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Abstract
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PATIENT SYMPTOMS, NEAR POINT VISUAL RESPONSES, AND OPTIMUM PRINT SIZE IN EDUCATIONAL READING MATERIALS

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TABLE OF CONTENTS

ABSTRACT:

This study was triggered by the observations of a private practitioner with an interest in vision and reading. Those observations centred around various symptoms patients reported when reading, and the observation of the onset or progression of myopia (nearsightedness) that occurred in an environment where reading was considered very important, ie: academic settings in particular.

The goal was to study subjects under conditions similar to their normal reading environment, and measure changes in specific visual responses, symptoms, and ease of reading in three different treatment conditions wherein only the size of the print used was changed.

Twenty-seven first year optometry students between the ages of 22 and 25 years volunteered for the project. Each one read a different print size, ie: 6 point, 10 point or 16 point size, for one continuous hour, three evenings in a row. A pre-test questionnaire regarding symptoms and average amount of time reading per day was given to each subject at the outset of the study. Findings for visual acuity at distance, phoria at near, and accommodative facility at near were taken prior to each experimental condition. A post-test questionnaire and the same visual findings were then repeated after each treatment condition. I had hypothesized that the 16 point print would be easiest to read, produce the fewest subjective symptoms, and trigger the least amount of esoward phoria shift or loss of accommodative facility than either the 10 or 6 point prints.

My results indicated that larger print (ie: 16pt vs 10pt vs 6pt) was significantly easier to read, and produced significantly fewer complaints of eyestrain, blur at far and blur at near. The data produced no significant changes in phoria between print sizes, but very significant esoward changes in phoria measures pre-post testing for each print size. A significant reduction in accommodative facility also occurred pre-post testing for the 6 and 16 point print, but there was no significant difference between the print sizes. More investigation is needed both in the age group studied here and in children. Findings may suggest that print standards presently in use are in need of upgrading.

INTRODUCTION:

Since books became a viable entity for reproducing and storing words and verbal language, learning and education have been highly dependent on the skill of reading. In developed countries such as Canada and the United States, this became particularly common in the 20th century.

Within such a developed society where reading is commonplace and necessary, individuals report various symptoms that relate to reading. Complaints that are reported include, but are not limited to: eye strain, blur at far or near, loss of place when reading, difficulties with comprehension, and double vision.

These symptoms are reported in the literature and textbooks, and the observations have been made, and clinically documented personally by myself over a period of greater than twenty-five years in private optometric practices in western Canada.

Within the time that I was in private practice, another observation that I made was the prevalence of myopia (nearsightedness) was common, as expected, but I became aware that its presence occurred not only within the typical onset ages of six - seven years or eleven - twelve years, but that it would also occur quite often in the late teens and early to mid-twenties. An example of this that really got my attention and has "stuck with me" is the late onset of myopia that occurred with three of my cousins. All three are male members of the same family, (one other brother and two sisters) who joined the Royal Canadian Mounted Police force at separate times, but each in his late teens or early twenties. None of them wore glasses at the time of entrance, but every one became mildly myopic sometime subsequent to or during his 10 month training period.

In the same vein, other patients reported observing that they could see better when they were out away from work on weekends than when at their office jobs or at school. One that I remember since it occurred early in my practice years was a dramatic reduction in spectacle prescription for nearsightedness in a person who had moved to the Columbia Valley and quit teaching for a less stressful and more outdoor oriented lifestyle. Many, many patients who were students typically had their myopia continue to increase in amount over the years, no matter what their age. And, contrary to the expected that we become less myopic, I saw numerous myopes in their beginning presbyopic

years of the late thirties to late fourties who became more myopic; myself and a friend of mine being just two of those examples.

The common visual thread in these patient complaints and myopia onset, seemed to be related to near point use of the eyes, use of the eyes in "mentally stressful" environments, and particularly use of the eyes for studying or reading. Computer usage in the last decade and a half would be added to the list, but it is, of course, another form of reading.

All of these clinical experiences led me to the search for "why?" So, I acquired extensive information on vision and reading, and vision and learning difficulties[1]. Visual acuity, refractive error, binocular, accommodative, and ocular motility deficits were among the topics. Visual electrophysiology, visual perception and processing, effects of visual training, sensitivity to contrast, and the effects of different colours on vision and reading were also discussed.

Descriptions of the visual symptomatology associated with reading is encountered within many of these same articles and in a host of others. A significant clinical reference for symptomatology and its associated causes is Scheiman and Wick's book *Clinical Management of Binocular Vision* [2]. In addition to the symptoms I have previously mentioned, (ie: eyestrain, blur at far, blur at near, loss of place when reading, difficulties with comprehension, and double vision) symptoms such as headache, inability to sustain near point work, poor concentration, words appearing to move, skipping lines, and slow reading are also listed.

Visual conditions associated with these various symptoms find binocular, accommodative and ocular motility dysfunction to be high on the list. Refractive errors, especially hyperopia, astigmatism, or anisometropia/aniseikonia account for other major non-pathological visual factors associated with symptoms during reading.

Over the same time period, I collected articles on myopia[3]. The common topics discussed were causes and expected progression of myopia, control and prevention of myopia, the role of near work in myopia onset, and the relationship of the accommodative system, vergence system and phoria measures prior to and during myopic changes. The role of the cornea and influence of emmetropization in myopia development were explored.

During this literature search, I encountered a book, *Optometric Management of Nearpoint Vision Disorders* by Martin H. Birnbaum[4]. This text, published in 1993, has extensive and comprehensive references on the topic of myopia development, was inspired by the very same clinical observations which had confused and confounded me, and became one of my primary sources for the clinical visual response signs that I would investigate in my research.

Birnbaum's opening sentences in his Preface to *Optometric Management of Nearpoint Vision Disorders* read like this: "When I entered optometric practice in 1962, I encountered many clinical phenomena that seemed inconsistent with what I had learned in school. I saw patients who developed myopia at age 19 or 20, well past the age at which I had been taught that myopia progression usually ceases. I saw patients with asthenopic symptoms, but no apparent visual problem, and others with severe functional vision disorder, but no symptoms. I saw patients who demonstrated exophoria on cover test, but showed esophoria on the von Graefe phoria measure, esophoric shifts during cheiroscopic tracing, or esophoric fixation disparity. I saw patients with convergence insufficiency who shifted into esophoria and convergence excess as vision therapy proceeded. I saw patients with reading or learning difficulties who wished to determine whether vision disorder might be a cause; although I frequently found no significant vision disorder, I was not confident that my knowledge was sufficient to rule out vision-related factors. As a consequence of these experiences, I felt insecure and inadequate. Since I was resolved to provide the very best care possible, I sought to expand my understanding of vision in order to resolve these uncertainties and be better able to care for patients." [5]

Birnbaum contends, as do many sources, that myopia is related to the prolonged use of the eyes for near visual tasks, reading being a major player in this field since it is such a critical part of our society. "Two major near-work theories exist: the *use-abuse* theory and *Skeffington's nearpoint stress* theory. The use-abuse theory is specific to myopia, attributing myopia to abuse of the visual system caused by excessive use of the eye for close work. Skeffington's model..... holds that not only myopia, but also a broad variety of vision disorders occur because the nearpoint tasks imposed by our culture are incompatible with human physiology."[6]

It was not my purpose in this paper to review the details of the all the theories on myopia and its relation to near use of the eyes, but rather, based on the literature and my own observations, to assume that there is a connection, and then to explore clinically some feature of the reading task, especially as it

relates to materials used in education, that may produce symptoms and/or responses that match those theorized to be clinical signs of nearpoint stress.

