INFORMATION TO USERS

This dissertation was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again – beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

A Xerox Education Company

73-9155

GROOTERS, Lyle Eugene, 1932-
THE RELATIONSHIP OF LETTER STYLE, LETTER SIZE, AND VIEWING DISTANCE TO THE READABILITY OF TRANSPARENT VISUALS.

The University of Oklahoma, Ed.D., 1973
Education, theory and practice

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE RELATIONSHIP OF LETTER STYLE, LETTER SIZE, AND VIEWING DISTANCE TO THE READABILITY OF TRANSPARENT VISUALS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF EDUCATION

BY

LYLE E. GROOTERS

Norman, Oklahoma

1972

THE RELATIONSHIP OF LETTER STYLE, LETTER SIZE,

AND VIEWING DISTANCE TO THE READABILITY

OF TRANSPARENT VISUALS

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGEMENT

This study was made possible only with the assistance and cooperation of many persons. The author is very grateful to the members of the Doctoral Committee: Dr. W. R. Fulton, Chairman of the Committee, who provided guidance and assistance for this study and throughout the entire graduate program; Dr. Robert Bibens, Dr. Gerald Kidd and Dr. T. J. Ragan, who provided many helpful suggestions and resource materials.

The author is also grateful to Dr. Richard Snowberg, who provided the initial idea for this study, for his assistance with the production of the stimulus materials, and to Dr. David Fleckenstein for his assistance with the essential statistical and computer programs.

Finally, the author is deeply grateful to his wife, Shirley, who provided cooperation and encouragement during the many years of graduate study which culminated in the writing of this thesis.

L. E. G.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

THE RELATIONSHIP OF LETTER STYLE, LETTER SIZE, AND VIEWING DISTANCE TO THE READABILITY OF TRANSPARENT VISUALS

CHAPTER I

INTRODUCTION

Until recently, audiovisual materials have been used as aids to instruction, supplementary to the efforts of the classroom teacher. During World War II, for instance, the armed services placed great reliance on the effectiveness of media as teaching tools. However, media was still regarded as supplemental, rather than as an integral part of the instructional process. With the development of newer media and new patterns for utilizing some of the older forms of media, teaching procedures and methods have changed it from a supplemental aid to a self-supporting, integrated part of the modern educational system of today.[1]

---

[1]Robert Heinich, "The Teacher in an Instructional System," in Instructional Technology: A Book of Readings, ed. by Frederich G. Knirk and John W. Childs (New York: Holt, Rinehart and Winston, 1968), p. 48.

Although there has been a continual increase in the use of projected visual materials for classroom instruction in elementary, secondary, and higher educational institutions, only a limited amount of information is available on how to produce visual materials in order to provide optimum readability for the student. The design for these materials has generally been left to the personal judgment of the educator or artist, rather than to guidelines substantiated by research.

There are a number of factors with which designers of visual materials should be concerned in order to increase the readability of visuals. Illumination, contrast, color background, negative or positive images, screen size and material, viewing distance and angle, and letter size are all directly related to the readability of the message of the visual.

While many of the areas noted have been subjected to adequate investigation, there are still some important questions that need to be asked regarding the preparation of visual materials. One of these is concerned with using various letter styles. Is there one letter style more readable than others? Is the same letter height adequate for all letter styles? Are the same letter height and letter style adequate for viewing at various distances? These and other questions all relate to the problem in this investigation.

Statement of the Problem

The problem of this study was to determine the extent to which there were differences in the readability of transparent visuals as influenced by letter styles, letter sizes, and viewing distances for college students.

Purpose of the Study

The purpose of this study was to investigate a number of the more commonly used letter styles and the various letter sizes in order to find the most readable combination of letter styles related to letter height projected at various distances.

Procedures and projection facilities used in this study were comparable to those in a typical classroom. This was done so tentative generalizations would be possible.

The specific objectives of this study were:

(1) To compare this study's findings on letter style and letter size with findings reported by other researchers.

(2) To compare the accuracy of responses to visual materials of selected letter styles and letter sizes when luminance was held constant with other similar studies.

(3) To compare the readability relationship between letter style and letter size projected at distances of 10, 20, 30, and 40 feet.

(4) To determine which was the smallest letter size ratio readable for projected visuals at distances of 10, 20, 30, and 40 feet.

Hypotheses

1. Letter style "A" (LeRoy Standard) is more readable than letter styles "B" (LeRoy Stymie Medium) and "C" (LeRoy Condensed Gothic) at all size levels.

2. Letter style "B" (with serifs) is more readable than letter style "C" (without serifs) at all size levels, but less readable than letter style "A" (without serifs) at all size levels, and at all viewing distances.

3. The largest letter size (1:20) will be readable with all letter styles and at all viewing distances.

4. Using a readability mean score of 75% as the cut off point, the smallest readable letter size of all letter styles at a viewing distance of 10 feet will be 1:50; at 20 feet will be 1:40; at 30 feet will be 1:30; and at 40 feet will be 1:20.

CHAPTER II

RELATED LITERATURE

As previously stated, there are a number of factors which can make the reading of visuals difficult. They are: (1) letter size, (2) illumination and contrast, (3) viewing distance and angle, (4) screen material, (5) color background, (6) negative and positive image, (7) letter style; and in some cases, the individual's eyesight may cause a problem.[1] These factors act singly or interact in combinations to produce some degree of good or poor readability.

Letter Size

It has been assumed that the one single factor which has a great influence on readability of visual materials is size. Various standards have evolved which specify a recommended minimum letter size in inches on original art work or in terms of a number ratio system.

---

[1]Richard L. Snowberg, "The Relationship Between Color Preference and Readability of Projected Black Characters with a Colored Background, Under Conditions of Controlled Luminance and Transmission" (unpublished Ed.D. dissertation, Indiana University, 1971), p. 9.

These standards vary from a ratio of 1:29 to 1:78 (see Table 1).[1] This system relates letter height to the overall height of the projected image on the screen. For example, a 1:20 letter size ratio indicates that the letter's height is 1/20th the height of the projected image on the screen. If the projected image on the screen is 60 inches in height, then the letter size of the visual would be 3 inches.

Another method of describing letter size is the Snellen system, which involves the use of the Snellen eye chart. Peters reported that the Snellen system is both a reliable and valid measurement of visual acuity.[2] While there are several forms of the Snellen Chart, the most widely used chart has six or seven lines of letters. The top line has all large size letters and each successive line below it has smaller characters. Each of the lines is identified by a number ratio indicating the relationship of letter size to readability distance. For example, the 20/20 line is considered the normal acuity line. The numerator of the fraction represents the reading distance, while the denominator indicates the distance

---

[1]James W. Costello, "The Readability of Projected Captions for Children 6-9 Years of Age" (unpublished Ed.D. dissertation, Indiana University, 1969), p. 3.

[2]Henry B. Peters, "Vision Screening with a Snellen Chart," American Journal of Optometry and Archives of the American Academy of Optometry, XXXVIII (1961), 489.

from which that line can be read by the normal eye. A person who is able to read only down to the 20/40 line is reading at 20 feet what normal vision is capable of seeing at 40 feet.

TABLE 1

SUMMARY OF RECOMMENDATIONS REGARDING MINIMUM LETTER SIZE FOR ORIGINAL ART WORK FOR PROJECTED VISUALS WITH HORIZONTAL FORMAT (6 3/4" x 9" ON 8 1/2" x 11" PAPER FOR ADEQUATE MARGINS)

Source	Ratio of minimum letter size to over-all height of visual	Recommended minimum letter size, inches on original art work
Van Antwerpen	1:78	0.125
American Chemical Society, _Hints to Authors_	1:64 (Minimum)	0.125
American Association of Petroleum Geologists, _Slide Manual_	1:58	0.141
L. S. Bonnell	1:54	0.139
University of Minnesota, _Aids to Technical Writing_	1:50	0.120
J. Kemp	1:50	0.180
Eastman Kodak Co., S.4 _Legibility Standards for Projected Materials_	1:50	0.125
Society of Automotive Engineers (no date)	1:40	0.200

TABLE 1--Continued

Source	Ratio of minimum letter size to over-all height of visual	Recommended minimum letter size, inches on original art work
Minnesota Mining and Manufacturing Co. (3M), Creative Teaching	1:36	Scaled Template
United States of America Standards Institute Y15.1-1959	1:34	0.175 Upper Case 0.200 Upper and Lower Case
American Chemical Society, Handbook for Speakers	1:34 (Adopted USA Standard)	
American Chemical Society, Hints to Authors	1:32 (Preferred)	0.250
B. A. Jones, Slides: Confusing or Clear?	1:32	0.200
B. A. Jones, Make Slides Worthwhile	1:32	0.240
John Asher, Effective Photographic Slides	1:29	By scale only

In a visual acuity study, Snowberg investigated the readability of projected black characters with colored backgrounds. In one section of that study, he also used black letters on a white background.[1] The letter style and letter size reported in the Snowberg study were similar to style "A" and the four letter sizes to be used in this study. The results of Snowberg's letter size ratio mean scores are as follows: 1:20 = 10.000, 1:30 = 9.896, 1:40 = 9.042, and 1:50 = 7.188. These results will be compared with the results of this study in a later section of this paper.

Illumination and Contrast

Two factors affecting discrimination are illumination and brightness contrast. Studies by Tinker[2] and Gilbert and Hopkinson[3] point out that visual acuity increases when illumination is increased. (Visual acuity refers to the sharpness of an individual's eyesight.) Riggs defined visual acuity as "the capacity to discriminate the fine details of objects in the field of view."[4] Sloan recommends an illumination level of 12-18 foot lamberts (FL), because this is "most representative of

---

[1]Snowberg, op. cit., p. 49.

[2]Miles A. Tinker, "Brightness Contrast, Illumination, Intensity and Visual Efficiency," American Journal of Optometry and Archives of American Academy of Optometry, XXXVI (May, 1959), 234.

[3]M. Gilbert and R. G. Hopkinson, "The Illumination of the Snellen Chart," British Journal of Ophthalmology, XXXIII (May, 1949), 307.

[4]Lorrin A. Riggs, "Visual Acuity," in Vision and Visual Perception, ed. by Clarence H. Graham (New York: John Wiley and Sons, Inc., 1965), p. 321.

conditions under which the eyes are normally used."[1] Research has shown that the ideal level of luminance for reading is 10 FL. It seems reasonable to test screen vision in this project at the 10-20 FL level.

There is some disagreement in the literature reviewed regarding contrast, because the term is used in different contexts. Bartley has clarified this by differentiating between intensity contrast and brightness contrast. He describes intensity contrast as a property of the stimulus, whereas brightness contrast is the sensory experience the eye receives.[2] In addition to brightness and contrast, Luckiesh believes that the size of letters and time available for seeing are important factors regarding the readability of visual materials.[3] In a study by Metcalf, an attempt was made to determine the separate and joint effects of image size, brightness, and contrast of visual materials in terms of time required for discrimination. His conclusions were that when visibility is measured by both reaction time and accuracy of response, it is (1) significantly affected by the visual angle, (2) significantly affected by contrast

---

[1]Louise L. Sloan, "Measurement of Visual Acuity," A.M.A. Archives of Ophthalmology, XXXXV (June, 1951), 725.

[2]Howard S. Bartley, Principles of Perception (New York: Harper and Bros., 1968), p. 113.

[3]Matthew Luckiesh, Light, Vision and Seeing (New York: Van Nostrand Co., 1944), p. 56.

between the image and background, and (3) not significantly affected by the brightness of the background.[1]

A close relationship exists between acuity, contrast, and illumination. As the contrast ratio of a visual target decreases, its overall illumination must be increased to maintain the same visual acuity. Standardized acuity testing requires both a controlled illumination and a definite target distance. The universally accepted subject-to-target distance for testing is 20 feet.[2] At 20 feet, through infinity, the light rays are nearly parallel when they enter the eye. It provides a valid index for measuring acuity for all long distances.

Viewing Distance and Angle

The current recommendations for viewing distance from the screen are generally based on a screen width to maximum viewing distance relationship of 1 to 6; although in some cases, they may range from a low of 1 to 2.5 to a high of 1 to 7 (see Table 2).[3]

---

[1]Richard M. Metcalf, "The Effects of Visual Angle, Brightness, and Contrast on the Visibility of Projected Materials" (unpublished Ed.D. dissertation, Indiana University, 1968), p. 56.

[2]"Vision Screening in Schools," The Sight-Saving Review, XXXI (Spring, 1961), 51.

