.00	3	3.00	2.68	.054
Level by Group by Trial	4.38	2	2.19	1.96	.149
Color by Group by Trial	6.44	6	1.07	.96	.460
Level by Color by Group by Trial	4.50	6	.75	.67	.675

Contrast Sensitivity (5.7 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	133.09	68	1.96		
Constant	851.74	1	851.74	435.17	.000
Level	.40	1	.40	.20	.654
Color	5.60	3	1.87	.95	.419
Group	2.41	2	1.20	.61	.544
Level by Color	.10	3	.03	.02	.997
Level by Group	4.94	2	2.47	1.26	.290
Color by Group	4.81	6	.80	.41	.870
Level by Color by Group	8.78	6	1.46	.75	.613

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	32.43	68	.48		
Trial	.49	1	.49	1.03	.313
Level by Trial	.63	1	.63	1.32	.255
Color by Trial	4.02	3	1.34	2.81	.046
Group by Trial	.94	2	.47	.98	.380
Level by Color by Trial	.23	3	.08	.16	.923
Level by Group by Trial	.52	2	.26	.54	.583
Color by Group by Trial	2.80	6	.47	.98	.447
Level by Color by Group by Trial	.69	6	.11	.24	.962

Contrast Sensitivity (7.5 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	426.78	68	6.28		
Constant	1640.18	1	1640.18	261.33	.000
Level	1.85	1	1.85	.29	.589
Color	10.99	3	3.66	.58	.628
Group	25.59	2	12.79	2.04	.138
Level by Color	7.47	3	2.49	.40	.756
Level by Group	13.24	2	6.62	1.06	.354
Color by Group	43.39	6	7.23	1.15	.342
Level by Color by Group	11.19	6	1.87	.30	.936

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	177.32	68	2.61		
Trial	4.10	1	4.10	1.57	.214
Level by Trial	1.14	1	1.14	.44	.511
Color by Trial	18.16	3	6.05	2.32	.083
Group by Trial	1.65	2	.82	.32	.731
Level by Color by Trial	5.97	3	1.99	.76	.519
Level by Group by Trial	2.61	2	1.31	.50	.608
Color by Group by Trial	22.33	6	3.72	1.43	.217
Level by Color by Group by Trial	23.18	6	3.86	1.48	.198

Contrast Sensitivity (11.4 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	395.72	68	5.82		
Constant	952.08	1	952.08	163.60	.000
Level	10.88	1	10.88	1.87	.176
Color	26.49	3	8.83	1.52	.218
Group	9.92	2	4.96	.85	.431
Level by Color	3.44	3	1.15	.20	.898
Level by Group	13.51	2	6.75	1.16	.319
Color by Group	41.45	6	6.91	1.19	.324
Level by Color by Group	13.80	6	2.30	.40	.880

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	76.21	68	1.12		
Trial	.66	1	.66	.59	.446
Level by Trial	.05	1	.05	.04	.836
Color by Trial	.67	3	.22	.20	.896
Group by Trial	1.31	2	.65	.58	.560
Level by Color by Trial	2.66	3	.89	.79	.502
Level by Group by Trial	1.36	2	.68	.61	.547
Color by Group by Trial	6.21	6	1.04	.92	.484
Level by Color by Group by Trial	2.01	6	.34	.30	.935

Contrast Sensitivity (13.5 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	2090.04	68	30.74		
Constant	3159.37	1	3159.37	102.79	.000
Level	5.92	1	5.92	.19	.662
Color	22.61	3	7.54	.25	.864
Group	45.35	2	22.67	.74	.482
Level by Color	240.26	3	80.09	2.61	.059
Level by Group	11.35	2	5.68	.18	.832
Color by Group	26.00	6	4.33	.14	.990
Level by Color by Group	50.73	6	8.46	.28	.947

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	513.79	68	7.56		
Trial	3.98	1	3.98	.53	.470
Level by Trial	6.32	1	6.32	.84	.364
Color by Trial	51.37	3	17.12	2.27	.089
Group by Trial	22.37	2	11.18	1.48	.235
Level by Color by Trial	1.30	3	.43	.06	.982
Level by Group by Trial	.03	2	.01	.00	.998
Color by Group by Trial	16.60	6	2.77	.37	.898
Level by Color by Group by Trial	70.14	6	11.69	1.55	.176

Contrast Sensitivity (16 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	3059.76	68	45.00		
Constant	4405.88	1	4405.88	97.92	.000
Level	36.46	1	36.46	.81	.371
Color	55.67	3	18.56	.41	.745
Group	35.81	2	17.90	.40	.673
Level by Color	428.78	3	142.93	3.18	.030
Level by Group	7.18	2	3.59	.08	.923
Color by Group	106.42	6	17.74	.39	.880
Level by Color by Group	37.62	6	6.27	.14	.991

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	452.61	68	6.66		
Trial	.16	1	.16	.02	.879
Level by Trial	11.30	1	11.30	1.70	.197
Color by Trial	22.09	3	7.36	1.11	.353
Group by Trial	4.29	2	2.14	.32	.726
Level by Color by Trial	12.78	3	4.26	.64	.592
Level by Group by Trial	13.93	2	6.96	1.05	.357
Color by Group by Trial	5.16	6	.86	.13	.992
Level by Color by Group by Trial	76.64	6	12.77	1.92	.090

Contrast Sensitivity (20.5 cy/deg) : Level, Color, Group and Trial

Between Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	203.07	68	2.99		
Constant	9696.30	1	9696.30	3246.83	.000
Level	.09	1	.09	.03	.861
Color	1.92	3	.64	.21	.886
Group	6.08	2	3.04	1.02	.367
Level by Color	8.47	3	2.82	.95	.424
Level by Group	3.51	2	1.75	.59	.558
Color by Group	12.47	6	2.08	.70	.654
Level by Color by Group	8.32	6	1.39	.46	.832