According to Birnbaum, "Signs of nearpoint stress include the following:

- skews and constrictions in the phoria, vergence, and accommodative findings;
- esophoria, orthophoria, or less than the desirable exophoria at near;
- exophoria at near greater than normal;
- shifts toward overconvergence during sustained nearpoint activity;
- absorption of the desirable low hyperopic buffer, with shifts toward emmetropia, myopia, or adverse high hyperopia;
- low positive relative accommodation (PRA) finding;
- asthenopia during near-vision tasks;
- avoidance of near work;
- maintenance of an exceptionally close near-working distance."[7]

Goss, Christensen et al, and Fulk and Cyert did studies which support esophoria at near as a pre-myopia onset or progression finding. Goss also found evidence for a lowered PRA as a sign of pre-myopic change. "Children who develop juvenile onset myopia tend to have lower PRA findings, more plus on the binocular cross-cylinder test, and a more esophoric or less exophoric nearpoint phoria as compared to children who remain emmetropic."[8] "The current literature suggests that bifocals may slow the rate of childhood myopia progression in some types of cases, including patients with nearpoint esophoria. One study also found lower rates with bifocals when the binocular cross cylinder findings were higher in plus. ..... Higher rates of myopia progression have been reported to be associated with nearpoint esophoria. Several studies have found lower levels of accommodation under various conditions in myopes than in emmetropes."[9] "This paper has corroborated Birnbaum's finding of the esophoric shift in some individuals."[10] "These results supported the hypothesis, generated by retrospective studies, that bifocals slow the progression of myopia in children with near point esophoria."[11]

Gwiazda et al found support for greater myopic shifts of tonic accommodation "during the period of acquisition and progression of myopia, regardless of age."[12] Rosenfield et al documented "a transient myopic shift during the 10-20 s immediately following a moderate (20 min) period of sustained near-vision."[13] Rosenfield and Ciuffreda observed "a significant post-task shift in the far point of accommodation immediately after a sustained period of near vision....."[14] The shift in the FPA was toward greater myopia.

In my practice I had encountered the concept of transient myopia occurring after near work. I had also noted on an irregular basis that some young beginning myopes, who refracted at approximately -1.00 of myopia, would fail and sometimes dramatically reject -1.50 at near, but focus easily the +1.50 in a +-1.50 flipper evaluation of accommodation facility during entrance skill testing. I had not noted any connection between myopia onset and esophoria at near.

As a result, I was curious about the near point phoria findings, and I had a suspicion already about accommodative facility dysfunction, so I chose to investigate these two visual responses before and after an extended period of reading time. I also had chosen six symptoms to investigate, those that I referred to early in this paper, namely: eyestrain, blur at far, blur at near, loss of place, comprehension difficulties, and double vision. The symptoms could be rated, on a rank order basis, after the same reading period.

But then the question arose: Reading what? (The materials chosen would constitute the independent variable in my study, and the outcome variables of symptomatology and near point visual responses would, of course, depend on the materials chosen.) Educational books were my interest. But what grade level? Readability (difficulty of material) and print size would vary depending on the grade level.

For reasons of subject reliability and age of onset of myopia (ie: adult, or late onset, as opposed to early onset.), materials appropriate to ages 15 and up (but not to presbyopic age) were selected as test materials.

What materials were appropriate for ages 15 to 35? And what components of the reading material might produce a clinically measurable response?

Again, referring back to clinical practice, many patients had complained of difficulties when print size became smaller. I personally had noticed this, especially when able to randomly change font size in word-processing programmes. It occurred to me that print sizes considered appropriate for a specific age range may, in fact, not be appropriate. So, I decided that my treatment conditions of the independent variable would be to compare a print size considered appropriate for the age range chosen, and to compare that with non-recommended print sizes.

In order to prepare such a comparison, a search for typography information was launched to determine the current appropriate print size recommendations. My searching yielded two main sources.

The primary North American investigator of typography and readability of print was M.A. Tinker, who published extensively in this area.

Perhaps his most comprehensive publication was his book, *Legibility of Print*[15], wherein he described his investigation of: upper versus lower case letters, digits, styles of type face, italic print versus Roman lower case, capitals versus lower case print, boldface type, mixed type forms, size of type, line width, leading, spatial arrangements of the printed page, colour of print and background, printing surfaces, newspaper typography, formulas and mathematical tables, special printing situations, illumination, light sources, slope of the reading page, angular alignment, flat versus curved print, effect of vibration, and length of reading period.

Tinker pointed out that he was investigating the "legibility" of print, as opposed to the "readability" of print ("readability" referring to a measure of the level of mental difficulty of reading materials for which there is a specific formula).

In his words, "Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shape of letters and other symbols, characteristic word forms, and all other typographical factors such as type size, line width, leading, etc., are coordinated to produce comfortable vision and easy and rapid reading with comprehension. In other words, legibility deals with the coordination of those typographical factors inherent in letters and other symbols, words, and connected textual material which affect ease and speed of reading."[16]

It is beyond the scope of this paper to review the entire details of typography, but as a result of Tinker's extensive investigations, recommendations were made for optimum print sizes, leading, line widths, types of print, illumination, etc. to be used in reading materials.

Garzia[17] in his book, *Vision and Reading* published in 1996, neatly summarizes the subject of typography, and makes reference no less than twenty-four times to Tinker's work.

The recommendations with relevance to the study that has been undertaken here concern the style and size of font, the amount of spacing between lines, and the width of lines.

The standard print used in Tinker's time was Scotch Roman. Investigations comparing it to other similar prints found that similar ones were equally legible. Times Roman, being very similar, is a standard for printers now and is the font being used for this document.

Tinker quoted the standard print to be 11 point (point = 1/72 inch and is a measure of type size and leading), 22 picas wide (pica = 1/6 inch and is a measure of line width), with 2 point leading (space between lines). Prints of 10 point or 12 point were found to be of equal legibility and Tinker recommended a "safety zone" for each print size. Ten point print was to have 14 - 31 picas line width and 2 point leading; 11 point was to have 16 - 34 picas and 1-2 point leading; and 12 point print was to have 17 - 33 picas width and 1 - 4 point leading. Garzia, designates line width as being 10 - 12 words, or 60 - 70 characters per line.

As mentioned previously, the font being used in this document is Times Roman. The print size is 14 point, and the leading is 2 point.

10 point font would look like this.

12 point like this.

16 like this.

6 point like this.

Typography information in hand, reading materials could be prepared. I chose 10 point print as the recommended size and picked 6 point and 16 point as the sizes I would compare. I hypothesized that the 6 point print would be subjectively more difficult to read, produce more symptoms, and possibly produce a greater esoward phoria change and a greater reduction in the accommodative facility than either the 10 or 16 point text.

Similarly, I predicted the same results pattern with the 10 point versus the 16 point print. In other words, I predicted that the 16 point print would be the easiest to read, produce the fewest symptoms, result in the least esoward phoria change, and produce the least reduction in accommodative facility of the three print sizes investigated.

In summary, then, this study sought to gain information that may relate some variable of the reading task to common complaints and/or to near visual stress. The study was also primarily interested in the academic setting, as I wished to investigate these factors in educational reading material. Since two of the major variables in reading text are the size and type of font used, this study was designed to examine possible effects of different font size (all of one font type) on individual subjective comfort and the visual system responses.

