An Investigation of the Relationships Between Reading Speed and Paper Hue Intensity, Age and Gender

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Introduction

Due in part to health care improvements and the post World War Two Baby Boom, (Siegel, 1972), the population of older adults is growing and will continue to grow. By 2030 approximately 20 percent of the U.S. population will be over age 65 (Verma, 1989). By attending to readability (the ease of reading a printed page) and legibility (the speed with each letter or word can be recognized), some age-related difficulties may be circumvented.

Beginning with a 1931 study, Tinker and Paterson began reporting about their research on reading speed and other reading factors. Additional researchers, especially Stanton and Burtt (1935) added to that research. Based in part on the 1931 study Tinker and Paterson (1940) later published a little research-based book (*How to Make Type Readable. A Manual for Typographers, Printers and Advertisers, 1940) which* defined color combinations, leading, line width and type face choices. In this book, Paterson & Tinker stated that greater contrast between paper hue and ink color allows improved differentiation of letter shapes from the background.

A literature review revealed several factors that affect gender-related readability and legibility for aging adults. The literature review explored five relevant areas: (1) aging process of the eye, (2) contrast sensitivity with aging, (3) research utilizing reading speed as the significant criterion, (4) contrast legibility studies and (5) gender and readability studies.

Aging Process of the Eye

Sight allows humans to learn about the environment through reading, movies, television and observation of others. Vision begins when light enters the eye via the transparent lens, is changed into electrical signals by the retina which sends them to the brain where they are interpreted. Around the age of twenty, each of these elements beings to change and some visual functions diminish. Verner and Davison (1982) state that defective vision increases from 23 percent at age twenty to 95 percent at the age of seventy.

Accommodation difficulty changing focus from near to distant objects) and Presbyopia (the inability to see small print or focus on nearby images) affect all aging adults. Around age 65 almost 100 percent of adults cannot focus on close objects. Other causes of vision changes can include prescription drugs, environmental factors and various diseases. Health problems can include glaucoma, cataracts, miosis, macular degeneration and diabetic retinopathy (Verma, 1989, Lyle, 1974).

Contrast Sensitivity with Aging

Perceiving edges and sharp outlines allows one to see shapes (Arden, 1978). Caird & Williamson (1986) found that decreasing contrast sensitivity can be a major cause of visual difficulty especially in dim light or under glaring lights. Several studies have used contrast sensitivity as the preferred method of measuring vision. Owsley, Sekuler and Siemsen (1983) found that contrast sensitivity function is a good predictor of a subject's visual performance. They surmise that it can probably be attributed to the amount of light reaching the retina.

Reading Speed as a Significant Criterion

Legge, Rubin, Pelli, et al. (1988), Brown (1981), Cooper (1985) utilized reading speed as a major criterion in studies. Their results found that reduced contrast or low light levels can create problems for most low vision subjects. Reading speed is also easier and more straightforward to use than legibility as an objective measure (Legge, Rubin, Pelli & Schleske, 1985a; Legge, Rubin & Luebker, 1987; Legge, Rubin, Pelli, et al., 1988).

Contrast Legibility Studies

Paterson and Tinker stated in 1940 that printers should have the maximum contrast between the ink and background. The best arrangement is a dark hue for the letters and a light hue for the background (for example, dark blue or black for the ink and white or cream for the paper).

Gender and Readability Studies

Three international studies found that women were significantly more likely to have vision problems with age. The Attebo, Mitchell and Smith (1996) study (the Blue Mountains Eye Study from Australia) found that seventy nine percent of the persons with severe visual impairment over 49 years of age were female. Taylor, Livingston, Stanislavsky and McCarty (1997) reported that Australian urban women older than 40 years of age had significantly higher rates of blindness. Age adjusted rates of blindness were .066% in men and .17% in women. The West, Munoz, Rubin, Schein, Bandeen-Roche, Zeger, German and Fried (1997) study from Baltimore, Maryland (the Salisbury Eye Evaluation Project), confirmed higher rates of vision loss in women which affected daily life and could contribute to more women in care settings.

These studies form the foundation for this study that measured contrast sensitivity as people age. While many people have researched legibility and readability, no studies have defined gender-related contrast sensitivity as it correlated to paper of various hues and intensities for aging adults.