Within Subjects Effects

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	63.98	68	.94		
Trial	5.55	1	5.55	5.89	.018
Level by Trial	1.29	1	1.29	1.37	.245
Color by Trial	6.69	3	2.23	2.37	.078
Group by Trial	2.47	2	2.24	1.31	.275
Level by Color by Trial	1.78	3	.59	.63	.598
Level by Group by Trial	.66	2	.33	.35	.705
Color by Group by Trial	3.71	6	.62	.66	.685
Level by Color by Group by Trial	2.47	6	.41	.44	.851

Table 1

Mean reading scores for pilot subjects

	No Overlay		Overlay		Total	
Scores	Mean	Sd	Mean	Sd	Mean	Sd
Comprehension	26.6	6.48	27.1	4.86	26.8	8.1
Reading Rate	244	109	278.8	76.6	261.44	136

Table 2

Assignment chart for groups: A=Color, B=Grey, C=Nothing

Preferred Overlay	Blue	Pink	Amber	Straw
	A	B	C	A
	B	C	A	B
	C	A	B	C
	A	B	C	A
	B	C	A	B
	C	A	B	C
Group Assigned to	A	B	C	A
	B	C	A	B
	C	A	B	C
	A	B	C	A
	B	C	A	B
	C	A	B	C
	A	B	C	A
	B	C	A	B

Table 3

Mean pre and post reading scores for 92 subjects on Nelson Denny Reading Test

	Pre Trial		Post Trial	
Scores	Mean	Sd	Mean	Sd
Correct	25.47	6.02	27.51	5.13
Completed	30.55	5.68	33.38	4.42
ReadingRate	224.90	83.29	278.96	96.24

Table 4

Mean pre and post reading scores by reading level (high/low)

	Pre		Post	
# Correct	Mean	Sd	Mean	Sd
Low (N=46)	20.28	3.5	25.02	5.49
High (N=46)	30.65	2.49	30	3.22
# Completed	Mean	Sd	Mean	Sd
Low	26.41	5.04	31.30	5.31
High	34.70	2.17	35.46	1.56
Reading Rate	Mean	Sd	Mean	Sd
Low	187.83	68.56	241.74	79.39
High	261.98	80.74	316.17	97.97

Table 5.

Mean pre and post Nelson Denny reading scores by group (color, grey, nothing)

	Pre		Post	
# Correct	Mean	Sd	Mean	Sd
Color Group	25.39	5.93	27.32	5.61
Grey Group	25.19	5.86	27.07	5.41
Nothing	25.83	6.47	28.17	4.36
# Completed	Mean	Sd	Mean	Sd
Color Group	30.16	5.75	33.67	4.46
Grey Group	30.26	5.66	32.42	5.00
Nothing	31.27	5.67	34.07	3.64
Reading Rate	Mean	Sd	Mean	Sd
Color Group	221.84	91.90	275.00	104.90
Grey Group	215.61	87.37	278.48	106.28
Nothing	237.67	69.75	283.53	77.20

Figure Captions

Figure 1. How the addition of an overlay improves the contrast ratio of print. Without an overlay, the ambient light (500 cd) reflects back from the light and dark elements of print (80% and 20%). The reflected values are added to the ambient light value. These are plugged into the equation (Imax - I min)/(Imax + I min) (Campbell & Maffei, 1974) to find the contrast value. Taking the inverse of this equation allows us to compare contrast levels of print with and without an overlay, which reduces light as it passes through twice. In this case, the addition of a 50% transmission overlay triples the contrast level (personal communication with Harry Snyder, 1992).

Figure 2. Contrast sensitivity of pilot subjects who improved with the overlays versus those who did not.

Figure 3. Spectral curves for the 4 tinted overlays used, provided by Edmund Scientific.

Figure 4. Change scores for number correct on the Nelson Denny comprehension test for high and low reading levels.

Figure 5. Pre and post contrast sensitivity of all experimental subjects.

Figure 6. Contrast Sensitivity of subjects whose comprehension (number correct) improved with an overlay versus those who did not.

Figure 7. Contrast Sensitivity of Low and High Readers.

Figure 8. Relative IDPS scores of low and high reading levels.

Figure 9. "Optimal colors" of low and high IDPS scorers.