METHODS:

Subjects' Inclusion/ Exclusion Criteria:

Twenty-seven subjects took part in the study. Each one completed an informed consent form and pre-test questionnaire regarding symptoms and the number of hours spent reading each day (see Appendix A and B) at the initial session.

Subjects were all chosen from the Pacific University College of Optometry 1st year class. All were in the age range of 21-25 (as of January 1, 1997); all were in an academic setting; all had English as a first language or had learned it prior to age 12; all were assumed to be capable of reading at grade 11 readability level; all were capable of visual acuity of 20/20 aided or unaided at both far and near and capable of 3rd degree fusion at near to a level of 50 seconds of arc; all had had a comprehensive visual examination prior to the study (within 6 months and records available), were able to participate in 3 different sittings of approximately 90 minutes each on 3 consecutive days in late afternoons or evenings, and were capable of reading continuously for one hour. A pre-test screening appointment was held with each subject to review these criteria before acceptance into the study. (A copy of the inclusion/exclusion criteria is available in Appendix C)

Five subjects qualified for the study with neither a contact lens or spectacle prescription (nor had they had refractive surgery); of those wearing an habitual Rx, seven wore contact lenses and the balance wore their glasses for the study (one subject inadvertently wore her contact lenses instead of glasses on the third trial). To minimize bias, I deliberately did not make myself aware of the subjects' prescriptions until all the data had been gathered. After data collection was complete, copies of the subjects' prescriptions were obtained from their files: of the contact lens wearers, one was a hyperope; all other Rx wearers were myopes between -0.25D -> -5.75D (equiv sphere). One myopic subject had 2.50D of with-the-rule astigmatism, and one had 4.00D with-the-rule astigmatism.

Instumentation and Protocol/ Procedure:

Instrumentation consisted of specially prepared booklets of three different sizes containing the text from *Brave New World* scanned into the Word computer programme and adjusted to sizes 6 point, 10 point and 16 point print (see Figure 1). The number of words per line was held constant at ten - twelve per line, leading at 2 point, and margins were done at the standard

gutter settings used by printers. In this way, only the print size changed from one treatment to the other.

Subjects sat in a standard examination lane at the College of Optometry Family Vision Clinic.

Visual acuities were taken with either a standard projection chart and room illumination at one half the overhead lighting (as per the dimmer control in each room), or a wall chart with Sloan Letters for 4.6 meters (15.5 feet) and full room illumination. Lighting during the reading sessions and near facility testing was normal room illumination plus the overhead reading lamp. Care was taken to direct the light at the reading material without shadows or glare in the subject's eyes.

Near point phoria and accommodative facility testing was done at 40 cm. Phorias were measured using a Maddox Rod with attached rotating prism device held in front of the right eye. Subjects maintained fixation on a letter (to control for accommodation) directly above a transilluminator light. Instructional set was: "Keeping the letter clear, where is the red line relative to the letter: going straight through it, to your right, or to your left?" and "Tell me when the red line is lined up straight up and down through the letter." Two measurements were taken and recorded for each trial and additional loose prisms were used as necessary. Lighting was maintained at normal room illumination.

Accommodative facility was done using +- 2.00D flippers while the subject read from an article in *Macleans* magazine. Subjects were instructed to "...begin reading here. I will be putting some lenses in front of your eyes and I would like you to tell me as soon as the print is clear enough to read. When it is, simply call out "Clear". I will then flip to the other set of lenses and I would like you to call out "Clear" again as soon as it is clear enough to read. We will continue doing this for one minute." The total number of lens flips achieved within one minute was divided by two and recorded as cycles/minute. Plus lenses were presented first.

During each trial, subjects remained seated in the standard optometric examination chairs, and read for one continuous hour with the booklets maintained at 40 cms. and the overhead reading lamps directed at the reading material as previously described. (See Figure 2.) Subjects were told that they were reading from a book called *Brave New World*, and that they were to: "..read for understanding, not for speed". They were offered a stool as a footrest to be used at their discretion. (This was done to make the reading

experience as near normal for that individual as possible, and yet control test parameters.) Pages read were recorded each time in order to avoid re-reading at the next sitting. A timer was set for one hour and subjects told to continue reading until asked to perform re-testing at the end of the reading period.

Each subject sat for three different trials, so the different booklets were chosen randomly for each person before their first and second sittings, the third sitting being whichever print that person had not yet read. Visual acuities, near point phorias and accommodative facilities were taken pre and post test for each sitting. A post test questionnaire was completed after each sitting (see Appendix D). Subjects completing the testing were asked not to discuss the study with their classmates in order to keep subject bias to a minimum.

-- Insert Figure 1. & Figure 2. --

RESULTS:

In our introduction, we hypothesized that the largest print (ie:16 point) would produce fewer subjective symptoms, be rated subjectively as the easiest print size to read, and produce the least "negative" visual responses as measured by near point phoria and accommodative facility.

Results were as follows:

Subjective Visual Complaints:

Symptoms:

Symptoms investigated in the study were: "eyestrain" (asthenopia), "blur at far", "blur at near", "loss of place", "difficulties with comprehension", and "double vision" (diplopia). For each print size, subjects answered "yes" or "no" to the question of whether they experienced the symptoms during or after the reading session, and then rated the "yes" responses by rank order, with 0 = no symptoms, 1 = rarely, 2 = occasionally, 3 = frequently, 4 = every time.

	Symptoms (mean rank)					
Print Size	Eyestrain	Blur at Far	Blur at Near	Loss of Place	Compre-hension Difficulty	Double Vision
6 pt print	2.519	2.22	2.185	2.056	2.111	2.093
10 pt print	1.833	2.074	1.944	2	1.981	1.981
16 pt print	1.648	1.704	1.87	1.944	1.907	1.926
chi square (cor-rected for ties)	p= .0001	p= .0109	p= .0782	p= .8322	p= .4018	p= .2466

Table 1. Mean ranking of subjective symptoms for 6, 10, and 16 point print size with chi square analysis of statistical significance.

----- Insert Figure 3 ----

These results show a strong statistically significant linear relation agreeing with our hypothesis for "eyestrain" (chi square p=.0001), a weaker relation for "blur at far" (chi square=.0109), and a weak relation for "blur at near" (chi square=.0782). The other symptoms showed no statistical difference between conditions (chi square p=.8322, p=.4018, p=.2466).

Ease of Reading:

In addition to any symptoms noted during or after the reading sessions, subjects were also asked to rate the "ease of reading" for each print size, wherein
0 = impossible, 1 = very difficult, 2 = difficult, 3 = easy, 4 = very easy.

Print size	Ease of reading (mean rank)
6 pt rank	1.096
10 pt rank	2.115
16 pt rank	2.788
Chi square (corrected for ties)	p= .0001

Table 2. Mean ranking for ease of reading with chi square analysis of statistical significance.

--- Insert Figure 4 ---

These results support our hypothesis that the 16 point print would be easiest to read, 10 point next in ease, and 6 point print the most difficult to read. Again, these results were highly significant (chi square p=.0001).

Visual Responses:

Near Point Phorias:

Near point phorias as measured by Maddox Rod were taken prior to and immediately following the reading session each time. Results are tabulated below:

Print size	Mean pre-read phoria	Mean post-read phoria	Mean phoria change	Standard error	Paired t-value	P value
6 pt	4.889 exo	2.907 exo	1.981 esoward	.399	-4.969	.0001
10 pt	4.731 exo	3.139 exo	1.593 esoward	.349	-4.563	.0001
16 pt	4.528 exo	2.852 exo	1.676 esoward	.345	-4.864	.0001
ANOVA p value between Txs			.5497			

Table 3. Pre and post phoria changes, mean phoria change, standard error t-test and ANOVA analysis of statistical significance.