This study extended Paterson and Tinker's (1940) and Stanton and Burtt's (1935) research to include older adults and also to determine if there are gender differences in the ability to read on various hue intensities. It utilized updated statistical methods, a wider age range, gender identification, the use of a modern reading test and modern paper choices and test replication.

The specific research questions addressed in this study were:

1. To what extent does paper hue intensity affect the reading speed of persons of varying ages?
2. To what extent do paper hue intensity and gender affect the reading speed of persons of varying ages?
3. What are the relationships between reading speed and paper hue intensity, age and gender?

Methods

Research Design

This study utilized a repeated measure single subject design and sampled adults aged twenty and over. This research added middle aged and older adults to Stanton and Burtt's 1935 study. Keppel and Zedeck (1989) define the repeated measures single subject design as "an experiment in which [all] subjects are each tested under all treatment conditions" (p. 267).

Advantages of a repeated measure single subject design included:

1. A smaller error term, since by using one subject the natural differences between subjects did not need to be part of the factor.
2. Individual differences were controlled since each subject served as his or her own control, thus increasing homogeneity.
3. A significantly reduced need for subjects (Keppel & Zedeck, 1989).

To lessen the disadvantages of this design (sensitization effects, practice effects and carry-over effects) measures were taken such as counterbalancing the treatment order, creating awareness of the purpose and design of the study and providing specific directions to participants.

The independent variable studied was the hue intensity of paper. Dependent variables studied were gender, age and reading speed. Controlled variables included room environment, type size and the ability to read and vision problems.

One hundred fifty subjects were determined to be statistically necessary for this study. Equal numbers of male and female subjects (75 each) were evenly divided into five age groups with an age range was 76 years (20 years to 96 years). Age groupings were 20-32, 33-45, 46-58, 59-71 and 72-96. The mean age was 51.83 years old and the median age was 50 years. The standard deviation was 17.31.

Ethnic backgrounds of the sample included Caucasian (88.7%), African American (7.3%), Native American and Pacific Islander (1.3% each), Arabic (.7%) and other nationalities (.7%). Education levels of the subjects included less than high school or finished high school (13.3 percent), some college (32.7 percent), bachelor's degree (28.0 percent) and graduate degree (26 percent).

The convenience sample was drawn from a church in a northern Detroit suburb (n=119) and educational settings in a hospital and two universities (n=31).

The three colors used in the research were black-and-white photographed with an artist's gray scale. The formula "$(L_{Letters} - L_{background}) \div (L_{Letters} + L_{background})$" (Legge, Rubin, & Luebker, 1987) was utilized for a

contrast number. The ink color equaled black and the paper hue equaled the number from the formula. The paper hues with the greatest range (blues, reds and greens) were chosen for this research. Their ranges were .086, .134 and .134. The Metropolitan Achievement Test (MAT6) (1985) was used to measure reading speed.

Research data consisted of demographic data, reading speed scores and paper hue intensity. The statistical analysis used for questions one and two was a one factor repeated measures analysis of variance. It tested for age and gender-related reading speed differences on the three intensities of colored papers. The statistical analyses for question three were correlations plus stepwise regressions. They were conducted to explain differences in the dependent variables.

Results

Question One

To answer question one, "To what extent does paper hue intensity affect the reading speed of persons of varying ages?", paper hue intensity scores, MAT6 reading speed scores and the five age groups were needed. A general factorial ANOVA was used as a test of significance. Table 1 identifies the mean number of lines read on all three paper intensities

Table 1
Means of Lines Read by Age Groups on Light, Medium and Dark Intensities

	Means		
Ages in Group	Light Intensity	Medium Intensity	Dark Intensity
20-32	31.77	33.53	36.16
33-45	40.67	36.50	37.93
46-58	35.60	34.77	35.37
59-71	34.67	33.10	35.57
More than 72	29.50	31.80	29.80

Scores on light intensities indicated that the three light intensities are statistically diverse and that there are also differences in the reading speed scores of the five age groups. An interaction was also found between reading speed scores on the three light paper intensities when combined with age. Table 2 presents the results of the analysis of variance among the light paper intensities, age groups and reading speed.

Table 2

The Relationships Among Age Groups and Reading Speed Scores on Light Intensities of Paper

Source of Variation	Significance of F
Light Paper Intensities	.000*
Age Groups	.023*
Light Intensity by Age Groups	.000*
*$p < .05$	

No statistically significant relationship among age, medium intensities of paper and reading speed was found. Table 3 presents the results of the analysis of variance among the medium paper intensities, age groups and reading speed.