How an Overlay Improves the Contrast Ratio of Print

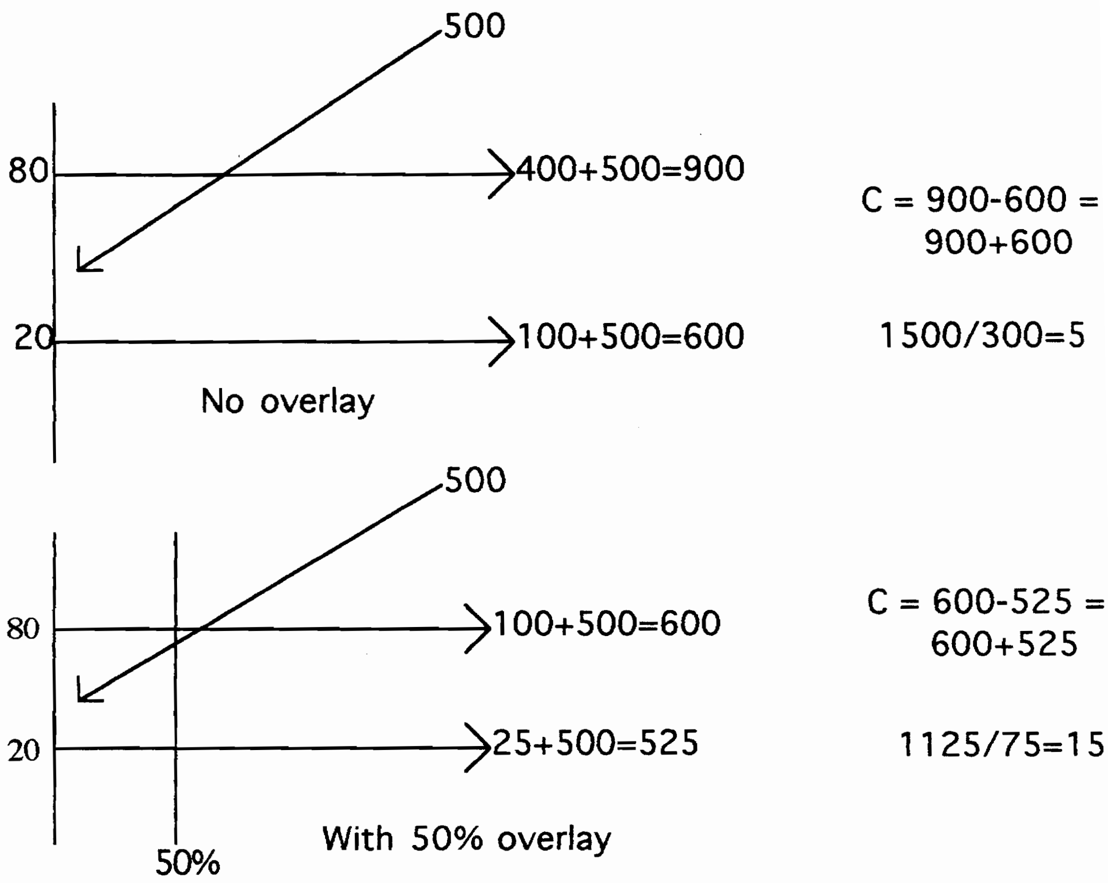

Figure 1. How the addition of an overlay improves the contrast ratio of print.

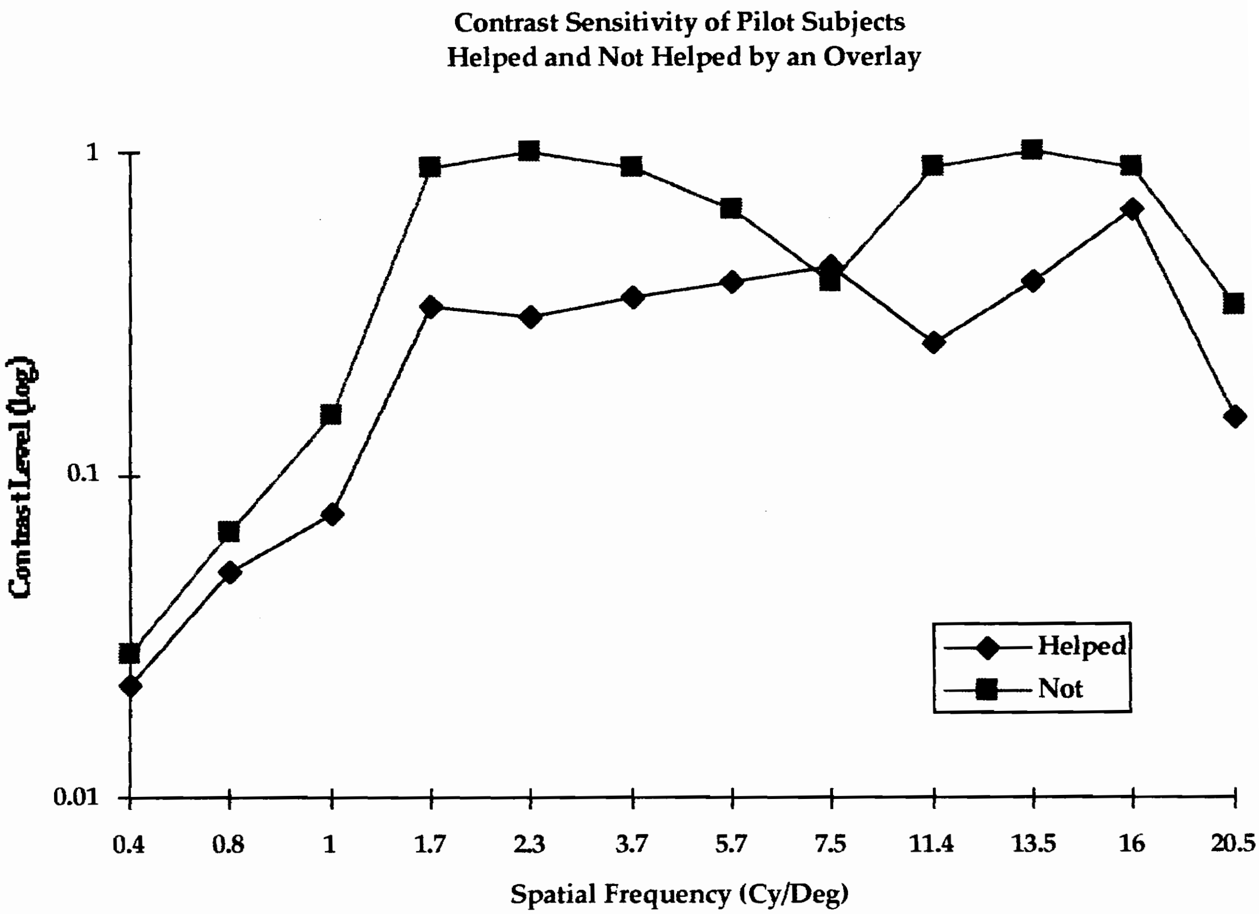

Figure 2. Contrast sensitivity of pilot subjects helped and not helped by an overlay.