--- Insert Figure 5. ---

These results indicate a highly significant esoward shift between the pre-reading phoria and the post-reading phoria for all print sizes (paired t test p=.0001).

Further analysis of the data by ANOVA shows no statistical difference between treatments (p=.5497), or in other words, there was a significant near point phoria shift for each print size to a more esoward posture, but no significant difference in the amount of near phoria shift from one print size to the other.

These findings do not support our hypothesis.

Accommodative Facility:

Accommodative facility at near was measured using lens flippers as described in the methods section. The number of lens flips per minute was recorded both prior to and immediately following each one hour reading session. These data and analysis are tabulated below:

Print size	Mean pre-read facility	Mean post-read facility	Mean change facility	Standard error	Paired-t value	P value
6 pt	10.778	10.037	.741 reduction	.255	2.904	.0074
10 pt	11.148	10.667	.481 reduction	.284	1.694	.1023
16 pt	11.222	10.444	.778 reduction	.285	2.726	.0113
ANOVA p value between Txs			.641			

Table 4. Mean values for pre and post facility changes, mean facility changes, standard errors, and paired-t test and ANOVA analysis of statistical significance.

---- Insert Figure 6. ----

Accommodative facility results show a statistically significant reduction (paired t test, p=.0074) in facility for the 6 point print, and for the 16 point print (paired t test, p=.0113), but no significant reduction (paired t test p=.1023) for the 10 point print. There was also no difference between print sizes in the amount of reduction in facility.

These findings do not agree with the hypothesis, except for the results from the 6 point text.

DISCUSSION:

The results of this study agreed with my hypothesis that 16 point print would be easier to read than either 6 point print, or 10 point print. Tinker's investigations did not suggest that. His results were that 11 point was most preferred, 10 and 12 point prints were equal and a close second in rank, 9 point was next and 8 point fifth in rank[18]. (He had subjects rate only the 8, 9, 10, 11, and 12 point prints.)

I believe that the larger stimulus size on the retina allows the information to be processed with less demand from the binocular alignment system and accommodation, and should thus be easier to read. Of my 26 subjects (one failed to complete the post-test rank order questionnaire), 15 actually ranked the "ease" in the order I hypothesized: 16 - 10 - 6. All 26 ranked the 6 point print as most difficult. Eight subjects found the 10 and 16 point to be equal. One rated the 6 point and the 10 point to be equal, but the 16 point was still easiest. And two people ranked the 16 point more difficult than the 10 point.

I also had hypothesized that the 16 point would produce fewer symptoms. This was true for eyestrain, blur at far and blur at near.

I have previously discussed sources of various symptoms that may arise from within the visual system, ie: accommodation, binocularity, motility and refraction. According to Birnbaum[19], simply the near task demand itself causes a physiological response which produces asthenopia. Eyestrain or "asthenopia" could arise from deficiencies in any of these areas, especially as the target gets smaller, as the focusing, alignment and eye movements all need to be more precise. In this study, 20 of the 26 reporting subjects reported eyestrain of some degree, following one or more of the reading sessions.

Blur is dependent on the basic refraction of the eyes, and on the accommodation system. Binocularity can even give rise to an apparent "blur" if a target is tending to double, but is not separated entirely. Again, the smaller the target, the smaller the angle subtended, the more critical the visual acuity required and the more precisely accommodation must be regulated. Logically, the smaller print should be more likely to cause symptoms.

Twelve subjects of the 26 noted blur at far, and this was statistically significant in the order of the hypothesis. Several subjects reported the blur only after the 6 point reading, which supports the concept that accommodative spasm or hysteresis is more likely to occur with a more

difficult task (smaller target, more precise accommodation required). Visual acuities were recorded before and after each reading session, but I had not chosen acuity as an outcome variable, so these findings have not been included in this paper. Analysis of those data may be attempted as a future project, and probably should be, given the statistical outcome of the subjective complaint of blur.

Blur at near was reported by nine subjects, and typically, they did not report blur at far, or the far blur was ranked with less frequency than the near blur. This was true of seven of those nine subjects. Interestingly, only one of these seven was a hyperope, all the rest were myopes, and all of the seven, except one, had accommodative facility findings in the range of 10-16 cycles per minute (the one subject had facilities of 3-5 cycles per minute the first session, then 9-10 cycles per minute for the other two sessions.) The other two who reported near blur, reported strong symptoms in all categories (ie: 3 or >3), but the symptomatology for 16 point print was less than for the other two print sizes (ie: 2 or less).

In my experience, loss of place tends to be dependent on binocularity, as does diplopia. Also, when loss of place occurs, comprehension is typically and understandably reduced, making it highly dependent on binocularity. These were not a significant complaint in this study. Perhaps this could be attributed to the fact that six of the subjects had significantly high exophorias (>10 prism diopters) at near and perhaps were suppressing some of the time (suppression was not controlled and high exophores were not excluded, as I was interested to have data from as near normal a class sample as possible). If this were happening, however, one would expect that it might not happen so readily with the large print, as the stimulus to fusion would be much grosser. In retrospective review of the seven high exophores' files, all but one actually did report either loss of place or comprehension difficulties, or both, but not diplopia. The subject with the greatest exophoria, had absolutely no complaints, rated all three print sizes as "easy" or "very easy", and read more pages than any other subject in the entire study! This subject likely was suppressing (although she had been able to pass the stereo screening). Of the other subjects who complained of loss of place or comprehension difficulties, rankings were generally no different between print sizes, and accompanying comments suggested that it was easy to read, just hard to understand the story. One subject commented on being more rested for the second two trials, and two or three subjects with loss of place complaint felt the 16 point print caused loss of place more frequently. This variability in findings would support the lack of significance. (The data have not been statistically analyzed from this point of view.)

Of the entire group of 26, ten reported none of the above three symptoms, thus re-enforcing the overall lack of significance of those symptoms. Only two of the 26 reported no symptoms whatever, yet those two had significant myopic refractive errors (-3.00D -> -4.00D) and measurable binocular or accommodative deficiencies (one with >18 exophoria at near, and one with reduced accommodative facilities - 0 cpm-5cpm).

Results of nearpoint phoria testing showed a highly significant esoward shift for the entire group, pre-post testing for all three print sizes. As previously stated in the Results section, there was not a significant difference between print sizes.

According to Birnbaum[4], Goss[8,9], Christensen, Korth, and Marcolivio[10], and Fulk and Cyert[11], esophoria in myopes is suggestive of a more rapid myopia progression risk. Esophoria in an emmetrope may, similarly, be a myopia onset risk.

Although these data have not been analyzed in this fashion, for purposes of discussion, I counted the numbers of esophores in the group of 27(3-6 exophoria is considered the norm at near. For puposes of this study, any subject with a pre-test finding < 3 prism diopters exophoria was classified as an esophore.). Ten subjects qualified in this manner. Six were myopes > -0.50D, three were emmetropes (0.00 -+0.50D), and one was a hyperope > +0.50D.

Based on the aformentioned research findings, nine of the 10 esophores may be at risk for an incipient myopic refractive change. Of those esophores, five had pre-post esoward phoria changes >1prism diopter. Perhaps they would be at greater risk?