[3]Milton I. Patrie, "The Relationship Between Viewing Position and Achievement Self-Paced Responses to Projected Alphanumeric Characters" (unpublished Ed.D. dissertation, Syracuse University, 1968), p. 31.

The angle at which the viewer sits from the screen has a direct relationship to the readability of the visual. Studies by Patrie[1] and Costello[2], who tested students and angles up to 45° left and right of 0° projection axis, showed that the greater the angle from 0°, the greater the number of errors that were recorded in their acuity testing. Most authorities recommend a viewing angle of 30° from the screen center (see Table 2).

Screen Material

In the studies just mentioned, both Patrie and Costello used a matte surface screen. The manufacturer's recommended viewing area for a matte surface screen is 30° from the center axis, and for a beaded-glass screen the viewing area is 22°. The beaded screen does have greater reflection.[3] However, because of the wider viewing angle and economic factors, the majority of projection screens in schools today are the matte surface material. A matte surface screen will be used in this study.

---

[1]Patrie, op. cit., p. 31.

[2]Costello, op. cit., p. 23.

[3]Audiovisual Projection, Kodak Pamphlet No. S-3 (Rochester, N. Y.: Eastman Kodak Company, 1971), p. 3.

TABLE 2

VIEWING AREAS RECOMMENDED BY AUTHORITIES

Authority	Viewing Distance Min.	Viewing Distance Max.	Viewing Angle (degrees)	Comments[a]
Dale	2W	6W	30	With reservations
DAVI	2.5W	5W	30	
Eastman Kodak	2W	6W	30	Beaded min. dist. 2.5W
EFL	2W	6W	45	Fan or oval area
Erickson	2W	6W	30	Greater distances if visuals good
Foy Cross & Cypher	2W	6W	30	
Freedman & Berg	2W	6W	30	
Indiana	2W	6W	30	
Kinder	2W	6W	30	20-25° Beaded screen
Los Angeles School	2W	6W	30	
R. P. I.	2W	6-7W	30	Edge angle measure
Sands	2W	6W	30	Measure angle from screen edge
Silverstone & Brandon	2W	6W	50[b]	
Sumner	2.5W	7W	20	
Thomas & Swartout	2W	6W	50	Fan-shaped area
U. S. O. E.	2W	6W	30	
Wittich & Schuller 3rd ed.	2W	6W	22.5[b]	

[a]Viewing area sides converge at screen center unless otherwise stated.

[b]Half of recommended total-included-angle.

Color Background

Another factor affecting readability of a visual is the color background. A study by Snowberg concludes that in terms of visual acuity, a white background should be used for superior legibility.[1] However, for non-critical viewing, Snowberg recommends that green backgrounds should be used rather than the more popular yellow, which is in current use. This recommendation is based on the fact that yellow was the least preferred color in his study while green ranked near blue as the most popular. Both green and yellow ranked high on the scale, although lower on the overall critical acuity scale than white.

Negative and Positive Image

A study by Weaver using positive and negative images, black letters on white background and white letters on black background, found that the positive image was significantly better than the negative image.[2]

As a result of the two above mentioned studies, the current study will be conducted using a positive (black) image on a white background.

---

[1]Snowberg, op. cit., p. 78.

[2]Terry D. Weaver, "A Study of the Comparative Legibility of Projected Positive and Negative Black and White Slides" (unpublished Ed.D. dissertation, Indiana University, 1971), p. 52.

Letter Style

While there has been some attention given to most of the factors affecting the readability of projected visual materials, there is one important aspect for which a real paucity of evidence exists: that is, the letter style of a visual. There has been very little research conducted on the relative acuity of the different styles of lettering available for producing visual materials. For the most part, research has been conducted on type fonts available to printers and type for typewriters. Adams, Rosemier, and Sleeman studied the readability of typewriter lettering for overhead transparent visuals.[1] The results of their investigation indicated that the smaller size letters (elite and pica) should be avoided in the preparation of projectuals. They also reported that four out of the five groups tested found that the 6/32 inch primer size type with serifs was more readable than the 6/32 inch bulletin type without serifs.

Certain letters are more easily recognized than others, because of their general form or shape. Sheard stated that letters used for research purposes should be selected from several different levels of difficulty.[2]

---

[1]Sarah Adams, Robert Rosemier, and Phillip Sleeman, "Readable Letter Size and Visibility for Overhead Projection Transparencies." Audiovisual Communication Review, XIII (Winter, 1965), p. 416.

[2]Charles Sheard, "Some Factors Affecting Visual Acuity," American Journal of Physiological Optics, II (April, 1921), 170.

In a study conducted by Richards, letters with and without serifs were used.[1] His subjects were first tested with 10 FL of lumination and then again with 1 FL. The serif letters were miscalled less often at 10 FL and more so at 1 FL. There were less mistakes in naming the letters without serifs at both luminances. (The letter style Stymie Medium has serifs.) Sloan has rated letters according to their relative difficulty level. In tests conducted on 234 eyes, the letter S was the most difficult to read, and the letter Z was the easiest[2] (see Table 3).

Exposure Time

Exposure time is another variable which may affect the individual's ability to discriminate detail. The usual study in which exposure is considered a variable deals with exposures of short periods of time, i.e., a few seconds or fractions of seconds.[3] In the current study, as in most classroom situations, projection of visual materials involves medium to long exposure times of approximately 15 seconds or longer. Under these conditions,

---

[1]Oscar W. Richards, "A Comparison of Acuity Test Letters With and Without Serifs," American Journal of Optometry and Archives of the American Academy of Optometry, XXXXI (1964), 592.

[2]Louise L. Sloan, "New Test Charts for the Measurement of Visual Acuity at Far and Near Distances," American Journal of Ophthalmology, XXXXVIII (December, 1959), 808.

[3]Snowberg, op. cit., p. 19.

TABLE 3

RELATIVE DIFFICULTY OF SLOAN LETTERS

Letter	Percent of correct responses at threshold	Deviation from average percent correct
Z	94.0	12.0
N	91.6	9.6
H	89.3	7.3
R	86.3	4.3
V	84.6	2.3
K	82.1	0.1
D	79.5	-0.5
C	71.4	-10.6
O	71.0	-11.0
S	70.6	-11.4
	Average 82.0	

students have adequate time to read the visual information; and thus, exposure time is not a main concern of this study.

Visual Fatigue

Studies by Carmichael and Dearborn reported that a book can be read continuously for six hours by a normal subject without undue signs of fatigue.[1] They also

[1]Leonard Carmichael and Walter F. Dearborn, Reading and Visual Fatigue (Boston: Houghton Mifflin Co., 1947), p. 358.

reported that microfilm reading can be carried on for six hours without unduly fatiguing the normal subject. In this study, where a subject will be required to concentrate on visual targets for approximately 15 seconds per target, during a total time span of 15 to 20 minutes, fatigue should not be a factor of importance.

CHAPTER III

METHODOLOGY

The procedures used in this study are discussed under the following headings: (1) selection of population, (2) instrumentation, (3) stimulus materials, (4) instructions and procedures, (5) independent variables, (6) dependent variables, and (7) design.

Selection of Population

Sixty subjects were selected to participate in this study. The subjects were undergraduates and graduates in the 18-30 age group. All were enrolled in education courses at the University of Wisconsin-Whitewater. Participation in the study was on a volunteer sign-up basis. The subjects were randomly assigned to initial viewing distance groups (10, 20, 30, or 40 feet) by using a table of random digits.[1]

A pre-test was used to determine the condition of their eyesight. Those students whose eyesight tested below normal 20/20 on the Snellen Eye Chart were retained

---

[1]E. R. Lindquist, Design and Analysis of Experiments in Psychology and Education (Boston: Houghton Mifflin Company, 1964), 385.

in the sample, because the intention was to employ a group similar to that which might be found in a typical classroom with all the variances in visual acuity normally present. For this same reason, students who wore corrective lenses regularly wore them during the experiment.

Instrumentation

Projection facilities were standardized under carefully controlled conditions. The projection screen selected for this study was a Da Lite Model C white matte surface screen with a measured width of 8 feet. The testing room was an inside room with no windows and the screen brightness was calculated to be 12.5 FL.[1]

The stimulus materials were projected by Model 750 Kodak Carousel 2" x 2" slide projector. This model was equipped with a six inch f/3.5 lens and a 500 watt CBA lamp.

Stimulus Materials

Stimulus materials used in this study consisted of a series of 12 black on white positive 35mm test slides. The letter styles chosen for use in this study were the following letter templates: (1) LeRoy Standard, #61-0250; (2) LeRoy Stymie Medium, #61-1150; and (3) LeRoy Condensed Gothic, #61-0600 (see Figure 1). A

---

[1]Audiovisual Projection, S-3, *op. cit.*, p. 14.

LETTER STYLES

STYLE A.

THIS IS A SAMPLE OF
LEROY STANDARD, 61-0250

Z N H R V K D C O S

STYLE B.

THIS IS A SAMPLE OF
LEROY STYMIE MEDIUM,
61-1150

Z N H R V K D C O S

STYLE C.

THIS IS A SAMPLE OF LEROY
CONDENSED GOTHIC, 61-0600

Z N H R V K D C O S

Figure 1. Letter Styles Used on the Visual Acuity Slides

number three pen size was used with all three lettering templates in order to maintain the same letter stroke width.

Each target slide was designed to include one line of ten letters. The letters used in this study were the capital letters Z, N, H, R, V, K, D, C, O, and S, the same ones researched and difficulty rated by Sloan. The sequence of letters on each slide was randomly assigned by using a table of random digits.[1] The letters were designed to project to a specific letter height to screen image height ratio within a range of sizes known to discriminate legibility. The ratio of 1:20 was selected for the largest size by Costello, because this letter size could be identified by nearly all of his subjects.[2] The other letter sizes used in his study had the ratios of 1:30, 1:40, and 1:50. These ratios were also employed in this study (see Figure 2).

In order to standardize all the target slides, the 1:40 ratio line was designated as the 20/20 acuity line. This target slide was projected on the screen and centered on the Snellen Eye Chart (#1930). The slide projector was moved forward until the 1:40 ratio line coincided with the Snellen 20/20 line on the Snellen

---

[1]Lindquist, op. cit., p. 385.

[2]Costello, op. cit., p. 27.

1:20	K	D	R	Z	N	S	O	V	C	H
1:30	H	R	D	V	O	K	N	Z	S	C
1:40	C	Z	V	H	S	D	O	N	K	R
1:50	O	D	Z	H	S	N	R	V	K	C

Figure 2. Letter Size Ratios Used on Visual Acuity Slides.

Chart. Both the 1:40 ratio line on the slide and the 20/20 line on the chart were measured. Both sizes were 3/8" in height. The distance from the slide projector to the projection screen was measured, and found to be 5'4". The distance from the slide projector to the projection screen will vary as the focal length of the projector lens is changed.

All of the target slides were prepared with opaque black letters on clear backgrounds. High contrast film was used to produce 35mm positives. The positives were then mounted in 2" x 2" slide frames. All photographic and mounting procedures were carefully controlled to insure uniform slides.

Instructions and Procedures

Participants in this study were tested individually. The tests began by asking the subject to stand at a designated position (20 feet from the screen) in a darkened room. After allowing a brief period of time for the subject's eyes to adapt to the beam of light projected on the screen, each was given a Snellen Eye Test, using the American Optical Chart #1930, to establish the visual acuity.

Preliminary Screening of Eyes

The instructions to the subjects were as follows:

"(Subjects' name), please stand on this line and cover your left eye. Do not press on your

> eye, but cover it completely so that you do not see the letters. Start reading the letters on the top line, left to right, reading out loud until you cannot distinguish the letters."

The right eye response was recorded on the test sheet.

> "(Subjects' name), will you please cover your right eye and using the same procedure, read the letters, starting with the top line until you cannot distinguish the letters."

The left eye response was recorded on the test sheet.

Test Orientation

Each subject was instructed to sit in a designated chair (20 feet from the screen). After the room was darkened, and the subject's eyes had become accustomed to the beam of light on the screen, the following instructions were read to each subject:

> "Please look at the projected light while I give you instructions for viewing the slides. You will be looking at a total of 48 slides. Each slide will contain one line of letters. Each line is composed of 10 letters. There will be 12 slides at each of the following distances: 20, 40, 30, and 10 feet.
>
> When asked to begin, you will be expected to read the letters out loud, reading from left to right. Do not rush through the line, but neither should you hesitate nor spend undue time on any one particular letter. Any time a letter is unclear to you, merely say 'x', and go on to the next letter. Let me repeat that again. Say 'x' for any letter which you cannot identify. This particular letter is not used in this series of slides and thus you need not worry about your use of 'x' for unknown letters.
>
> Please remain comfortably seated throughout the series of slides. Do not move forward or bend forward. Simply relax and identify those letters that you can see. It is not necessary nor desired that you squint.