Table 3

The Relationships Among Age Groups and Reading Speed Scores on Medium Intensities of Paper

Source of Variation	Sig. of F
Medium Paper Intensities	.283
Age Groups	.060
Medium Intensities by Age Groups	.065
*$p < .05$	

Scores on dark intensities indicated statistical diversity. An interaction was also found between reading speed scores on the three dark paper intensities when combined with age. Table 4 presents the results of the analysis of variance among the dark paper intensities, age groups and reading speed.

Table 4

The Relationships Among Age Groups and Reading Speed Scores on Dark Intensities of Paper

Source of Variation	Sig. of F
Dark Paper Intensity	.008*
Age Groups	.364
Dark Intensities by Age Groups	.044*

*p < .05

The first research question addressed the relationships among paper hue intensity, reading speed and age. Light and dark intensities varied significantly among age groups. In this research, reading speeds on both light and dark intensities of paper hue became slower (fewer lines read) as the adults aged. Medium intensity had no significant variance indicating that reading speed did not vary significantly with these paper hue intensities.

Question Two

The second research question considered the question of paper hue intensity and gender affecting the reading speed of persons of varying ages. A general factorial ANOVA was employed to compare the reading speed scores on each of the three paper intensities with the five age groups. No statistical interaction was found among the three hues, age groups and gender (Tables 5).

Table 5

Means of Lines Read by Gender on Light, Medium and Dark Intensities

	Means			N=150
Gender	Light Intensity	Medium Intensity	Dark Intensity	N
Male	33.63	35.41	35.19	75
Female	35.25	32.47	34.75	75

Participants' reading speed scores on light intensities of paper hues indicated that a statistical interaction was found between the three light hues and age groups. The ANOVA results in Table 6 illustrate the data regarding light paper intensities.

Table 6

The Relationships Among Reading Level Scores, Light Intensities of Paper, Age Groups and Gender

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	8297.60	120	69.15		
Hue Name	419.68	2	209.84	3.03	.052*
Age Groups	2151.56	4	537.89	7.78	.000*
Gender	99.23	1	99.23	1.44	.233
Light Paper Intensity by Age Group	1248.52	8	156.07	2.26	.028*
Light Paper Intensity by Gender	117.49	2	58.75	.85	.430
Age Groups by Gender	149.51	4	37.38	.54	.706
Light Paper Intensity by Age Groups by Gender	411.37	8	51.42	.74	.653
(Model)	4597.36	29	158.53	2.29	.001
(Total)	12894.96	149	86.54		

*p < .05

Scores on the medium intensities indicated a statistically significant interaction with gender. Table 7 highlights the relationship between gender and medium intensity paper hues and presents the complete analysis of variance results.

Table 7

The Relationships Among Reading Level Scores, Medium Intensities of Paper, Age Groups and Gender

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	9309.60	135	77.68		
Hue Name	228.76	2	114.38	1.47	.233
Age Groups	380.63	4	95.16	1.23	.303
Gender	325.61	1	325.61	4.20	.043*
Hue Name by Age Groups	1153.57	8	144.20	1.86	.073
Hue Name by Gender	55.61	2	27.81	.36	.700
Age Groups by Gender	167.03	4	41.76	.54	.708
Hue Name by Age Group by Gender	209.65	8	26.21	.34	.950
(Model)	2520.86	29	86.93	1.12	.326
(Total)	11830.46	149	79.40		

*$p < .05$

Scores on the dark intensities indicated a statistically significant interaction with age and gender. Table 8 highlights the relationship between gender and age and dark intensity paper hues and presents the complete analysis of variance results.

Table 8

The Relationships Among Reading Level Scores, Dark Intensities of Paper, Age Groups and Gender

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	8909.20	135	74.24		
Hue Name	154.49	2	77.25	1.04	.356
Age Groups	1123.67	4	280.92	3.78	.006*
Gender	7.26	1	7.26	.10	.755
Hue Name by Age Groups	687.17	8	85.90	1.16	.331
Hue Name by Gender	504.76	2	252.38	3.40	.037*
Age Groups by Gender	171.11	4	42.78	.58	.680
Hue Name by Age Groups by Gender	909.17	8	113.65	1.53	.154
(Model)	3557.63	29	122.68	1.65	.032
(Total)	12466.83	149	83.67		

*$p < .05$

Reading level scores, paper intensity, age group and gender were examined in question two. An analysis of variance for light paper intensities indicated an interaction among age groups. For medium intensities, gender was significant and age and gender were significant for dark paper intensities.