As evidenced by the statistical analysis, a significant number of subjects had a pre-post esoward phoria change following the near work. If that finding in itself is a risk factor for incipient myopia, those subjects would all be at risk of a myopic change, and since no difference was found between print sizes, they would be at risk regardless of the print size, at least within the three parameters measured in this study.

Does this study support any of the findings related to deficiency in accommodation?

I chose to examine accommodative facility findings, not measures of PRA as other researchers had done. I chose this because of personal observations in some cases of developing myopes, who rejected binocular -1.50D in a flipper accommodative facility test.

This study did show a significant reduction in pre-post facility for the 6 point and 16 point prints, but no significant differences in amount between print sizes.

Thirteen subjects of the 27 total had some accommodative difficulties ranging from the -2.00D becoming progressively more difficult to focus, to failing the -2.00D or the +2.00D, to exhibiting a facility reduction of =or> 1cpm, or becoming diplopic (indicating the effect of the accommodative system on vergence system).

Of the esophoric subjects, four had facility difficulties ranging from the -2.00D becoming more difficult to focus, to failing the -2.00D or becoming diplopic. Perhaps the combination of esophoria and accommodation deficit is another indicator of myopia risk? Almost certainly, these subjects would benefit from +addition lenses for near work, as it would relax their accommodation and reduce the esophoria. In the bifocal studies as reported by Goss[9], and Fulk and Cyert[11] myopia progression in children with esophoria was reduced in the group using bifocals. Traditional optometry would have us expect some symptoms in this scenario. These four subjects had symptoms either not at all or rarely!

What about pre-post test esoward change and accommodative facility?

All 13 subjects with accommodative difficulties also had esoward phoria changes of >2 prism diopters. Because of the interactions between accommodation and vergence via the AC/A, it is not surprising to have these two findings showing deficiencies in the same subject. But are these two findings together suggestive of higher myopic change risk?

Birnbaum suggests that high exophoria is a sign of nearpoint stress. In fact, all the outcome variables investigated in this study are in the nearpoint stress list. Every subject had at least one condition, whether subjective or objective response.

In terms of print sizes, larger print was subjectively easier to read. Although there were no significant differences in the amounts of pre-post phoria and accommodative facility changes between print sizes during this study,

perhaps the "ease" of using larger print over a long term could reduce overall physiological stress.

As in many research studies, more questions may have arisen from this study than answers. Also, a much larger sample size is needed in order to generalize these results. Some of the questions, particularly those regarding pre-myopia visual response risk factors, could be answered by following the subjects over the course of their four years in optometry school. Other interventions, such as appropriate near point lenses or visual therapy have not been addressed here, but are discussed by Birnbaum[4] and other authors throughout the literature.

CONCLUSIONS:

This study sought connections between print sizes and both symptoms and visual responses.

The symptoms and ease of reading results suggest that the size of print in textbooks and reading materials used by subjects in a higher educational setting is not the easiest to read, and does trigger symptoms of eyestrain, blurred vision at far and blurred vision at near.

All print sizes triggered an esoward pre-post phoria change. If this visual response proves to be a pre-myopic change, this would not support any of the print sizes, including the present print size recommended (ie: 10 point print).

There was no significant difference in amount of esoward phoria changes between the print sizes. Again, if the presence of esoward phoria shift is a visual risk factor, there would appear to be a mismatch between the subjective response results and the visual response results.

Accommodative facility was not reduced pre-post testing with the 10 point print. This may support the usage of that size print for persons of this age group.

Overall, based on the survey questionnaire, this study suggests for educators that the usage of larger print size when reading is acceptable in the age group 20-25 years.

For optometrists, it provides strong evidence for expecting an esoward phoria shift in patients following an extended period of reading. Although no significant difference between print sizes for phorias or accommodative facility was found, strong evidence was found for the use of larger print in this age group to reduce symptoms of eyestrain, blur at far and blur at near.

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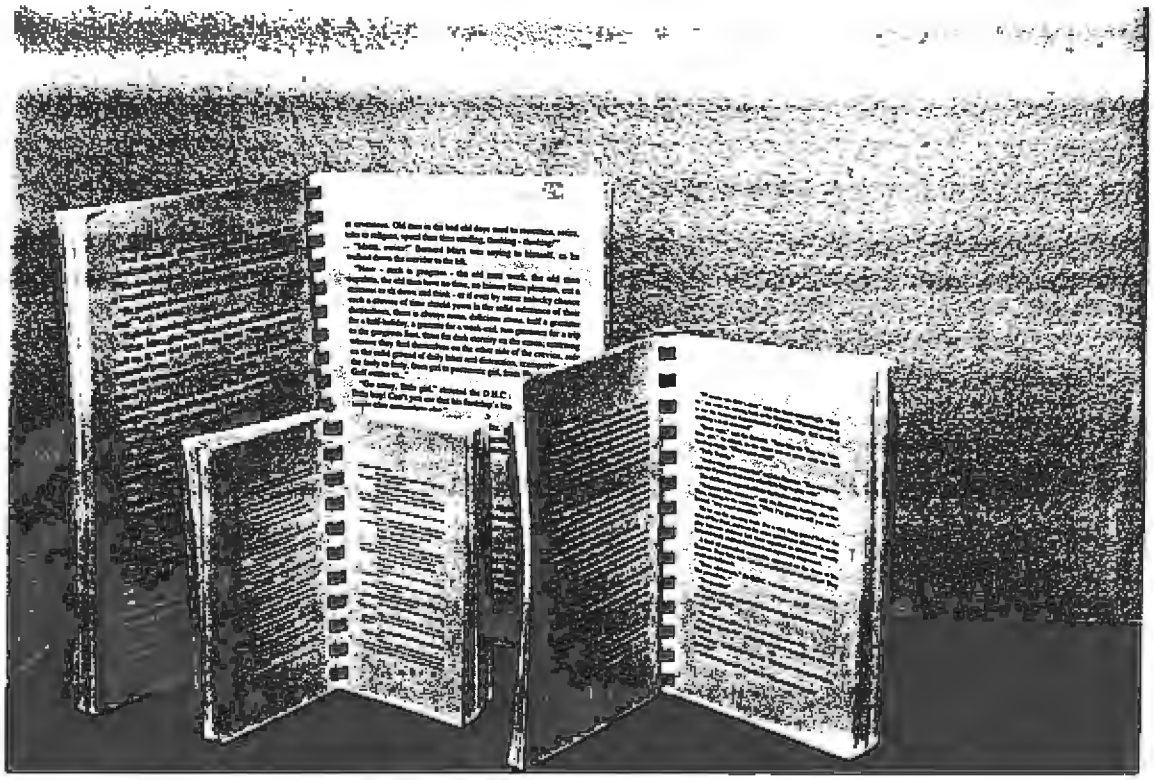

Figure 1. Photograph of test booklets with print sizes of 6 point, 10 point and 16 point text.