Upon completion of identification of a slide, the operator will change the slide, and will ask you to begin identification of the next slide."

At the conclusion of the instructions, the operator asked each subject if he or she had any questions. Before any of the responses were recorded for the first slide, the operator explained to the subject that the answers were to be recorded on a test sheet (see Appendix). With these preliminary instructions out of the way, the subject began to identify the letters on the target slides.

Independent Variables

The independent variables of this study were letter style, letter height, and viewing distance. All other variables such as illumination, viewing angle, screen material and size were constant or were held at levels of non-significance.

Dependent Variable

The dependent variable in this study was readability, or the ability to respond to the letters viewed on the 48 target slides. The number of correct responses on each slide was 10, with a total of 480 responses.

Design

A three way Analysis of Variance was used for the statistical design. This design accounts for the responses to the independent variables: 3 (letter styles, LeRoy Standard, LeRoy Stymie Medium, and LeRoy Condensed Gothic) x 4 (letter sizes, 1:20, 1:30, 1:40, and 1:50 letter-height-to-screen-image height ratios) x 4 (viewing distances, 10, 20, 30, and 40 feet).

Each of the 60 subjects were exposed to the four letter sizes of each of the three letter styles and the four viewing distances. When significant F-ratios at the .01 significance level were found to exist, the Scheffe' Multiple Comparison Test was used to determine the differences between individual means. The Scheffe' method uses the criterion that the probability of rejecting the null hypothesis when it is true, a Type I error, should not exceed .01 for any of the comparisons made.[1]

The raw data was recorded on data punch cards and analyzed by a computer using the NWAY1: General Analysis of Variance program, written and supported by the Academic Computing Center at the University of Wisconsin, Madison.[2] Means for the independent variables are presented in Table 4.

---

[1]George A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill, 1971), 270.

[2]NWAY 1: General Analysis of Variance, Academic Computing Center, (The University of Wisconsin, Madison, 1970).

TABLE 4

CELL MEANS OF 60 SUBJECTS IN EACH OF THE THREE LETTER STYLES BY FOUR LETTER SIZE RATIOS BY FOUR VIEWING DISTANCES

	Style A				Style B				Style C			
	Size				Size				Size			
Distance	1:20	1:30	1:40	1:50	1:20	1:30	1:40	1:50	1:20	1:30	1:40	1:50
10 ft.	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	9.983	9.983	9.967	9.733
20 ft.	10.000	9.983	9.100	7.667	9.967	9.733	8.550	6.900	9.900	8.950	5.600	1.667
30 ft.	9.800	9.367	6.117	2.367	9.883	9.133	6.383	1.833	9.250	5.483	.967	.167
40 ft.	9.167	6.883	1.450	.033	9.400	7.050	1.717	.033	7.350	1.467	.033	.000

CHAPTER IV

RESULTS

This chapter consists of two sections. The first section contains the analysis of variance and the associated multiple comparison tests used to determine the differences between individual means. The second section describes the attainment of specific objectives.

Analysis of Variance

The summary of the analysis of variance, as presented in Table 5, includes: the independent variables--letter style, letter size, and viewing distance; three two-factor interactions--letter style and letter size, letter style and viewing distance, and letter size and viewing distance; and one three factor interaction--letter style, letter size, and viewing distance. The .01 level of significance was adopted for examining experimental effects.

Letter style (L) was significant at the $p < .01$ level with $F = 263.478$.

Letter size (Z) was significant at the $p < .01$ level with $F = 908.392$.

Viewing distance (D) was significant at the $p < .01$ level with F = 1186.516.

Three two-factor interactions are shown in Table 5. The interactions between letter style and letter size (LZ) were significant at the $p < .01$ level with F = 14.203. A significance of F = 28.222, $p < .01$ was found in the interaction between letter style and viewing distance (LD). Also, the interaction between letter size and viewing distance was found to be significant with an F = 141.040, $p < .01$.

One three-factor interaction involving the three independent variables is shown in the analysis of variance on line LZD of Table 5. This interaction, which included letter style by letter size by viewing distance, was significant with an F = 19.062, $p < .01$.

The Scheffe' Multiple Comparison Test was computed to determine the significant differences between the means for the three letter styles.[1] There was no significant difference between letter style "A" (LeRoy Standard) and letter style "B" (LeRoy Stymie Medium). There was a significant difference between letter style "A" (LeRoy Standard) and letter style "C" (LeRoy Condensed Gothic at the $p < .01$ level. There was also a significant difference between letter style "B" (LeRoy Stymie Medium)

---

[1]Ferguson, op. cit., p. 270.

TABLE 5

SUMMARY OF ANALYSIS OF VARIANCE OF THE INDEPENDENT VARIABLES AND INTERACTIONS OF LETTER STYLE, LETTER SIZE, AND VIEWING DISTANCE FOR THE NUMBER OF CORRECT RESPONSES

Source	df	SS	MS	F Required	F Obtained
Letter Style (L)	2	2371.300	1185.651	4.60	263.478*
Letter Size (Z)	3	12263.300	4087.766	3.78	908.392*
Viewing Distance (D)	3	16017.960	5939.320	3.78	1186.516*
LZ	6	383.490	63.914	2.80	14.203*
LD	6	761.990	126.998	2.80	28.222*
ZD	9	5712.110	634.679	2.41	141.040*
LZD	18	1544.030	85.779	1.93	19.062*

$^*p < .01$

and letter style "C" at the $p < .01$ level (see Table 6).

TABLE 6

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST FOR THE SIGNIFICANCE BETWEEN PAIRS OF MEANS FOR LETTER STYLES

	5.656	7.545	7.614
"C" 5.656		1.889*	1.958*
"B" 7.545			.068
"A" 7.614			

Scheffe' value = .293
*$p < .01$

The Scheffe' test was used to obtain the significant differences between the means for the four letter size ratios (see Table 7). The ratios 1:20, 1:30, 1:40 and 1:50 were all significantly different from each other at the $p < .01$ level.

Table 8 shows the results of the Scheffe' test for determining the significant differences between the means for the four viewing distances of 10, 20, 30, and 40 feet. They were all significantly different from each other at the $p < .01$ level.

Table 9 shows the results of the Scheffe' test on the difference between the letter style means and the 1:20 letter size ratio. There was no significant difference at the $p < .01$ level between the three letter styles.

TABLE 7

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST FOR THE SIGNIFICANCE BETWEEN PAIRS OF MEANS FOR LETTER SIZE RATIOS

	4.212	5.823	8.161	9.558
1:50 4.212		1.611*	3.948*	5.345*
1:40 5.823			2.337*	3.734*
1:30 8.161				1.397*
1:20 9.558				

Scheffe' value = .376
*$p < .01$

TABLE 8

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST FOR THE SIGNIFICANCE BETWEEN PAIRS OF MEANS FOR VIEWING DISTANCES

	3.715	5.895	8.159	9.984
40' 3.715		2.180*	4.444*	6.269*
30' 5.895			2.263*	4.088*
20' 8.159				1.824*
10' 9.984				

Scheffe' value = .376
*$p < .01$

TABLE 9

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT THE 1:20 LETTER SIZE RATIO

	9.121	9.742	9.813
"C" 9.121		.621	.692
"A" 9.742			.071
"B" 9.813			

Scheffe' value = 1.05
*p< .01

Table 10 shows the results of the Scheffe' test on the letter style means and the 1:30 letter size ratio. At the p<.01 level, there was no significant difference between letter styles "A" and "B". However, there was significant difference at the p<.01 level between letter styles "B" and "C" and between styles "A" and "C".

The results of the Scheffe' test for determining the differences between the letter style means and the 1:40 letter size ratio appear in Table 11. At the p<.01 level, there was no significant difference between letter styles "A" and "B". Between letter styles "A" and "C" and between styles "B" and "C", there was significant difference at the p<.01 level.

Table 12 shows the results of the Scheffe' test on the difference between the letter style means and the 1:50 letter size ratio. Once again there was no significant difference between letter styles "A" and "B", but there was significant difference between letter styles "A" and "C" and between styles "B" and "C" at $p < .01$ level.

TABLE 10

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT THE 1:30 LETTER SIZE RATIO

	6.471	8.979	9.033
"C" 6.471		3.508*	2.562*
"B" 8.979			.054
"A" 9.033			

Scheffe' value = 1.05
*$p < .01$

TABLE 11

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT THE 1:40 LETTER SIZE RATIO

	4.142	6.663	6.667
"C" 4.142		2.521*	2.525*
"B" 6.663			.004
"A" 6.667			

Scheffe' value = 1.05
*$p < .01$

TABLE 12

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT THE 1:50 LETTER SIZE RATIO

	2.892	4.729	5.017
"C" 2.892		1.837*	2.125*
"B" 4.729			.288
"A" 5.017			

Scheffe' value = 1.05
*$p < .01$

The results of the Scheffe' test for determining the difference between the letter size ratios for letter style "A" are shown in Table 13. At the $p < .01$ level, there was no significant difference between letter size ratios 1:20 and 1:30, but there was significant difference at the .01 level between the remainder of the letter size ratios.

Table 14 shows the results of the Scheffe' test for determining the differences between letter size ratios for the letter style "B". At the $p < .01$ level, there was no significant difference between letter size ratios 1:20 and 1:30; but there was significant difference at the .01 level between the remainder of the letter size ratios.

The results of the Scheffe' test for determining the difference between the letter size ratios for letter

TABLE 13

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST FOR THE SIGNIFICANCE BETWEEN LETTER SIZE RATIO MEANS FOR LETTER STYLE "A"

	5.017	6.667	9.033	9.742
1:50 5.017		1.650*	4.016*	4.725*
1:40 6.667			2.366*	3.075*
1:30 9.033				.709
1:20 9.742				

Scheffe' value = 1.05
*p<.01

TABLE 14

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER SIZE RATIO MEANS FOR LETTER STYLE "B"

	4.729	6.663	8.979	9.813
1:50 4.729		1.934*	4.250*	5.084*
1:40 6.663			2.316*	3.150*
1:30 8.979				.834
1:20 9.813				

Scheffe' value = 1.05
*p<.01

style "C" is shown on Table 15. At the p<.01 level there was significant difference between all of the letter size ratios.

TABLE 15

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER SIZE RATIO MEANS FOR LETTER STYLE "C"

	2.892	4.142	6.471	9.121
1:50 2.892		1.250*	3.579*	6.229*
1:40 4.142			2.329*	4.979*
1:30 6.471				2.650*
1:20 9.121				

Scheffe' value = 1.05
*p$<$.01

In Table 16 the results of the Scheffe' test for determining the differences between the letter style means at the viewing distance of 10 feet may be found. At the p$<$.01 level there was no significant difference between the letter styles.

TABLE 16

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT A VIEWING DISTANCE OF 10 FEET

	9.917	10.000	10.000
"C" 9.917		.083	.083
"B" 10.000			.000
"A" 10.000			

Scheffe' value = 1.05
*p$<$.01

The results of the Scheffe' test for determining the differences between the letter style means at a viewing distance of 20 feet are shown in Table 17. At the $p < .01$ level there was no significant difference between letter styles "A" and "B"; however, there was significance at the .01 level between letter styles "A" and "C" and between letter styles "B" and "C".

TABLE 17

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT A VIEWING DISTANCE OF 20 FEET

	6.529	8.788	9.163
"C" 6.529		2.259*	2.634*
"B" 8.788			.375
"A" 9.163			

Scheffe' value = 1.05
*$p < .01$

In Table 18 are the results of the Scheffe' test for determining the differences between the letter style means at a viewing distance of 30 feet. At the $p < .01$ level there was no significant difference between letter styles "A" and "B", but there was significance between letter styles "A" and "C" and between letter styles "B" and "C".

TABLE 18

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT A VIEWING DISTANCE OF 30 FEET

	3.967	6.808	6.913
"C" 3.967		2.841*	2.946*
"B" 6.808			.105
"A" 6.913			

Scheffe' value = 1.05
*$p < .01$

The results of the Scheffe' test for determining the differences between the letter style means at a viewing distance of 40 feet are shown in Table 19. At the $p < .01$ level there was no significant difference between letter styles "A" and "B"; however, there was significant difference at the .01 level between letter styles "A" and "C" and between styles "B" and "C".