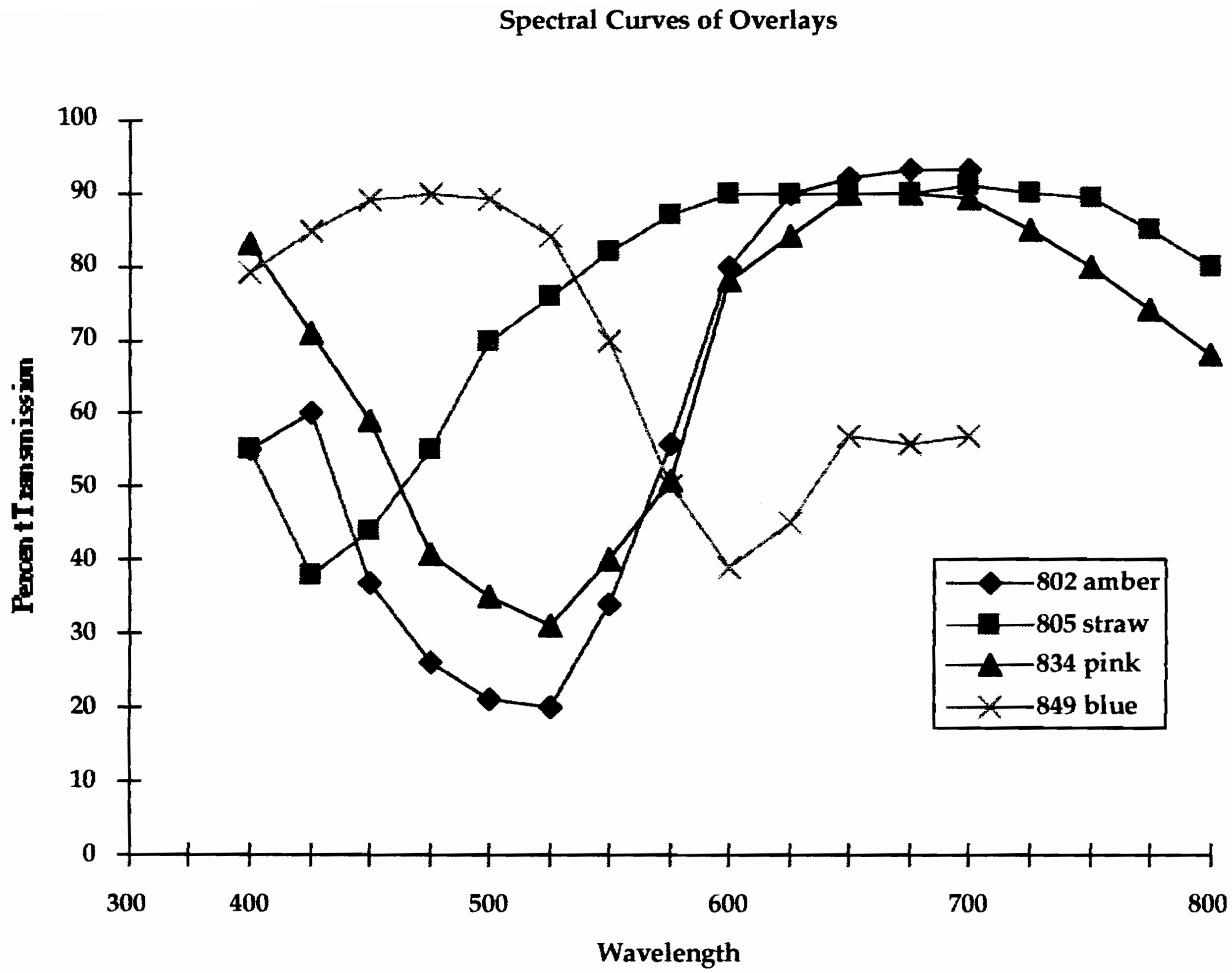

Figure 3. Spectral curves of overlays.