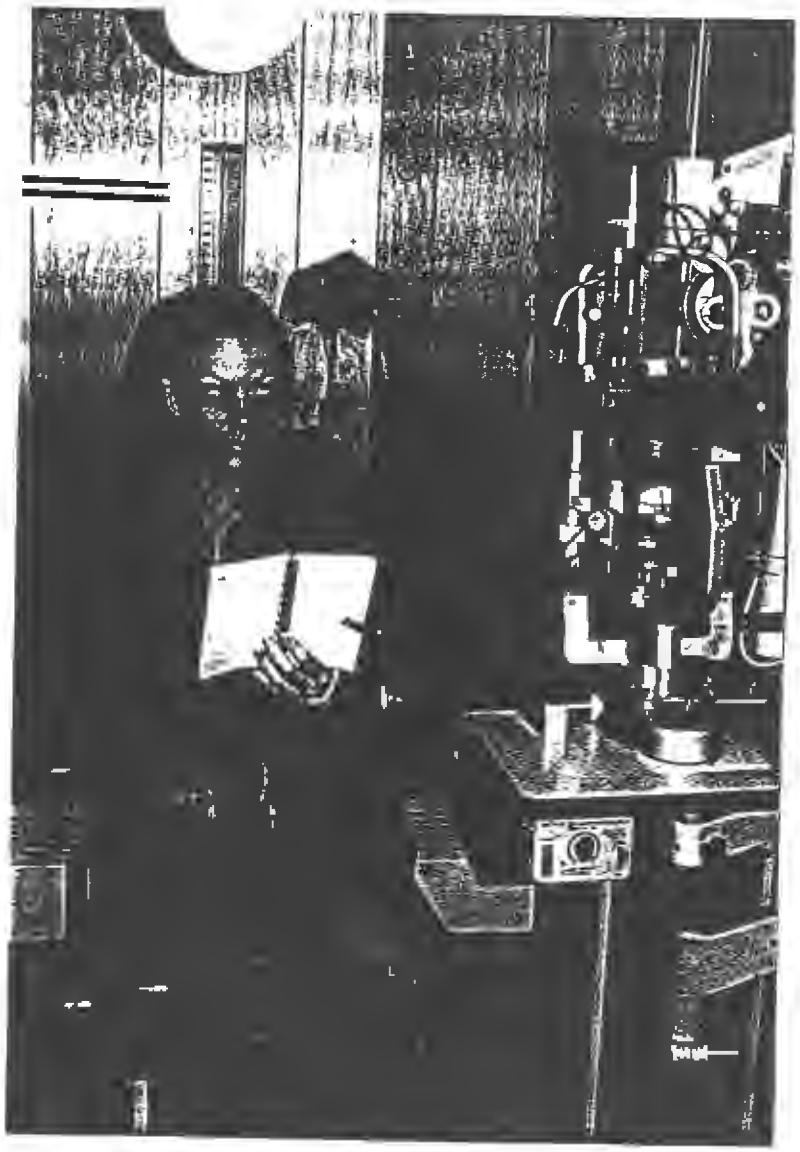

Figure 2. Photograph of experimental instrumentation with subject seated for reading session.

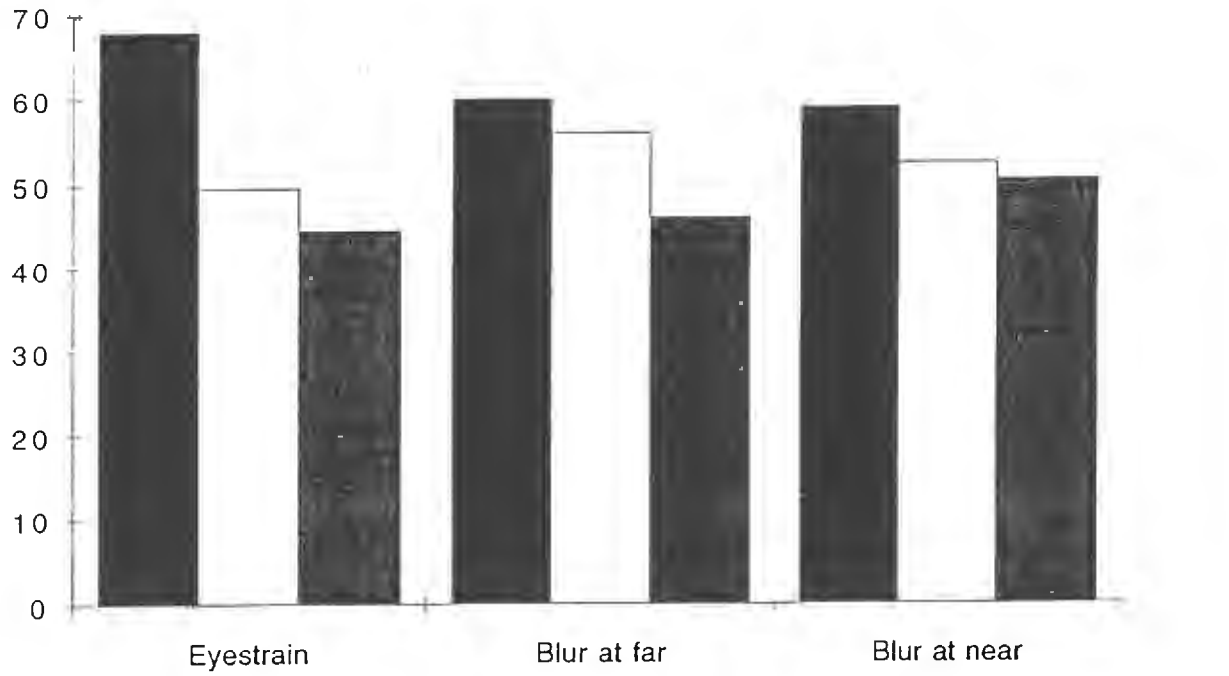

Figure 3. Bar graph of mean rank results for eyestrain, blur at far, and blur at near for each of three print sizes.

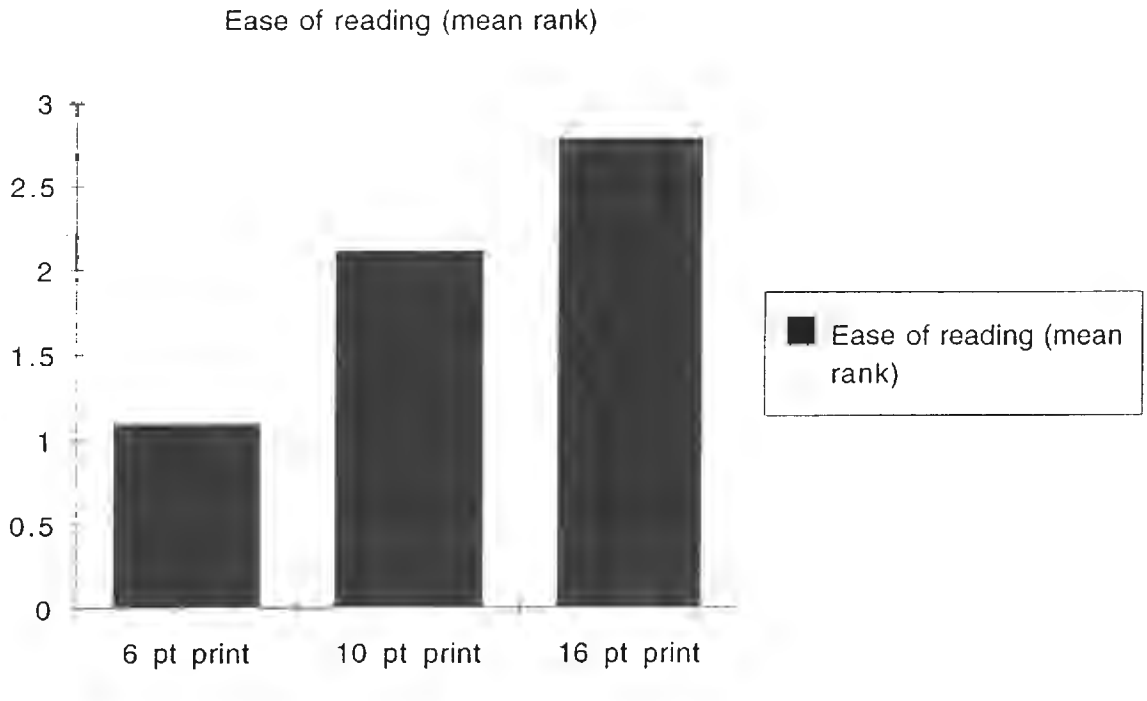

Figure 4. Bar chart of results for ease of reading for the three print sizes, with the greater numbers signifying greater ease.