In Table 20 are the results of the Scheffe' test for determining the differences between the viewing distance means at the 1:20 letter size ratio. At the $p < .01$ level there was a significant difference between viewing distance of 10 and 40 feet. Between the remainder of the viewing distances there was no significant difference.

In Table 21 are the results of the Scheffe' test for determining the differences between the viewing distance means at the letter size ratio of 1:30. There was no significant difference at the $p < .01$ level between viewing distances of 10 and 20 feet. At the remainder of the viewing distances there was significant difference at the .01 level.

TABLE 19

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AT A VIEWING DISTANCE OF 40 FEET

	2.213	4.383	4.550
"C" 2.213		2.170*	2.337*
"B" 4.383			.167
"A" 4.550			

Scheffe' value = 1.05
*$p < .01$

TABLE 20

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN THE VIEWING DISTANCE MEANS AT THE 1:20 LETTER SIZE RATIO

	8.639	9.644	9.956	9.994
40' 8.639		1.005	1.317	1.355*
30' 9.644			.312	.350
20' 9.956				.038
10' 9.994				

Scheffe' value = 1.33
*$p < .01$

TABLE 21

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN THE VIEWING DISTANCE MEANS AT THE 1:30 LETTER SIZE RATIO

	5.133	7.994	9.522	9.994
40' 5.133		2.861*	4.389*	4.761*
30' 7.994			1.528*	2.000*
20' 9.522				.472
10' 9.994				

Scheffe' value = 1.33
*$p < .01$

The results of the Scheffe' test for determining the difference between the viewing distance means at the letter size ratios of 1:40 and 1:50 are shown in Tables 22 and 23 respectively. At the $p < .01$ level there was significant difference between all of the viewing distances at both the 1:40 and 1:50 letter size ratios.

Table 24 shows the results of the Scheffe' test for determining the differences between the letter style means and the viewing distance means at the letter size ratio of 1:20. At the $p < .01$ level there was no significant difference between the letter styles and viewing distances.

TABLE 22

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN THE VIEWING DISTANCE MEANS AT THE 1:40 LETTER SIZE RATIO

	1.667	4.489	7.750	9.984
40' 1.667		2.820*	6.083*	8.317*
30' 4.489			3.261*	5.495*
20' 7.750				2.234*
10' 9.984				

Scheffe' value = 1.33
*$p < .01$

TABLE 23

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN THE VIEWING DISTANCE MEANS AT THE 1:50 LETTER SIZE RATIO

	.022	1.456	5.411	9.961
40' .022		1.434*	5.389*	9.939*
30' 1.456			3.955*	8.505*
20' 5.411				4.550*
10' 9.961				

Scheffe' value = 1.33
*$p < .01$

TABLE 24

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST
ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS
AND VIEWING DISTANCE MEANS AT LETTER
SIZE RATIO 1:20

Style	Dist		7.350	9.167	9.250	9.400	9.800	9.883	9.900	9.967	9.983	10.000	10.000	10.000
C	40'	7.350		1.817	1.900	2.050	2.450	2.533	2.550	2.617	2.633	2.650	2.650	2.650
A	40'	9.167			.083	.233	.663	.716	.733	.800	.816	.833	.833	.833
C	30'	9.250				.150	.550	.633	.650	.717	.733	.750	.750	.750
B	40'	9.400					.400	.483	.500	.567	.583	.600	.600	.600
A	30'	9.800						.083	.100	.167	.183	.200	.200	.200
B	30'	9.883							.017	.084	.100	.117	.117	.117
C	20'	9.900								.067	.083	.100	.100	.100
B	20'	9.967									.016	.033	.033	.033
C	10'	9.983										.017	.017	.017
A	20'	10.000												
B	10'	10.000												
A	10'	10.000												

Scheffe' value = 3.66
*$p < .01$

The results of the Scheffe' test for determining the differences between the letter styles means and the viewing distance mean at letter size ratios of 1:30, 1:40 and 1:50 are shown in Tables 25, 26, and 27 respectively.

Attainment of Specific Objectives

Objective one was to compare this study's findings on letter style and letter size with findings reported by other researchers. The findings of this investigation concerning letter size were in close agreement with three different studies reported by Costello,[1] Snowberg,[2] and Weaver.[3] In all of these, the letter size ratios used were the same as those used in this study, and they were all significant at the $p < .01$ level. Also, in each study, the largest letter size (1:20) was the most readable at 20 feet, as it was in this study.

The results of the letter style portion of the investigation were in agreement with a study reported by Richards,[4] but in disagreement with a study reported by Adams, Rosemier, and Sleeman.[5] In both of these studies,

---

[1]Costello, _op. cit._, p. 52.

[2]Snowberg, _op. cit._, p. 76.

[3]Weaver, _op. cit._, p. 48.

[4]Richards, _op. cit._, p. 592.

[5]Adams, _op. cit._, p. 416.

TABLE 25

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AND VIEWING DISTANCE MEANS AT LETTER SIZE RATIO 1:30

Style	Dist		1.467	5.483	6.883	7.050	8.950	9.133	9.366	9.733	9.883	9.883	10.000	10.000
C	40'	1.467		4.016*	5.416*	5.583*	7.483*	7.666*	7.899*	8.266*	8.416*	8.416*	8.533*	8.533*
C	30'	5.483			1.400	1.567	3.467	3.650*	3.936*	4.250*	4.400*	4.400*	4.517*	4.517*
A	40'	6.883				.167	2.067	2.250	2.483	2.850	3.000	3.000	3.117	3.117
B	40'	7.050					1.900	2.083	2.316	2.683	2.833	2.833	2.950	2.950
C	20'	8.950						.183	.416	.783	.933	.933	1.050	1.050
B	30'	9.133							.233	.600	.750	.750	.867	.867
A	30'	9.366								.367	.517	.517	.634	.634
B	20'	9.733									.150	.150	.267	.267
A	20'	9.883											.117	.117
C	10'	9.883											.117	.117
B	10'	10.000												
A	10'	10.000												

Scheffe' value = 3.66
*$p < .01$

TABLE 26

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST
ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS
AND VIEWING DISTANCE MEANS AT LETTER
SIZE RATIO 1:40

Style	Dist		.033	.967	1.450	1.717	5.600	6.117	6.383	8.550	9.100	9.967	10.000	10.000
C	40'	.033		.934	1.417	1.684	5.567*	6.084*	6.350*	8.517*	9.067*	9.934*	9.967*	9.967*
C	30'	.967			.483	.750	4.633*	5.150*	5.416*	7.583*	8.133*	9.000*	9.033*	9.033*
A	40'	1.450				.267	4.150*	4.667*	4.933*	7.100*	7.650*	8.517*	8.550*	8.550*
B	40'	1.717					3.883*	4.400*	4.666*	6.833*	7.383*	8.250*	8.283*	8.283*
C	20'	5.600						.517	.783	2.950	3.500	4.367*	4.400*	4.400*
A	30'	6.117							.266	2.433	2.983	3.850*	3.883*	3.883*
B	30'	6.383								2.167	2.717	3.584	3.617	3.617
B	20'	8.550									.550	1.417	1.450	1.450
A	20'	9.100										.867	.900	.900
C	10'	9.967											.033	.033
B	10'	10.000												
A	10'	10.000												

Scheffe' value = 3.66
*$p < .01$

TABLE 27

RESULTS OF THE SCHEFFE' MULTIPLE COMPARISON TEST ON THE DIFFERENCE BETWEEN LETTER STYLE MEANS AND VIEWING DISTANCE MEANS AT LETTER SIZE RATIO 1:50

Style	Dist		.000	.033	.033	1.667	1.667	1.833	2.367	6.900	7.667	9.733	10.000	10.000
C	40'	.000		.033	.033	1.667	1.667	1.833	2.367	6.900*	7.667*	9.733*	10.000*	10.000*
B	40'	.033				1.634	1.634	1.800	2.334	6.867*	7.634*	9.700*	9.967*	9.967*
A	40'	.033				1.634	1.634	1.800	2.334	6.867*	7.634*	9.700*	9.967*	9.967*
C	30'	1.667						.166	.700	5.233*	6.000*	8.066*	8.333*	8.333*
C	20'	1.667						.166	.700	5.233*	6.000*	8.066*	8.333*	8.333*
B	30'	1.833							.534	5.067*	5.834*	7.900*	8.167*	8.167*
A	30'	2.367								4.533*	5.300*	7.366*	7.633*	7.633*
B	20'	6.900									.767	2.833	3.100	3.100
A	20'	7.667										2.066	2.333	2.333
C	10'	9.733											.267	.267
B	10'	10.000												
A	10'	10.000												

Scheffe' value = 3.66
*p< .01

there was a comparison between letter styles with and without serifs. In each study the letter size was approximately the same and the viewing distance was 20 feet. This investigation and the study by Richards reported that the letters without serifs were more readable. However, the study by Adams, Rosemier, and Sleeman reported that four out of five groups found the letters with serifs were more readable.

Objective two was to compare the accuracy of responses to visual materials of selected letter styles and letter sizes when luminance was held constant with other similar studies. The responses were similar to those reported by the Snowberg study.[1] For instance, the population was 50 in Snowberg's study, 60 in this one; the subjects were of college age in both; the letter size ratios were the same; the letter style Snowberg used was similar to letter style "A" (without serifs) in this study; both used the viewing distance of 20 feet, black and white positive 2" x 2" slides, a Model 750 Kodak Carousel slide projector with a 500 watt lamp, and the slides were projected on a matte screen inside a classroom with no windows. The readable scores (cell means) for the two studies were as follows:

---

[1]Snowberg, op. cit., p.49.

Letter Size Ratio	Snowberg	Grooters
1:20	10.000	10.000
1:30	9.896	9.983
1:40	9.042	9.100
1:50	7.188	7.667

Objective three was to compare the readability relationship between letter style and letter size projected at distances of 10, 20, 30, and 40 feet. Using a mean score of 7.5 as the readability level, the results indicate that at 10 feet all letter sizes of the three letter styles were readable. As the viewing distance was increased, the number of readable letter sizes decreased.

The determination of the smallest letter size ratio readable at the four viewing distances mentioned as the fourth objective will be discussed in the summary under the heading Conclusions.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate a number of letter styles (LeRoy Standard, LeRoy Stymie Medium, and LeRoy Condensed Gothic), letter sizes (1:20, 1:30, 1:40, and 1:50 letter-height-to-screen-image-height ratios), and viewing distances (10, 20, 30, and 40 feet) commonly used in the preparation and showing of visuals in order to find the most readable combination of these variables. Sixty students were selected to participate in this study. Each subject was required to respond to a series of 12 black on white positive 35mm slides shown at distances of 10, 20, 30, and 40 feet. Each slide had one line of ten letters, or a total of 480 responses.

Letter style "A", LeRoy Standard, proved to be more readable than letter style "B", LeRoy Stymie Medium, (7.615 to 7.546), and letter style "C", LeRoy Condensed Gothic, (7.615 to 5.656). Letter style "B" was also more readable than letter style "C", (7.546 to 5.656). This data is shown in Table 6 and illustrated in Figure 3.