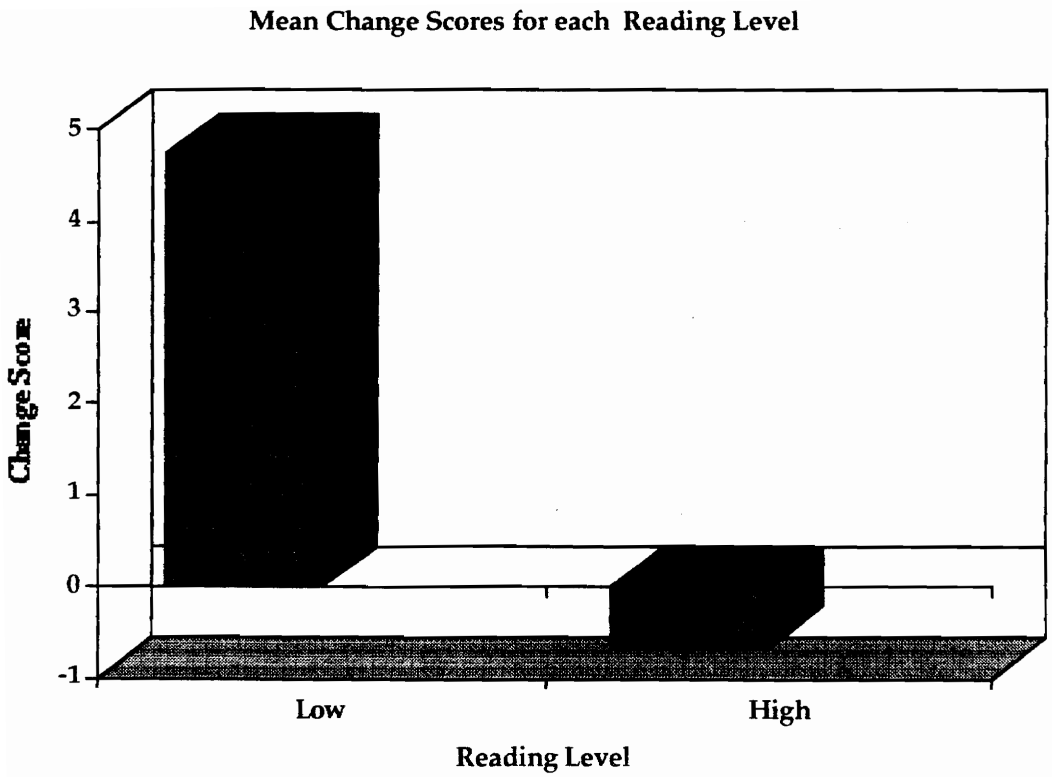

Figure 4. Mean change scores for high and low readers.

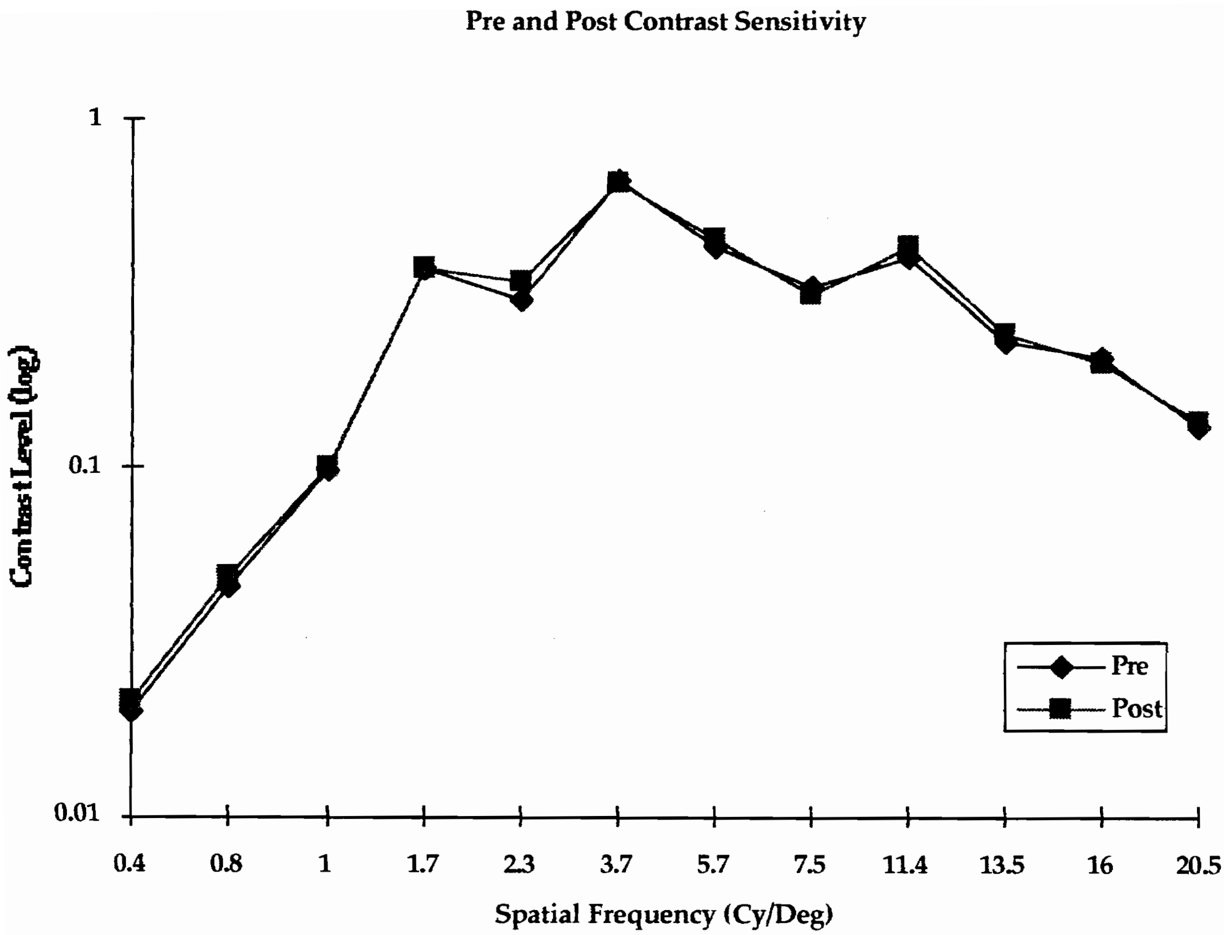

Figure 5. Pre and post contrast sensitivity.