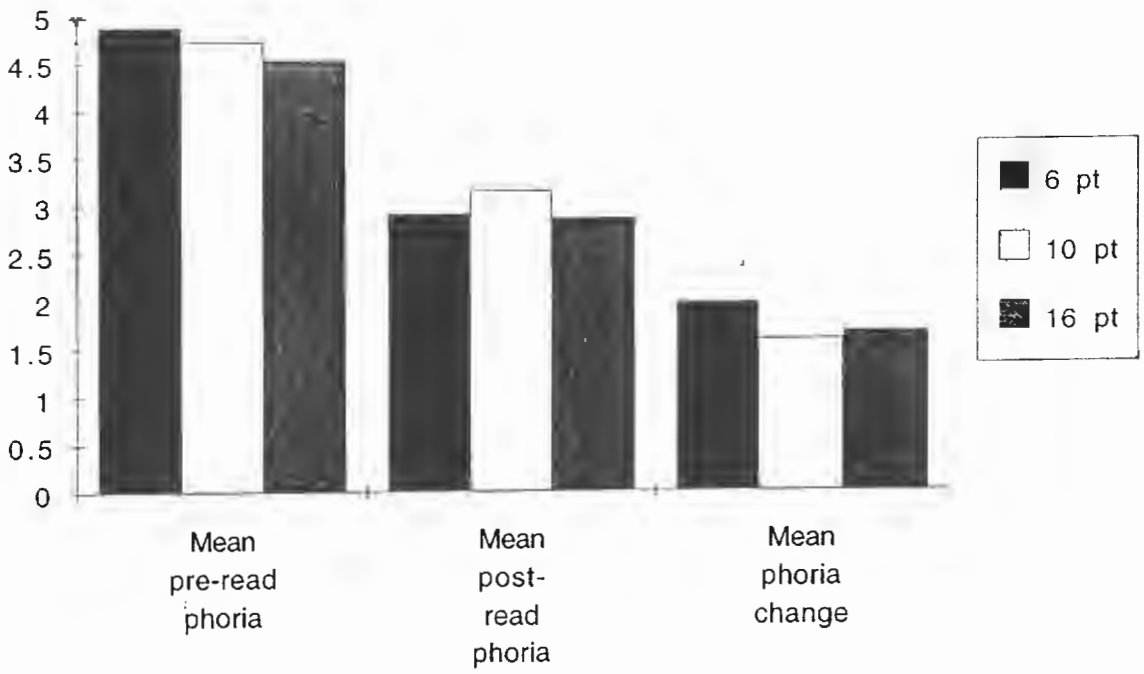

Figure 5. Bar chart results of mean pre-post phorias and mean phoria changes for three experimental print sizes.

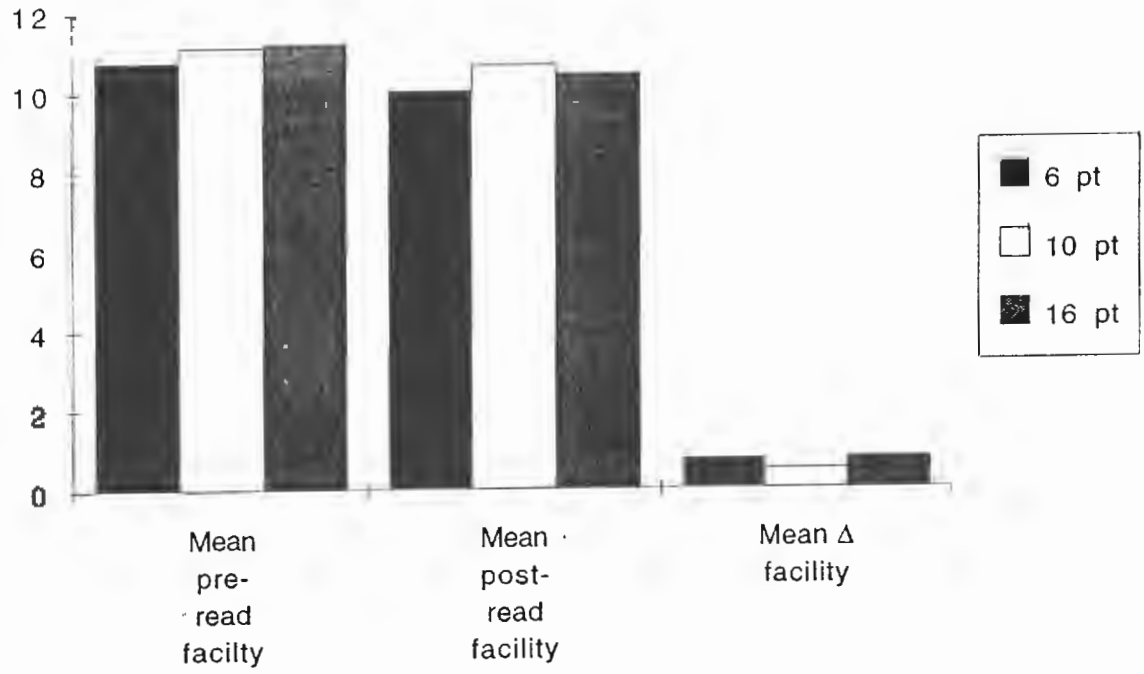

Figure 6. Bar chart showing pre-post test mean facility findings and mean facility changes for three experimental print sizes.

APPENDIX A:

INFORMED CONSENT FORM
PACIFIC UNIVERSITY COLLEGE OF OPTOMETRY

A. TITLE: Visual Risk Factors and Optimum Print Size in Educational Reading Material

B. PRINCIPLE INVESTIGATORS: B. Diane Madson, O.D. 359-3782

C. ADVISORS: Bradley Coffey, O.D., F.A.A.O., Paul Kohl, O.D., Anita McLain, Ed. D.

D. LOCATION: Pacific University College of Optometry Family Vision Center, Forest Grove, Oregon and private practice "office" of Dr. Madson at 727 Kitwanga Place, Sidney, B. C., Canada

E. DATE: October, 1997 to May, 1998

1. DESCRIPTION OF PROJECT

Since many individuals who seek optometric care have "subjective symptoms" related to the act of reading, and since myopia ("nearsightedness"), which manifests in adulthood as well as childhood, is quite prevalent in "good readers", the purpose of this study is to determine if there are any measurable visual system response differences between print sizes of one specific font type. Subjects will perform well-known optometric visual procedures prior to and immediately following reading of 3 different print sizes for a period of one full hour (at 3 different sittings). These procedures are: the measurement of visual acuity (ie:20/20, etc.) at far and near by standard visual acuity charts in standard visual examination rooms; measurement of 40 cm. (16") lateral phorias (lateral alignment of the two eyes) with the Maddox rod technique (a red striped lens with a measuring lens called a prism which is positioned in front of one eye while the other eye views a fixation letter above a light); measurement of accommodative facility (speed of re-focusing) at 40 cm. with plus/minus accommodative "flippers" (two sets of lenses of opposite types arranged like two pairs of glasses in a plastic frame with a handle; the two "pairs" of glasses are arranged with one set at the top, and one at the bottom, and the testing requires "flipping" from one set to the other); all procedures are done in a standard examination room, and require about 1 - 2 minutes each. Subjects will also answer a brief questionnaire about subjective symptomatology with reading tasks. There will be one prior to the "pre-reading" visual performance measuring and the reading session, and one following the "post-reading" visual performance measurements. The reading sessions will also occur in the same examination room environment where subjects will have comfortable seating and controlled levels of recommended illumination.