The letter size ratio of 1:20 (the largest) proved to be the most readable (1:20 - 9.558, 1:30 - 8.161,

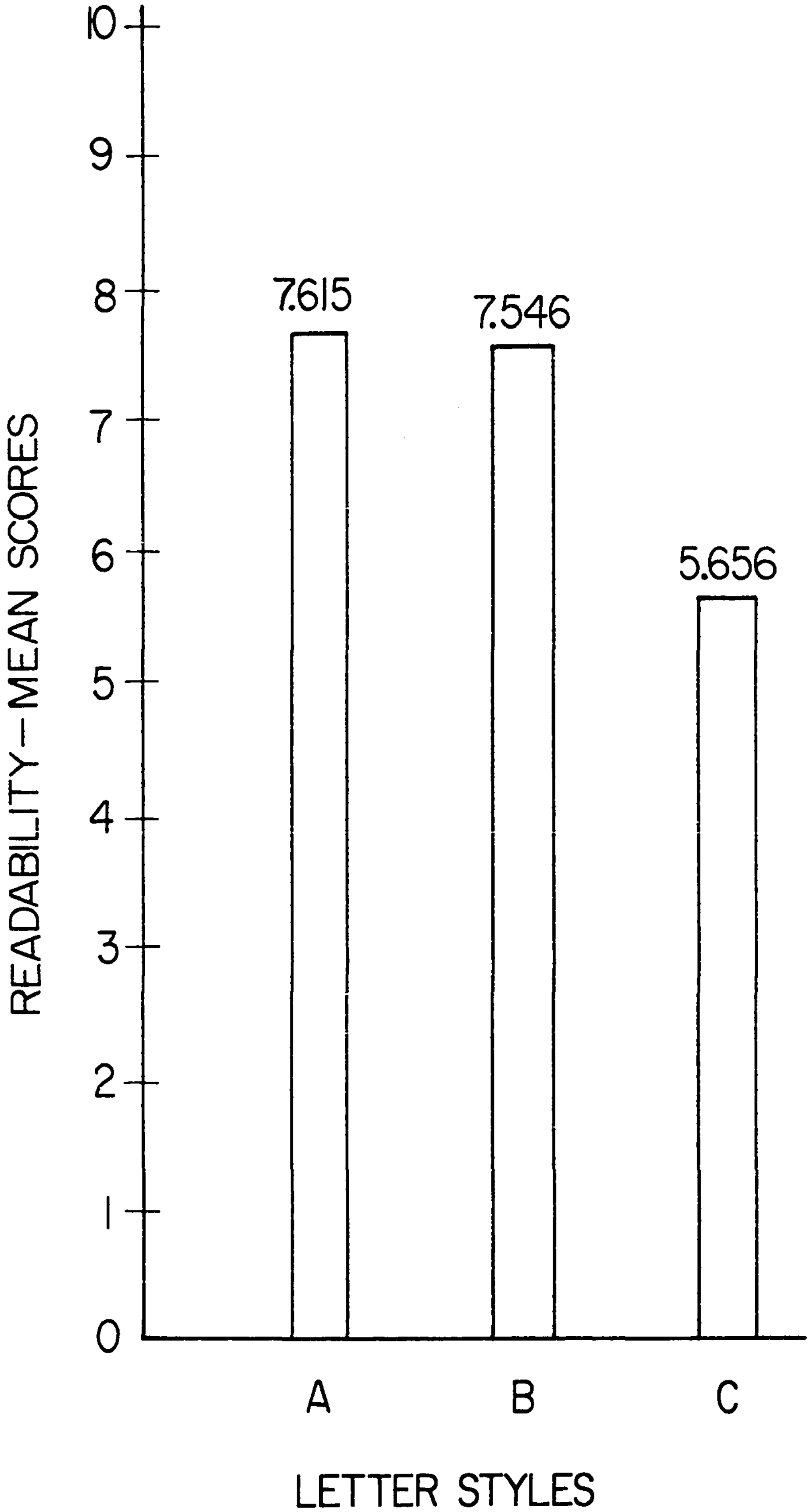

Figure 3. A Comparison of Readability (Mean Scores) of Letter Styles (Summary)

1:40 - 5.824, 1:50 - 4.213). This data is shown in Table 7 and illustrated in Figure 4.

Figure 5 and Table 8 show that at a viewing distance of 10', the test data was more readable than at the other viewing distances (10' - 9.984, 20' - 8.160, 30' - 5.896, 40' - 3.715).

Figures 6 - 9 illustrate the readability of the three letter styles from the four viewing distances. At a viewing distance of 10 feet, the mean score of all three letter styles was 9.7 or higher. As the viewing distance increased, the readability decreased.

The letter style readability of the four letter size ratios at the four viewing distances is illustrated in Figures 10 - 12. In all three cases, the largest letter size ratio (1:20) and closest viewing distance (10 feet) had the highest readability mean score.

Conclusions

Hypothesis one stated that letter style "A" would be more readable than letter styles "B" and "C". The data obtained through testing supports this statement (see Tables 4, 6 and Figure 3).

Hypothesis two predicted that letter style "B" (with serifs) would be more readable than letter style "C" (without serifs), but less readable than letter style "A". This statement is also supported by data in Tables 4, 6 and Figure 3.

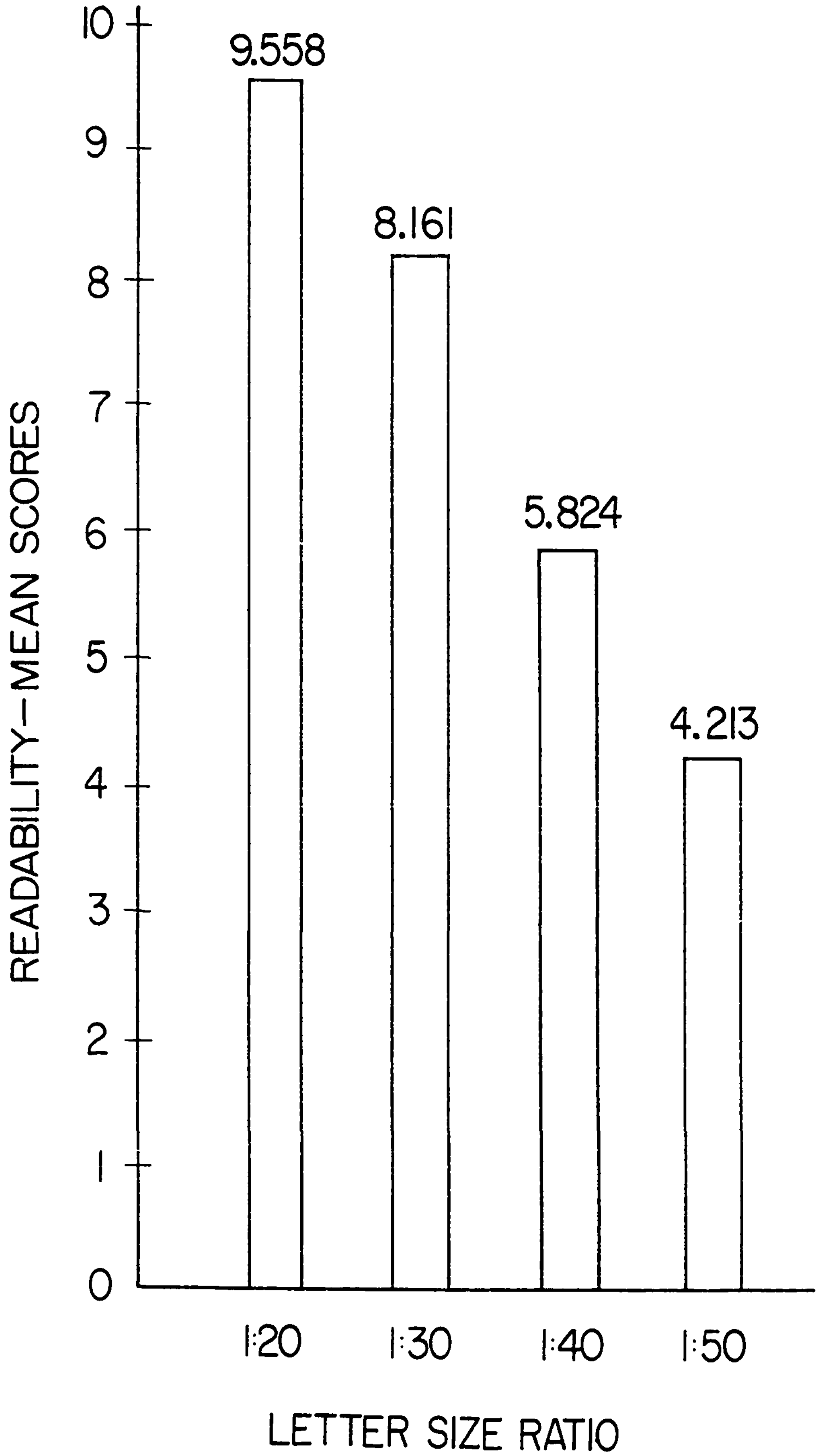

Figure 4. A Comparison of Readability (Mean Scores) of Letter Size Ratios (Summary)

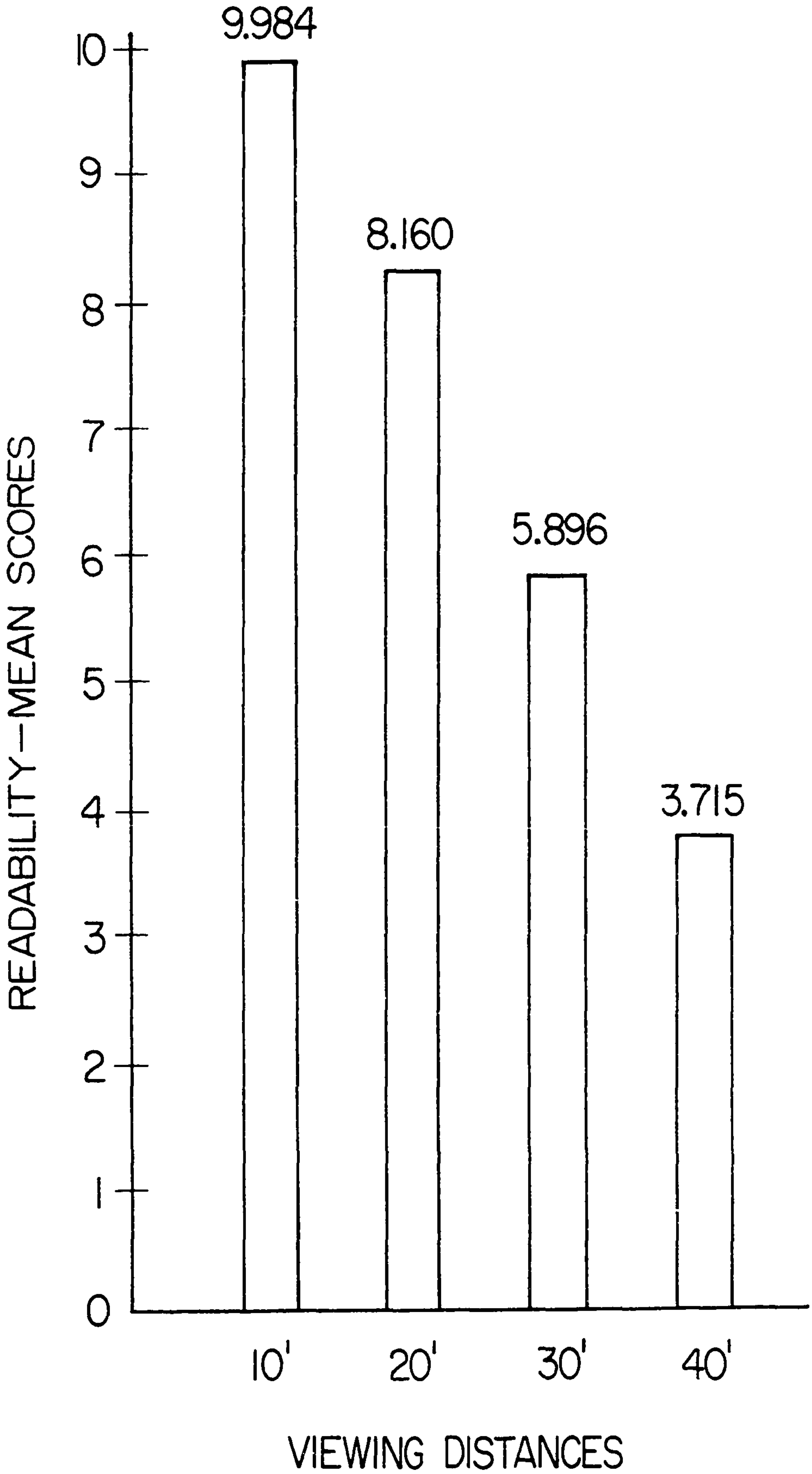

Figure 5. A Comparison of Readability (Mean Scores) of Viewing Distances (Summary)