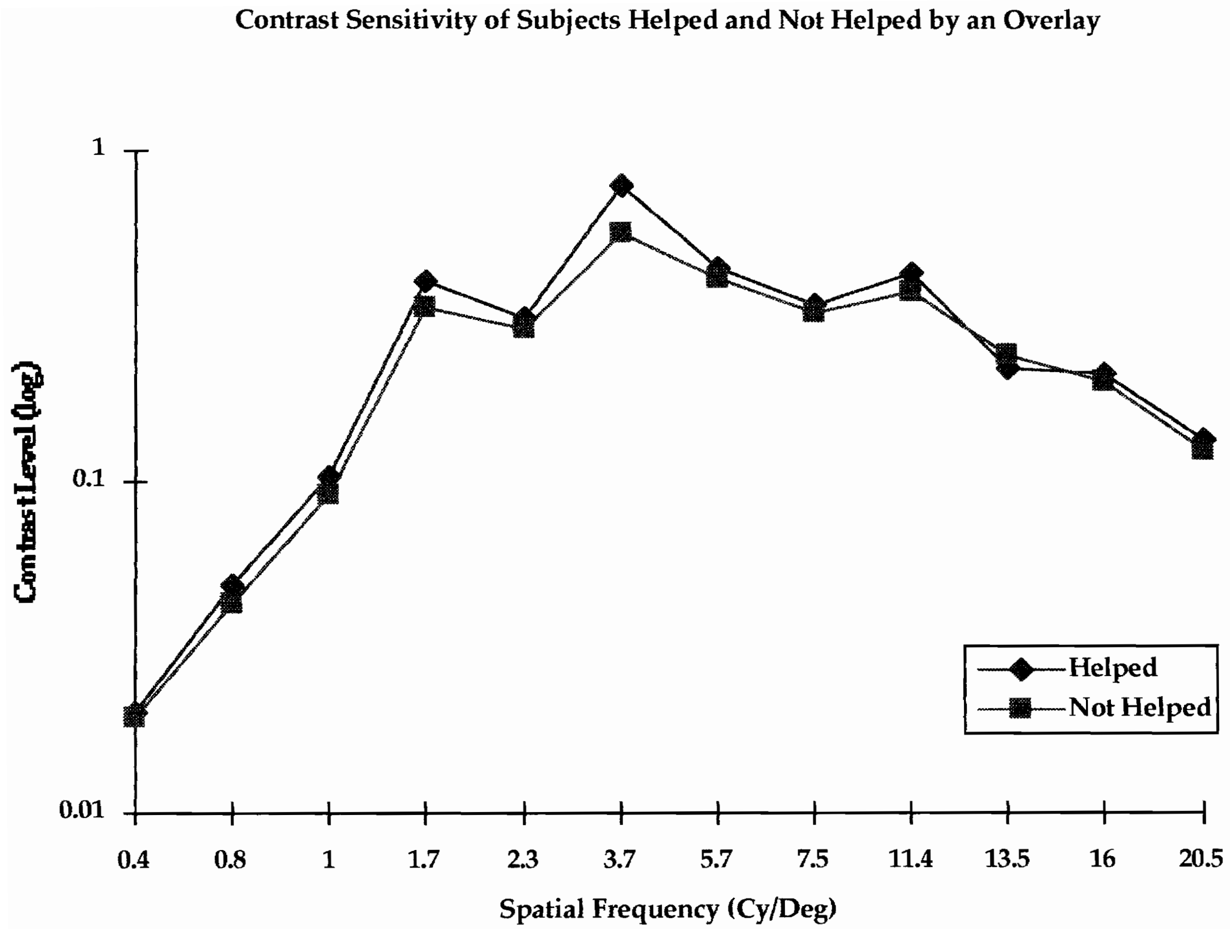

Figure 6. Contrast Sensitivity of Subjects Helped and Not Helped by an Overlay.