2. DESCRIPTION OF RISKS

The only known risks involved with this project are associated with being in the location where the experiment is being conducted, holding of the testing devices near to the face, and having confidential information released. As mentioned, all measurements taken are commonly used in an optometric visual examination, are non-invasive measurements, and require only about 5 minutes total to administer. During the "flipping" procedure, lateral phoria and all testing, devices can touch the face/eye region, so care is always taken that these are held properly and they are deliberately designed to be smooth and rounded for patient safety. Subjects will be asked to read for one continuous hour, but the ability to do so has been included in the study inclusion criteria, so all subjects are capable of this when they begin. As such, risks to subjects are no greater than that associated with a routine

oculo-visual examination, or a period of study or pleasure reading.Name-identifiable information will be kept confidential by the experimenters.

3. DESCRIPTION OF BENEFITS

Academic credits for Opt. 562 will be granted to participants of this study. Also, a better understanding of the current recommendations for printed text and understanding of the visual system's responses to reading text will be forthcoming.

4. ALTERNATIVES ADVANTAGEOUS TO SUBJECTS

None known.

5. CONFIDENTIALITY

Records of this project will be maintained in a confidential manner, and no name-identifiable information will be released.

6. COMPENSATION AND MEDICAL CARE

If you are injured in this experiment and it is not the fault of Pacific University, the experimenters, or any organization associated with the experiment, you should not expect to receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment.

7. OFFER TO ANSWER ANY ENQUIRIES

The investigators will be happy to answer any questions you may have at any time during the course of this study. If you are not satisfied with the answers you receive, please call Dr. Karl Citek at 359-2126. During your participation in the project you are not a Pacific University clinic patient or client and all questions should be directed to the researchers and/or the faculty advisors who will be solely responsible for any treatment (except for an emergency). You will not be receiving complete eye, vision, or health care as a result of participation in the project: therefore, you will need to maintain your regular program of eye, vision, and health care.

8. FREEDOM TO WITHDRAW

You are free to withdraw your consent and to discontinue participation in this project or activity at any time without prejudice or consequences to you.

I have read and understand the above. I am 18 years of age or over or this form is signed by both me by my parent or guardian.

Printed name of subject:

.....

Subject's signature:

.....

Signature of parent or guardian if subject is under 18 years of age:

.....

Address:

.....

City/ State:

.....

Phone: .....

Date.....

Name and address of someone not living with you who will always know your address:

.....

.....

Printed name and signature of interpreter if required:

.....

APPENDIX B:

THESIS bdm97

NAME:
DOB:
GENDER:
LVA:
HAB RX:spec,cl,rk,prk
DATE:
TIME:

PRE-TEST QUESTIONNAIRE (EXP COND# 1 2 3)

How many hours per day would you estimate that you spend reading and/or working on a computer?.....

< 1 hour
1- 3 hours
3 hours or more

Do you experience any of the following symptoms *after or during* reading?.....

discomfort or "eyestrain"?	Y N
blur far?....	Y N
blur near?....	Y N
"loosing your place"?....	Y N
difficulties with comprehension?	Y N
double vision?	Y N

If you answered "yes" to any of the above, could you please rate the *degree of your symptoms* on a scale of 0 - +4; 0 being no symptoms, 1= rarely, 2= occasionally (~1/ 10 times), 3= frequently (~ 1/ 5 times), 4 = always (every time read).

discomfort or "eyestrain"	0 1 2 3 4
blur far.....	0 1 2 3 4
blur near.....	0 1 2 3 4
"loosing your place".....	0 1 2 3 4
difficulties with comprehension.....	0 1 2 3 4
double vision	0 1 2 3 4

Any other comments????
.....
.....
.....

APPENDIX C:

THESIS SCIENTIFIC RESEARCH PROJECT (MADSON/97/98)
(approved for academic credits for Opt 562
Behavioral Optometric Science)

INCLUSION/EXCLUSION CRITERIA:

Inclusion criteria:

Subjects are to be in the age range of 15-25 (as of January 1, 1997) years of age, be in an academic setting (ie: students of high school, college, university); have English as a first language or have learned it prior to age 7 (as per patient questioning); be capable of reading at a grade eleven readability level (assumed because of academic level presently at); be capable of visual acuity of 20/20 aided or unaided at both near and far (as determined at CVE, but will be double-checked at pre-test time); be capable of 3rd degree fusion at near to a level of 50 arc seconds (as per CVE or at time of pre-test, if necessary); have had a comprehensive visual examination prior to the study (within 6 months & have the records accessible); have time to participate in 3 different sittings of ~90 minutes each on 3 consecutive days, namely, Thursday, Friday and Saturday; times to be from 5:30-7:00 pm or 7:30-9:00 on Thursday and Friday and from 4-5:30 or 6-7:30 on Saturday; be capable of reading continuously for one hour (as per questioning of subject).

Exclusion Criteria:

Subjects shall have no ocular pathology (as determined by the previous CVE), and use no medications or beverages that affect visual performance (for example, alcohol) prior to the experimental condition.

Location:

PUCO Clinic Service III, Rooms B,C & D

Materials:

If chosen for the study, subjects should bring their completed "Pre-test Questionnaire" with them (this should not be shared with anyone but the research personnel) as well as their completed "Informed Consent" form.

APPENDIX D:

THESIS bdm97

NAME:
DOB:
GENDER:
LVA:
HAB RX:spec,cl,rk,prk
DATE:
TIME:

POST-TEST QUESTIONNAIRE (EXP COND# 1 2 3)

During or after this reading period, did you experience any of the following symptoms?.....

discomfort or "eyestrain"?	Y N
blur far?....	Y N
blur near?....	Y N
"loosing your place"?....	Y N
difficulties with comprehension?	Y N
double vision?	Y N

If you answered "yes" to any of the above, could you please rate the *degree of your symptoms* on a scale of 0 - +4; 0 being no symptoms, 1= rarely, 2= occasionally (~1/ 10 times), 3= frequently (~ 1/ 5 times), 4 = always (every time read).

discomfort or "eyestrain"	0 1 2 3 4
blur far.....	0 1 2 3 4
blur near.....	0 1 2 3 4
"loosing your place".....	0 1 2 3 4
difficulties with comprehension.....	0 1 2 3 4
double vision	0 1 2 3 4

Please rate the "ease of reading" this particular print size on a scale of 0 - +4; 0 being impossible, 1= very difficult, 2= difficult, 3= easy, 4= very easy .....
0 1 2 3 4

Any other comments????
.....
.....
.....