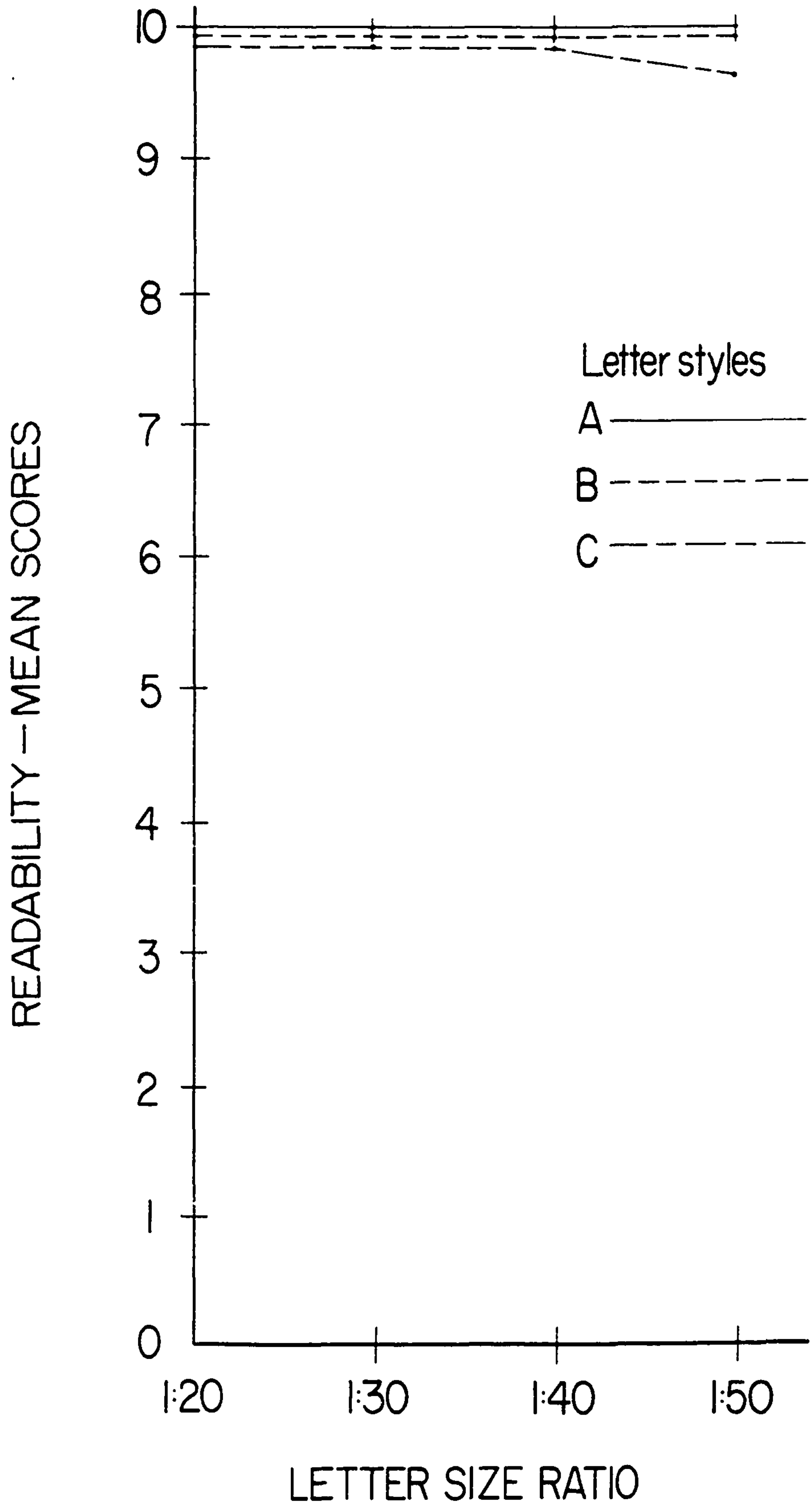

Figure 6. A Comparison of Readability (Mean Scores) of Letter Styles at a Viewing Distance of 10 Feet

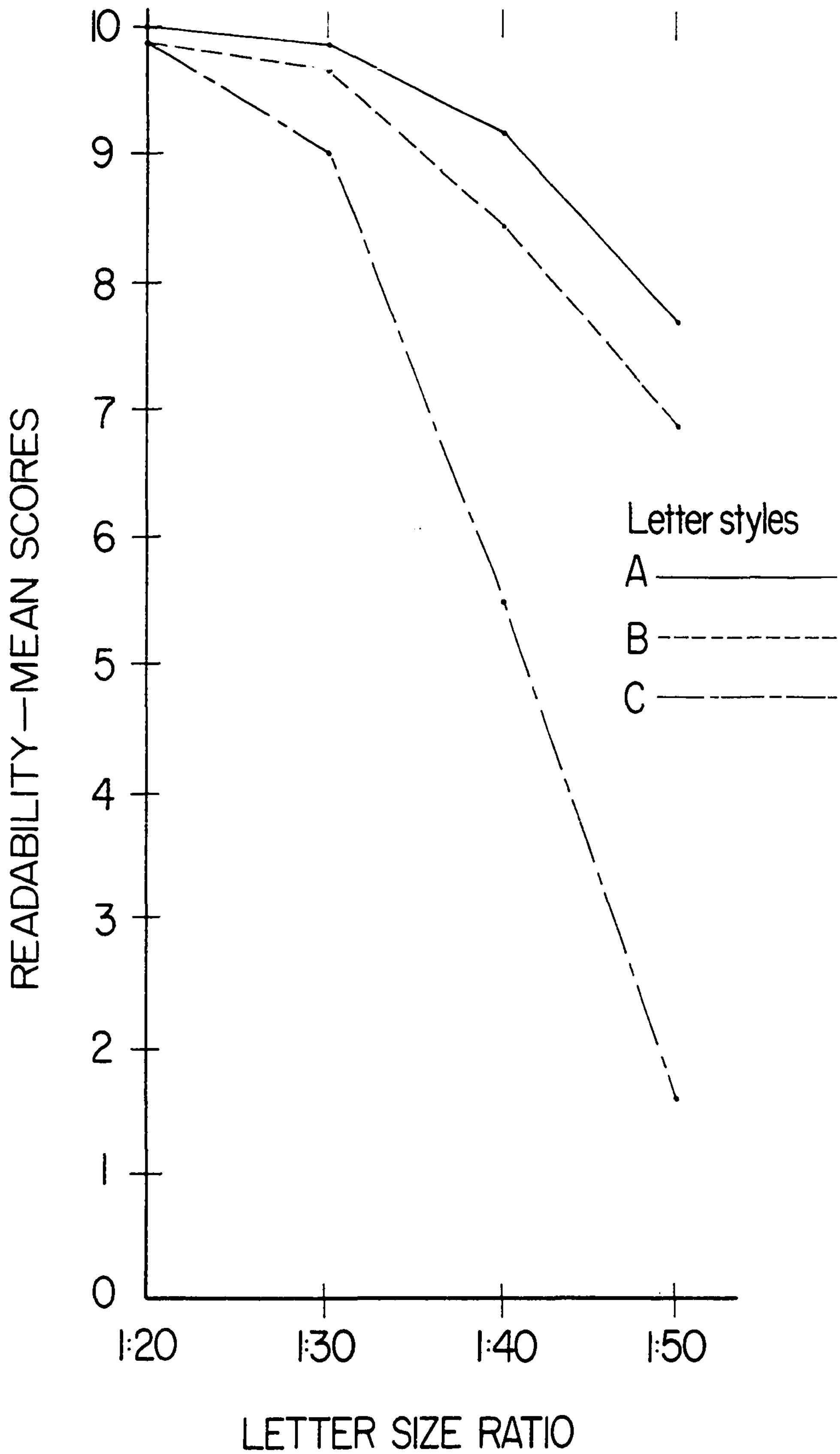

Figure 7. A Comparison of Readability (Mean Scores) of Letter Styles at a Viewing Distance of 20 Feet

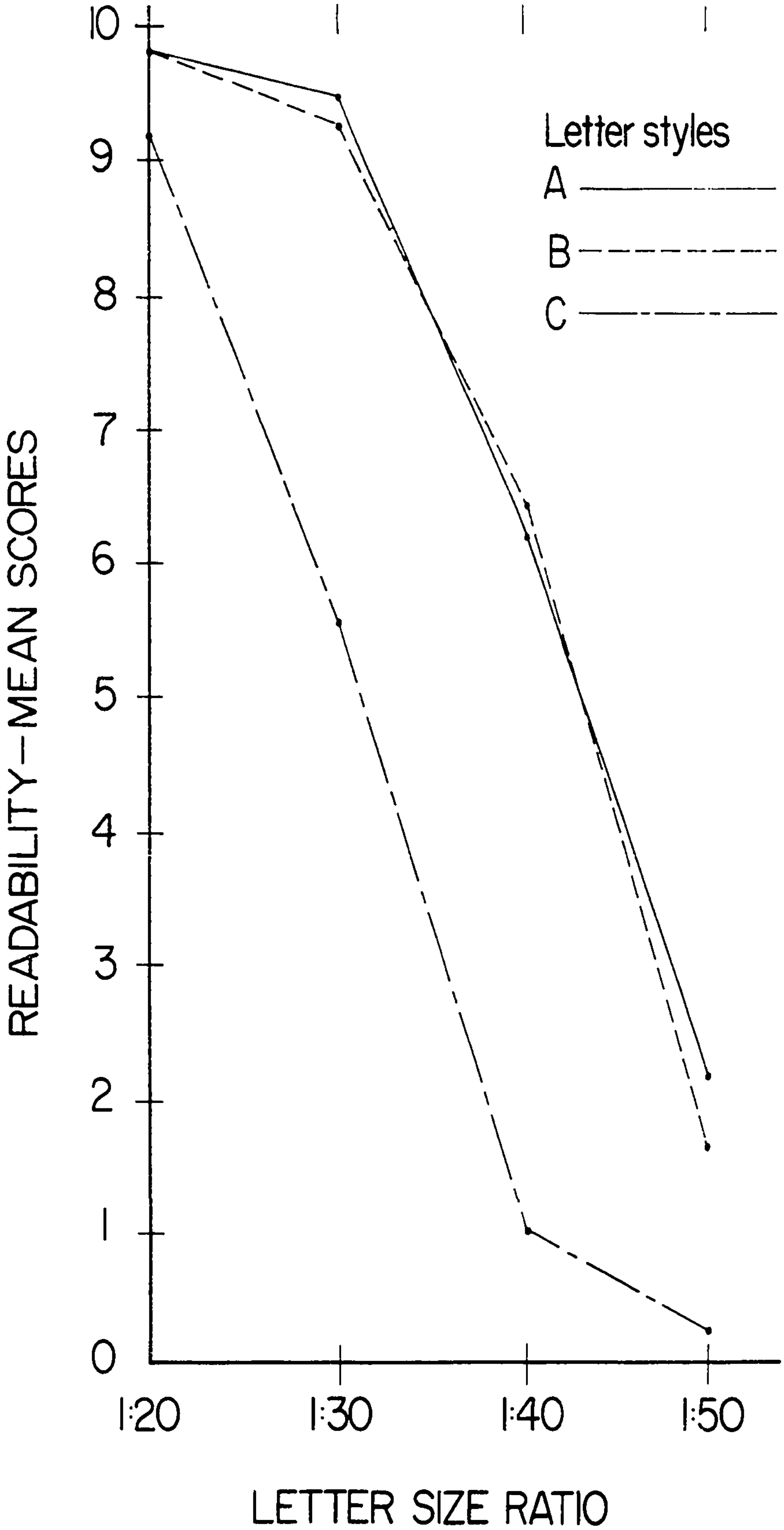

Figure 8. A Comparison of Readability (Mean Scores) of Letter Styles at a Viewing Distance of 30 Feet