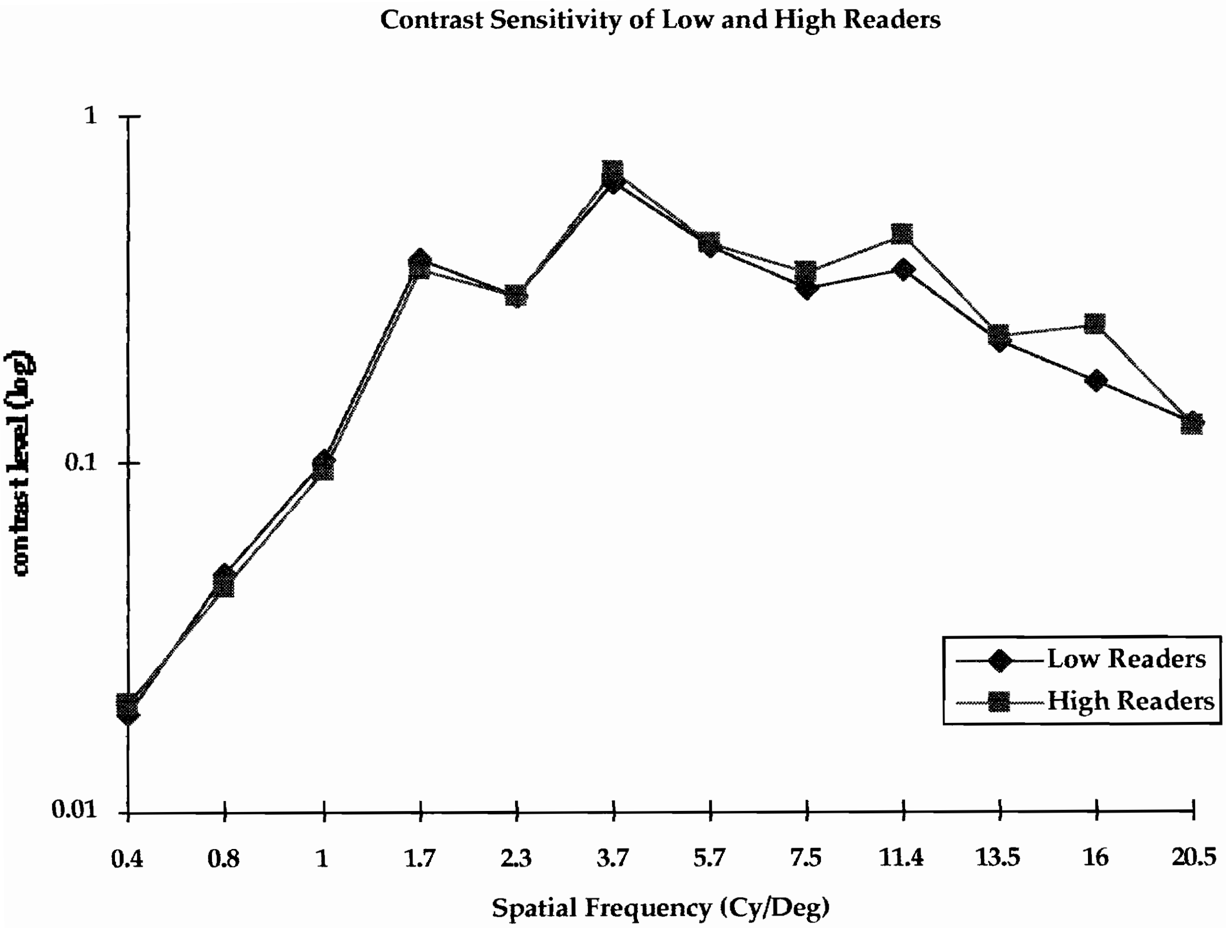

Figure 7. Contrast sensitivity of high and low readers

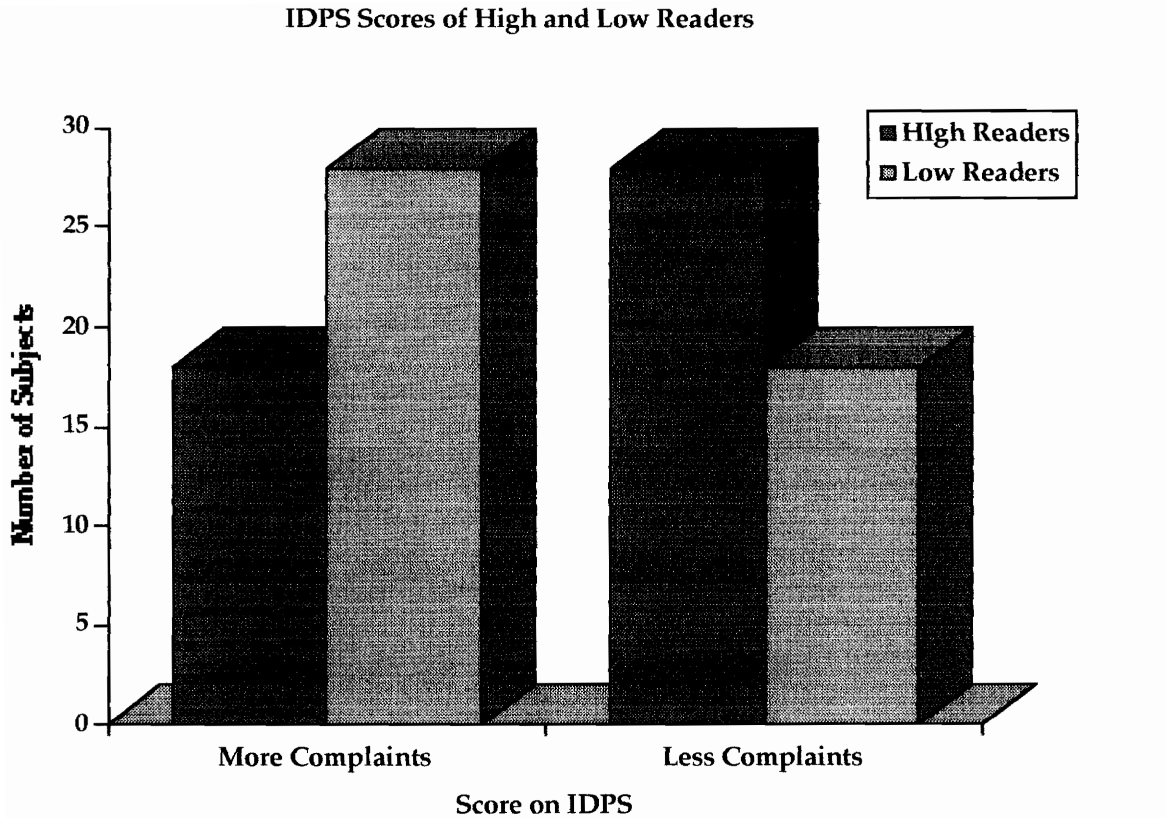

Figure 8. IDPS Scores of High and Low Readers

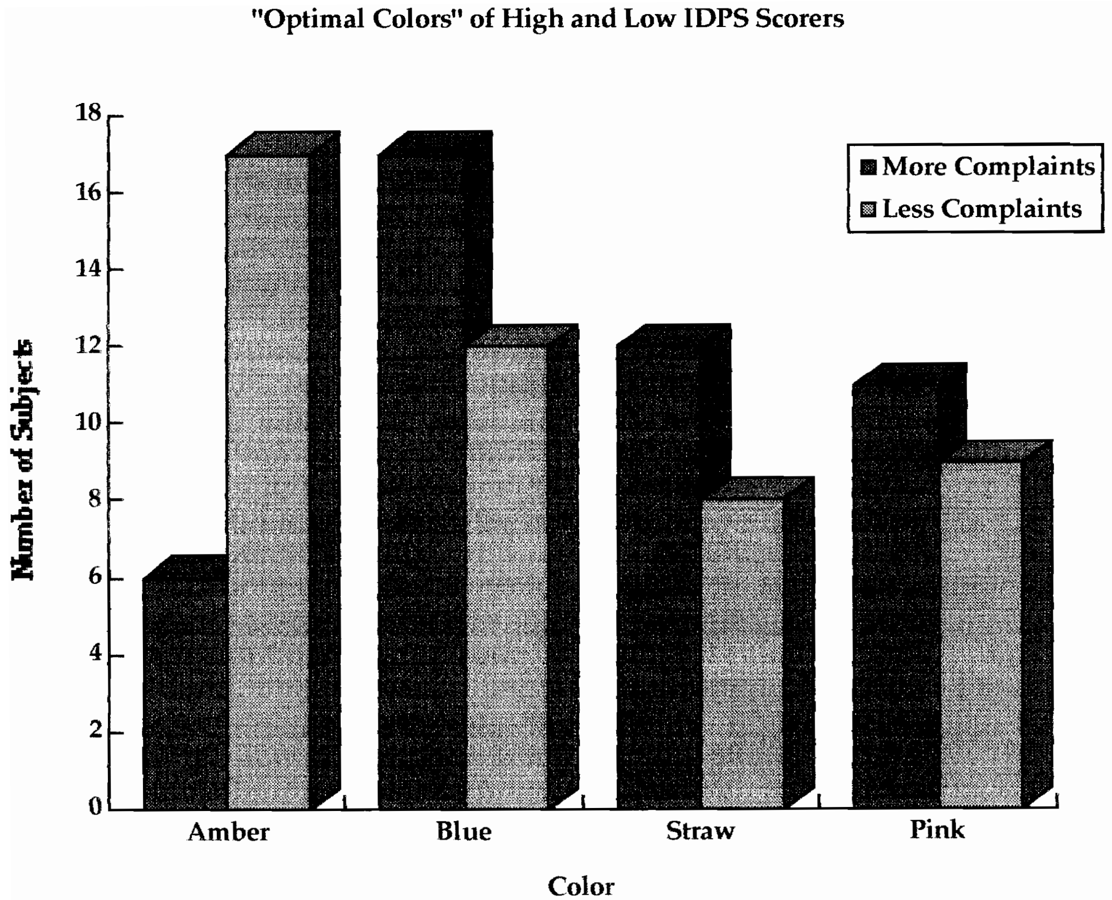

Figure 9. "Optimal Colors" of High and Low IDPS Scorers

VITA

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EDUCATION:

Virginia Polytechnic Institute and State University
Blacksburg, Virginia
Master of Science Degree in Psychology, Spring, 1994.
Concentration: Applied Experimental Psychology

Thesis Title: Do Colored Overlays Improve Reading? A Test of the Irlen Effect

Villanova University
Villanova, Pennsylvania
Bachelor of Arts Degree in Psychology, May 1991.
Minor: Biology

TEACHING EXPERIENCE:

Virginia Polytechnic Institute and State University
Instructor
Physiological Psychology Lab, Spring 1994.
Duties included all planning, instruction and evaluation for two sections made up of 31 upper-level Psychology majors. Techniques taught included measurement of galvanic skin response, electrocardiography, skin temperature, peripheral blood flow, electromyography, electroencephalography, and various biofeedback techniques. Further duties included leading the students in the dissection of sheep brains, and guiding them in the proposal, execution, and report of their own research projects using the above techniques.

Graduate Teaching Assistant
Cognitive Psychology, Fall 1993.
Helen J. Crawford, Ph. D, supervisor
Duties included assisting Dr. Crawford in the daily management of the class, attending lectures, grading assignments and exams, lecturing when Dr. Crawford was absent, preparing audio-visual presentations, and meeting with students requesting extra help.

Graduate Teaching Assistant
Social Psychology, Spring 1993.
Denise Martz, M.S. and Jen Wertz, M.S., supervisors
Served as Teaching Assistant for two sections of undergraduate social psychology. Duties included assisting Ms. Martz and Ms. Wertz in grading of exams and papers and filling in for them when they could not lecture.

Graduate Teaching Assistant
Sensation and Perception, Fall 1992.
Albert M. Prestrude, Ph. D, supervisor
Duties included attending lectures, assisting Dr. Prestrude in the daily management of the class, grading quizzes and exams, and meeting with and arranging study groups for students needing help.