Question Three

To answer question three, three stepwise multiple regressions correlated each paper hue intensity with participants' age and gender. Negative results indicated that older adults read fewer lines in the time allotted. Therefore, they experienced increased difficulty when reading on both light and dark paper intensities (Tables 9 and 10).

Table 9

The Relationships Between Three Light Paper Hue Intensities and Reading Level, Age & Gender

		B	T	Sig T
Age		-.086	-2.23	.028
(Constant)		38.98	17.93	.000
r	.18			
R^2	.032			
F	4.95			
Sig F	.028			

Table 10

The Relationships Between Three Dark Paper Hue Intensities, Age & Gender

		B	T	Sig T
Age		-.11	-3.01	.003
(Constant)		40.93	19.40	.000
r	.24			
R^2	.06			
F	9.08			
Sig F	.003			

Gender also was negatively correlated with medium paper intensities. Table 11 summarizes medium paper hue intensities and their relationships between reading speed and gender. The negative results indicated that women read fewer lines than men in the time allotted. Therefore, women experienced increased difficulty when reading on all three hues' medium intensities.

Table 11

The Relationships Between Three Medium Paper Hue Intensities, Age & Gender

		B	T	Sig T
Gender		-2.947	-2.05	.043
(Constant)		38.36	16.85	.000
r	.17			
R^2	.03			
F	4.19 .043			
Sig F				

T-tests were conducted separately with each light, medium and dark paper hue (green, red and blue). A Scheffe' test (at a significance level of .05) found no two groups were significantly different at the .05 level. This indicated that the three light, medium and dark paper intensity means were not significantly different; they were homogeneous subsets.

Correlations between participants' reading speed on the green hues indicated that participant's age and gender were correlated with the dark green paper intensity. This negative correlation indicated that older women experienced difficulty when reading on the dark green paper hue. No correlations were found with the blue paper hue.

When stepwise regressions were conducted, participants' reading speed scores were correlated with the

three paper intensities. Participants' ages were significant with light and dark paper intensities. Medium paper intensity was correlated with gender.

Table 12

Summarized Findings of Research Questions

Question	Source of Data	Significant Relationships
1. To what extent does paper hue intensity affect the reading speed of persons of varying ages?	MAT6 Reading Test Scores Participants' ages	Relationships among reading speed scores, age and paper intensity were significant for: › light intensities of paper with age groups. › dark intensities of paper with age groups.
2. To what extent do paper intensity and gender affect the reading speed of persons of varying ages?	MAT6 Reading Test Scores Participants' gender	Relationships among paper intensity, gender and age were significant for › light intensities of paper and age groups. › mediumintensities of paper and gender. › dark intensities of paper and gender with age groups.
3. What are the relationships between reading speed and paper hue intensity, age and gender?	MAT6 Reading Test Scores Participants' ages Participants' gender	Stepwise regressions discovered significant relationships between participants' age and reading speed on the light and dark red paper hues. Participants' reading speed on the dark green paper hue demonstrated a significant relationship with age and gender. Blue indicated no significant relationships. The light and dark paper shades were significantly related to participants' age. Participants' reading speed on medium shades was significant with gender.

Discussion

It is becoming increasingly important to create materials that are easy to read for the aging population as this group will soon will encompass 25 percent of the population. Lifelong learning as well as recreational, health, financial and legal reading are important for this group of aging adults. Unless care is taken to ensure that the printed pages are readable and legible, they are useless. More attention is being paid to older adults in designing many products (for example, automobiles and homes). Implications of this research may influence a photocopying business, typesetter or printing company's ability to aid customers as well as health care, education and recreational reading.

While it appears sensible to produce materials that all persons can utilize, it is not a commonly accepted practice. These questions are universally needed for a complete picture of printed materials and aging.

Two additional questions might be:

1. Does type size affect the reading speed of adults of varying ages as they read on an assortment of paper hue intensities?
2. What are the effects of line length on reading speed as people age?

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