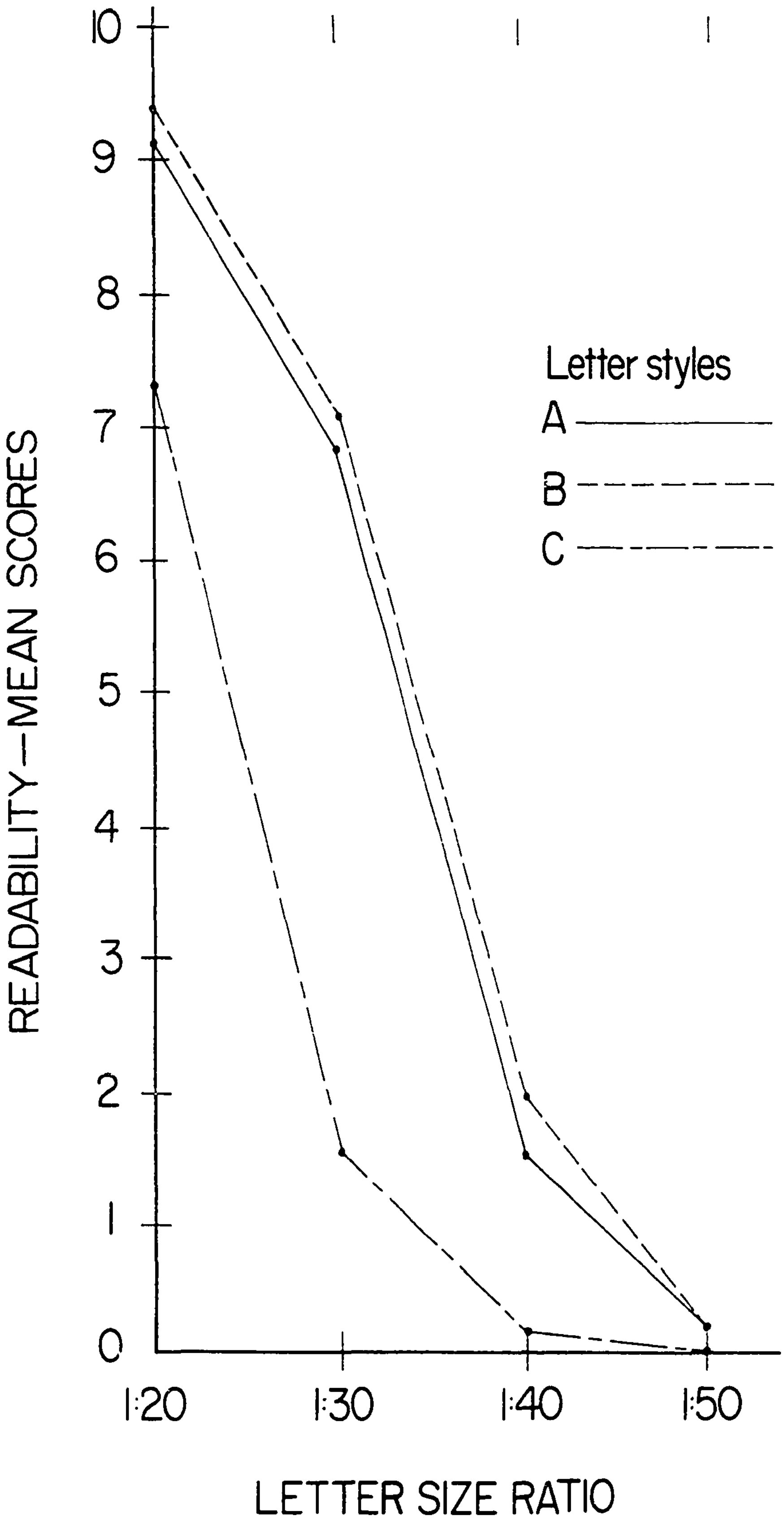

Figure 9. A Comparison of Readability (Mean Scores) of Letter Styles at a Viewing Distance of 40 Feet

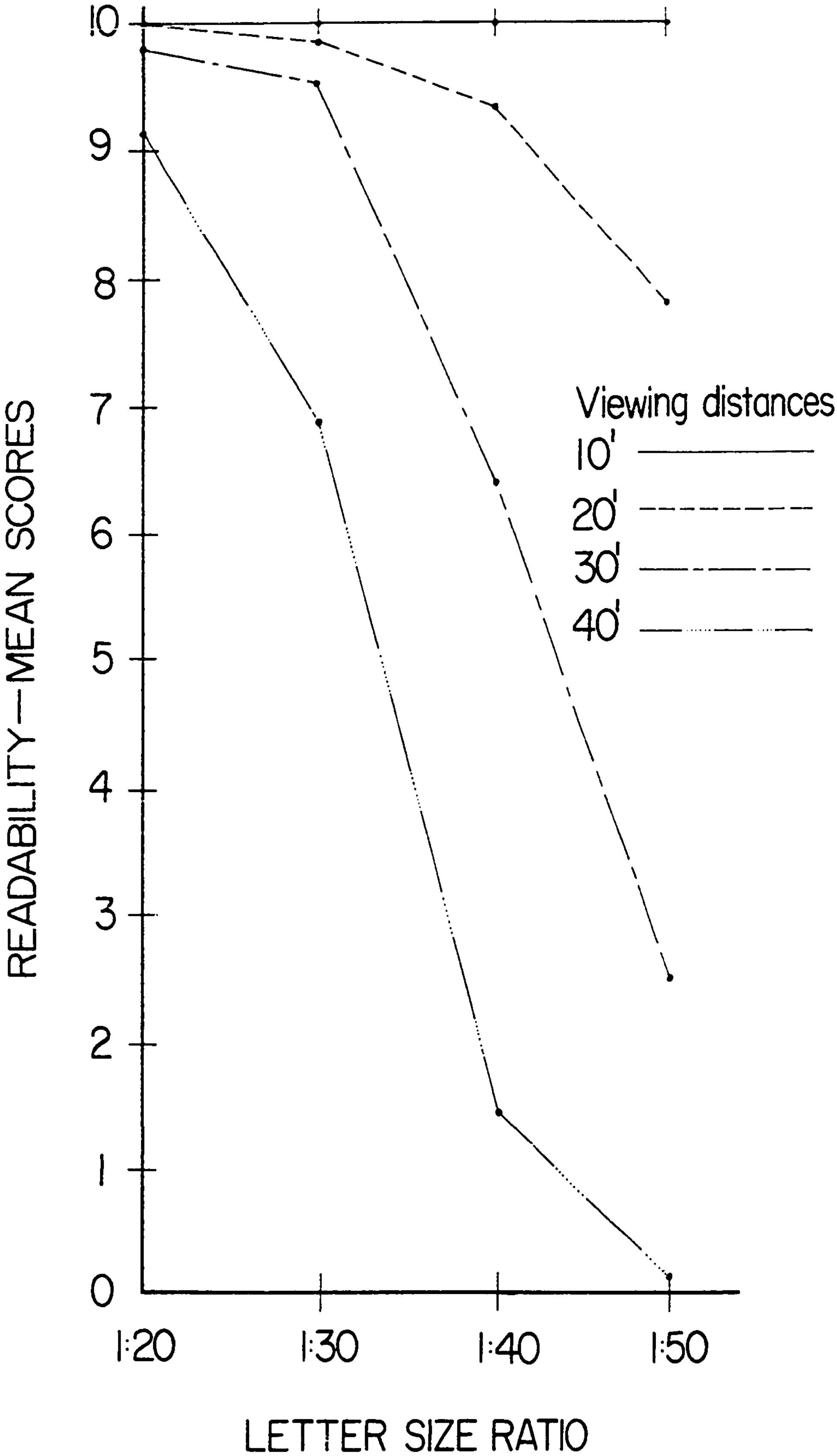

Figure 10. A Comparison of Readability (Mean Scores) of Letter Style "A" at Viewing Distances of 10-40 Feet

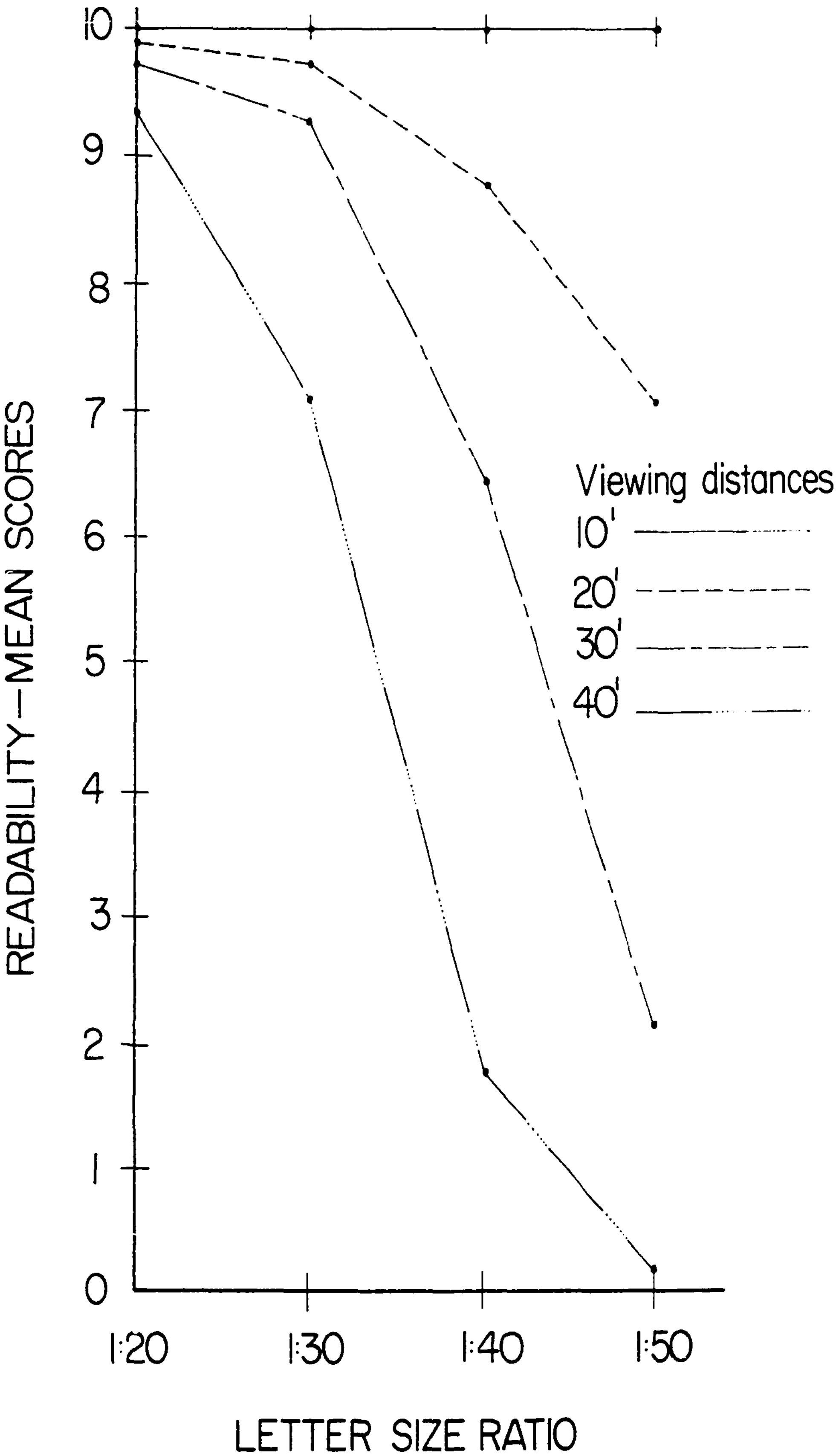

Figure 11. A Comparison of Readability (Mean Scores) of Letter Style "B" at Viewing Distances of 10-40 Feet

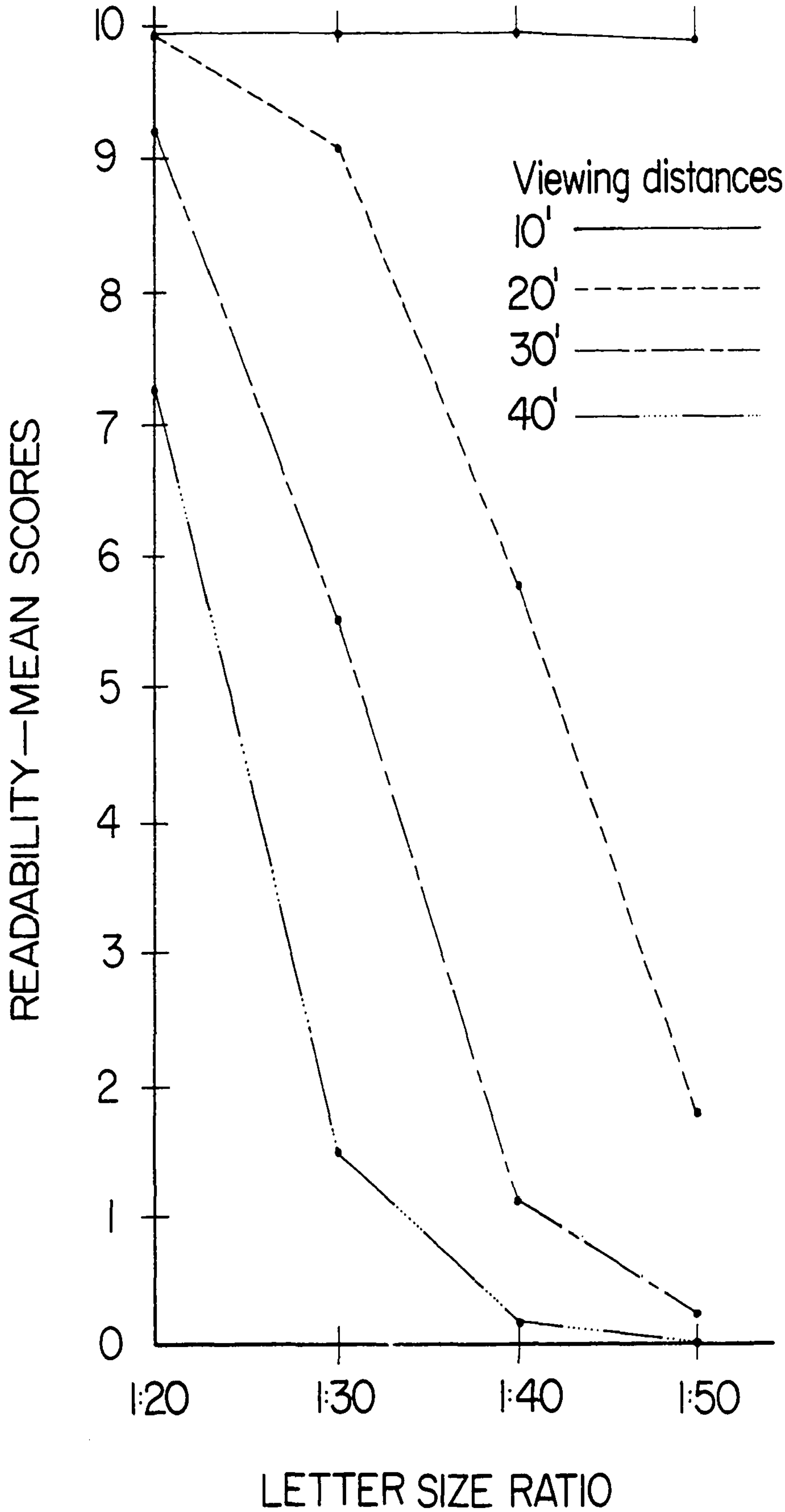

Figure 12. A Comparison of Readability (Mean Scores) of Letter Style "C" at Viewing Distances of 10-40 Feet

Hypothesis three predicted that the largest letter size ratio (1:20) would be more readable than the other letter sizes for all styles and viewing distances. Data from Tables 4, 7 and Figure 4 support this statement.