Graduate Teaching Assistant
Introductory Psychology Lab, Fall 1991- Spring 1992.
Taught five sections of introductory psychology labs of approximately 40 students each (two labs in fall, three in spring). Responsibilities included lesson planning, stimulating discussion among students, assigning and grading papers and other outside assignments and experiments, and administering quizzes and tests.

RESEARCH EXPERIENCE:

NASA Langley Aerospace Research Center
LARSS research - Alan Pope, Ph. D, supervisor
Designed and implemented a study aimed at detecting changes in EEG and reaction time during various levels of task engagement. Future applications might include cockpit feedback systems which will alert pilots when their attention begins to wane.

LARC research - Alan Pope, Ph. D, supervisor
Assisted members of the Human Automation and Integration Branch in their study of the physiological and verbal reactions of pilots to experimental cockpit applications during simulated flight. Assisted with setup and physiological monitoring of subjects.

Virginia Polytechnic Institute and State University

Sniffer Dog Research - Albert M. Prestrude, Ph. D (Chair)
Founding member of Sniffer Dog Research Program. Recruited and trained dogs in basic obedience and to detect various chemicals. (Currently in progress).

Thesis Research - Albert M. Prestrude, Ph. D (Chair)
Designed and implemented a study to test the relationship of the Irlen Effect, (which states that the placement of a colored overlay over print will improve the reading performance of reading disabled individuals), to the visual measure of contrast sensitivity.

Villanova University

Independent Research - Chip Folk, Ph. D, supervisor
Designed and implemented a study to assess the role that depth and color play in attention to visual information like that found in the cockpit.

Research Asst. - Loretta Rieser-Danner, Ph. D, supervisor
Assisted Dr. Rieser-Danner in recruiting and running subjects in her study of the reactions of infants to alarming human and non-human stimuli.

EQUIPMENT EXPERIENCE:

Cadwell EEG equipment
Lexicor EEG equipment
JNJ physiological monitoring equipment
Colbourne bioamplifier equipment
LC Technologies eyegaze system
LabView software
SAS and SPSS statistical software
Various word processing and graphics softwares