Hypothesis four predicted that using a mean score of 75% or 7.5, the smallest readable size for all letter styles would be: 1:50 at 10 feet, 1:40 at 20 feet, 1:30 at 30 feet and 1:20 at 40 feet. The data in Table 4 in part supports this statement. Letter styles "A" and "B" mean scores are all above 7.5 for the prescribed letter sizes and viewing distances. In letter style "C", only the letter size ratio of 1:50 at a viewing distance of 10 feet meets the requirement of 7.5 or above.

From the results obtained in this study, the following conclusions have been made:

(1) At a viewing distance of 10 feet or less, all four letter sizes of the three letter styles used in this study are acceptable for use on visuals.

(2) At a viewing distance of 20 feet, all letter sizes of letter style "A" and "B" are acceptable, but only the two largest letter sizes of letter style "C" are acceptable.

(3) At a viewing distance of 30 feet, only the two largest letter sizes of letter styles "A" and "B", and the largest letter size of letter style "C" are acceptable.

(4) At a viewing distance of 40 feet, only the largest letter size (1:20) of letter styles "A" and "B" are acceptable for use in the preparation of projected visuals.

Recommendations

A wide variety of recommendations have been made concerning standards for projecting visual materials, including the minimum letter size in inches on original art work, the ratio of letter height to screen image height, the Snellen System ratio, the 6W distance rule, and others. It is felt that there is a need for a simple practical system for determining the most readable letter size for visuals from various viewing distances. Table 28 was developed as a result of the research for this study, and is a suggested standardization for selecting the minimum letter size in relation to the viewing distance.

Future Research

There is a need for additional research in the area of readability of projected visual materials. Letter styles should be expanded to include a number of the latest photo and mechanical lettering devices, the press-on type lettering, and various large-type typewriter lettering. The most readable combination of letter size and viewing distance should be considered along with the various styles of letters.

TABLE 28

RECOMMENDED STANDARDS FOR LETTER SIZE AND VIEWING DISTANCE

Room Size (From screen to rear of room)	Minimum Letter Size Of Visual On Screen
10'	5/16"
20'	3/8 "
30'	1/2 "
40'	3/4 "

BIBLIOGRAPHY

BIBLIOGRAPHY

Books

Bartley, S. Howard. *Principles of Perception*. New York: Harper and Brothers, 1968.

Carmichael, Leonard, and Dearborn, Walter F. *Reading and Visual Fatigue*. Boston: Houghton Mifflin, 1947.

Ferguson, George A. *Statistical Analysis in Psychology and Education*. New York: McGraw-Hill, 1971.

Heinich, Robert. "The Teacher in an Instructional System." *Instructional Technology: A Book of Readings*. Edited by Frederick G. Knirk and John W. Childs. New York: Holt, Rinehart and Winston, 1968.

Lindquist, E. F. *Design and Analysis of Experiments in Psychology and Education*. Boston: Houghton Mifflin, 1956.

Luckiesh, Matthew. *Light, Vision and Seeing*. New York: Van Nostrand Co., 1944.

Riggs, Lorrin A. "Visual Acuity." Chap. 11, *Vision and Visual Perception*. Edited by Clarence H. Graham. New York: John Wiley and Sons, 1965.

Winer, B. J. *Statistical Principles in Experimental Design*. New York: McGraw-Hill, 1962.

Articles

Adams, Sarah, Rosemier, R., and Sleeman, P. "Readable Letter Size and Visibility for Overhead Projection Transparencies." *A. V. Communications Review*, XIII (1965), 412-417.

Gilbert, M., and Hopkinson, R. G. "The Illumination of the Snellen Chart." *British Journal of Ophthalmology*, XXXIII (May, 1949), 305-310.

Peters, Henry B. "Vision Screening with a Snellen Chart." *American Journal of Optometry and Archives of the American Academy of Optometry*, XXXVIII (1961), 487-505.

Richards, Oscar W. "A Comparison of Acuity Test Letters With and Without Serifs." American Journal of Optometry and Archives of the American Academy of Optometry, XXXXI (1964), 589-592.

Sheard, Charles. "Some Factors Affecting Visual Acuity." American Journal of Physiological Optics, II (April, 1921), 168-184.

Sloan, Louise L. "Measurement of Visual Acuity." A.M.A. Archives of Ophthalmology, XXXXV (June, 1951), 704-725.

Sloan, Louise L. "New Test Charts for the Measurement of Visual Acuity at Far and Near Distances." American Journal of Ophthalmology, XXXXVIII (December, 1959), 807-813.

Tinker, Miles A. "Brightness Contrast, Illumination, Intensity and Visual Efficiency." American Journal of Optometry and Archives of American Academy of Optometry, XXXVI (May, 1959), 221-236.

"Vision Screening in Schools: Recommendations of the National Society for the Prevention of Blindness." Sight-Saving Review, XXXI (Spring, 1961), 50-58.

Unpublished Materials

Costello, James W., "The Readability of Projected Captions for Children 6 - 9 Years of Age." Unpublished Ed.D. dissertation, Indiana University, 1969.

Metcalf, Richard M., "The Effects of Visual Angle, Brightness, and Contrast on the Visibility of Projected Material." Unpublished Ed.D. dissertation, Indiana University, 1968.

Patrie, Milton I., "The Relationship Between Viewing Position and Achievement on Self-Paced Responses to Projected Alphanumeric Characters." Unpublished Ed.D. dissertation, Syracuse University, New York, 1968.

Snowberg, Richard L., "The Relationship Between Color Preference and Readability of Projected Black Characters with a Colored Background, Under Conditions of Controlled Luminance and Transmission." Unpublished Ed.D. dissertation, Indiana University, 1971.

Weaver, Terry D., "A Study of the Comparative Legibility of Projected Positive and Negative Black and White Slides." Unpublished Ed.D. dissertation, Indiana University, 1971.

Other Sources

Audiovisual Projection, S-3, New York: Eastman Kodak, Rochester, 1971.

NWAY 1: General Analysis of Variance, Academic Computing Center, The University of Wisconsin, Madison, 1970.

APPENDIX

TEST RESPONSE SHEET

STUDENT # ___ GLASSES ___ CONTACTS ___ LEFT EYE 20/__

AGE ___ SEX ___ UN. GRAD ___ GRAD ___ RIGHT EYE 20/__

SLIDE #	LETTER ORDER	SCORE	STYLE
15	N O R H Z V D C K S	_____	30-B-20
27	K O V C Z H D N S R	_____	40-C-20
36	H O R C V N D Z K S	_____	50-C-20
1	K D R Z N S O V C H	_____	20-A-20
24	S R Z H V K O N D C	_____	40-B-20
10	H R D V O K N Z S C	_____	30-A-20
33	N S Z H V O R C K D	_____	50-B-20
9	R C S Z V K H N O D	_____	20-C-20
19	C Z V H S D O N K R	_____	40-A-20
6	S C D O V Z H R K N	_____	20-B-20
28	O D Z H S N R V K C	_____	50-A-20
18	D V S R O Z K H C N	_____	30-C-20
18	D V S R O Z K H C N	_____	30-C-40
28	O D Z H S N R V K C	_____	50-A-40
6	S C D O V Z H R K N	_____	20-B-40
19	C Z V H S D O N K R	_____	40-A-40
9	R C S Z V K H N O D	_____	20-C-40
33	N S Z H V O R C K D	_____	50-B-40
10	H R D V O K N Z S C	_____	30-A-40
24	S R Z H V K O N D C	_____	40-B-40
1	K D R Z N S O V C H	_____	20-A-40
36	H O R C V N D Z K S	_____	50-C-40

27	K O V C Z H D N S R	______	40-C-40
15	N O R H Z V D C K S	______	30-B-40
15	N O R H Z V D C K S	______	30-B-30
27	K O V C Z H D N S R	______	40-C-30
36	H O R C V N D Z K S	______	50-C-30
1	K D R Z N S O V C H	______	20-A-30
24	S R Z H V K O N D C	______	40-B-30
10	H R D V O K N Z S C	______	30-A-30
33	N S Z H V O R C K D	______	50-B-30
9	R C S Z V K H N O D	______	20-C-30
19	C Z V H S D O N K R	______	40-A-30
6	S C D O V Z H R K N	______	20-B-30
28	O D Z H S N R V K C	______	50-A-30
18	D V S R O Z K H C N	______	30-C-30
18	D V S R O Z K H C N	______	30-C-10
28	O D Z H S N R V K C	______	50-A-10
6	S C D O V Z H R K N	______	20-B-10
19	C Z V H S D O N K R	______	40-A-10
9	R C S Z V K H N O D	______	20-C-10
33	N S Z H V O R C K D	______	50-B-10
10	H R D V O K N Z S C	______	30-A-10
24	S R Z H V K O N D C	______	40-B-10
1	K D R Z N S O V C H	______	20-A-10
36	H O R C V N D Z K S	______	50-C-10
27	K O V C Z H D N S R	______	40-C-10
15	N O R H Z V D C K S	______	30-B-10

VITA

Lyle E. Grooters was born in Sioux Center, Iowa, April 1, 1932. He received his elementary and secondary education in the public schools of Cedar Falls, Iowa, and graduated from Cedar Falls High School in 1950.

After high school graduation, he entered Iowa State Teachers College. In 1951 he entered the U.S. Air Force. During the next four years he attended and taught at several Air Force electronic schools. He also spent one year in Korea as a radio maintenance technican.

After being released from the Air Force in 1955, he enrolled at Iowa State Teachers College, Cedar Falls, Iowa, graduated June, 1959, with a Bachelor of Arts Degree in Industrial Arts. He taught electronics, drafting and was the Audiovisual Coordinator at Washington Senior High School in Cedar Rapids, Iowa, from 1959-64. During the summers he attended Long Beach State College and in 1962 he received his Master of Arts Degree.

During the summer of 1964 he received the H. Wilson Summer Audiovisual Scholarship and attended the University of Colorado. In the fall of 1964 he became the Audio-visual Director for the Fort Dodge, Iowa Public Schools and Junior College. In the summer of 1965 he attended the Instructional Media Institute at Syracuse University. In 1966 he became the Audiovisual and Television Director at Wheeling High School, Wheeling, Illinois. During the summer of 1967 he attended Indiana University. He joined the faculty of Wisconsin State University-Whitewater as Assistant Director of Instructional Media Services in 1968.

He attended the University of Oklahoma during the summer of 1970. During the academic year of 1971-72 he was awarded a Teacher Improvement Grant to enter graduate school at the University of Oklahoma where he was a graduate assistant in the Educational Media Center. In the spring of 1972 he was awarded the AECT Memorial Scholarship of $1000 to continue his research and graduate studies. In the fall of 1972 he rejoined the faculty at the University of Wisconsin-Whitewater, the position he currently holds.