

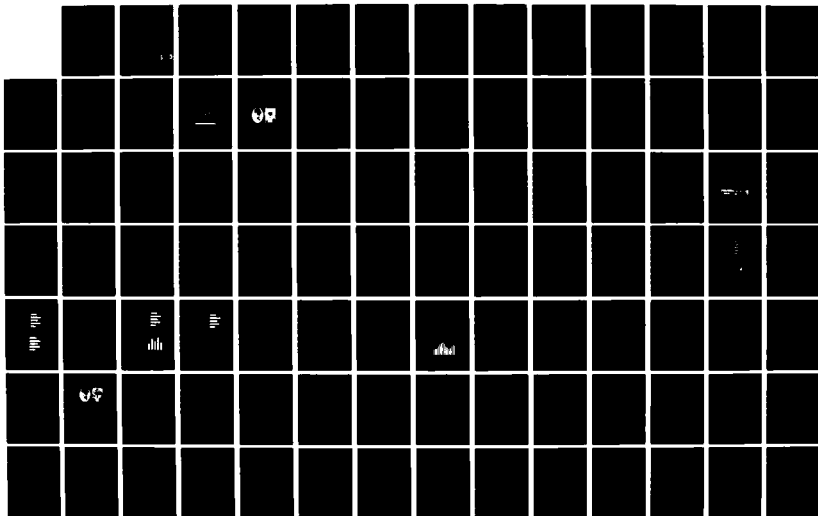
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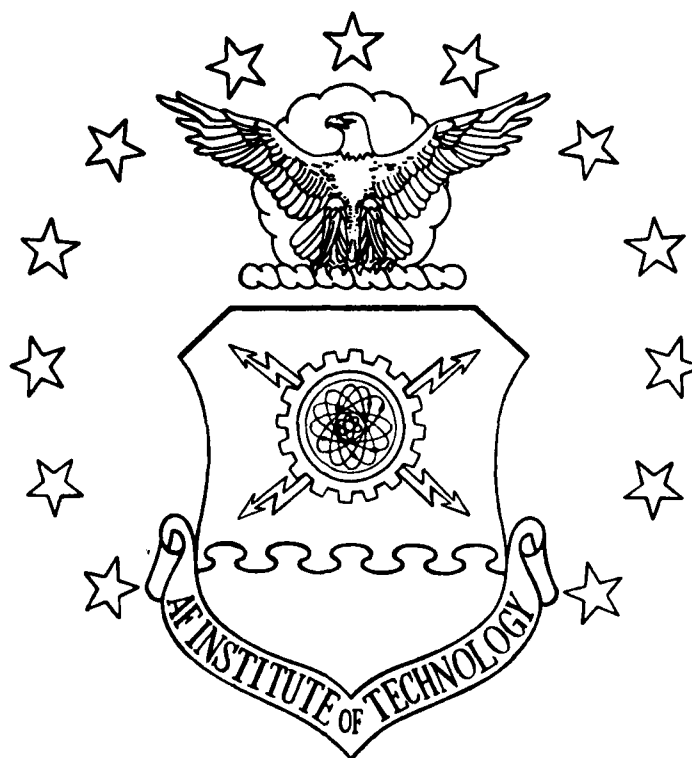




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A SYNTHESIS OF RESEARCH ON COLOR,
TYPOGRAPHY, AND GRAPHICS
AS THEY RELATE TO READABILITY

THESIS

Melvin E. Lamoreaux
Captain, USAF

AFIT/GLM/LSH/85S-40

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A SYNTHESIS OF RESEARCH ON COLOR, TYPOGRAPHY, AND
GRAPHICS AS THEY RELATE TO READABILITY

THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

Melvin E. Lamoreaux, B.A.

Captain, USAF

September 1985

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Acknowledgements

While readability experts have been active in dissecting the language and constructing readability formulas from the results of their studies, they have not focused on factors which might impact upon readability other than language itself. This research was conducted to establish a data base on prior research in color, typography, and graphics so that researchers may continue these studies to determine the true impact of color, typography, and graphics upon readability.

In the course of this research, many have provided valuable assistance. I wish to thank Mr. Andrew Poullis and his staff for their timely assistance in my search for the various journals used in this research. I am also deeply indebted to my advisor, Dr. Freda Stohrer, for her encouragement and patience, as well as a firm hand when I needed it. Finally, I am eternally grateful to my wife, Carol, for her understanding and her support during these last few months.

Melvin E. Lamoreaux

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Abstract

This thesis provides a foundation for future research on the use of color, typography, and graphics to improve readability. Articles from the broad fields of education and psychology, as well as from the fields of journalism and printing, have been reviewed for research relating color, typography, and graphics to reading ease, speed, or comprehension. The most relevant articles reviewed are presented in an annotated bibliography; the remaining articles are also presented in a bibliographic format.

This literature review indicates that recognition and recall of printed material may be improved through the use of headings, underlining, color, and, especially, illustrations. Current research suggests that individuals can remember pictures far longer than past research indicates. However, researchers are divided on the usefulness of illustrations to improve reading comprehension. On the other hand, reading comprehension can be improved through the use of statistical graphs and tables if the reader is properly trained in the use of these devices.

Those factors which influence the ease and speed of reading but are ineffective in improving recall or comprehension are type style, type size, column width, line length, multiple column formats, or typographical arrangements other than the horizontal style of printing.

Further research on the interaction between language, color, typography, and graphics is needed. More specifically, research needs to be conducted on

the combined use of language, color, typography, and graphics to improve reading ease, speed, and comprehension. Research also needs to be conducted on the readability of written text appearing on computer monitors and in computerized dot-matrix print.

A SYNTHESIS OF RESEARCH ON COLOR, TYPOGRAPHY, AND GRAPHICS AS THEY RELATE TO READABILITY

I. Overview

General Issue

An 'information explosion' has accompanied the technological advances of the past several decades. The number of scientific journals published today exceeds 100,000, and the number of scientific papers published is double this (Martin, 1981:95). It has been estimated that the "sum total of human knowledge" has been doubling every five years since the 1970s (Martin, 1981:95). Advances in computer and communication technology have made it possible for managers, scientists, and educators to access numerous articles of interest and to receive these articles within minutes.

Although technology has increased the availability of information, the basic problem of readability remains. Concern over readable literature is shared by many in both industry and government. Readability studies in industry have led to simpler language in bank notes and labor agreements (Siegel, 1980:42-43; Walker, 1981). Government readability studies have led to improvements in both the structure of forms used by many social service agencies and the language used in those forms (Siegel, 1980:42-43). At the same time, the Department of Defense is applying readability research to the analysis of technical data used by technicians.

For example, the target reading level specified by the Department of Defense for most technical manuals is the ninth grade. Studies have

found, however, that these technical manuals are written at the 12 to 14th grade reading level (Wojcicke, 1979:7-8). This reading grade level is appropriate for someone with an IQ of 120 or more, and it is estimated that "only 12 percent of the general population" possesses an IQ of this magnitude (Wojcicke, 1979:8). Since the mean IQ of high school graduates is estimated to be 110; then, according to readability research, most of these technical manuals are incomprehensible to those that must use them (Wojcicke, 1979:8).

A further problem appears when we consider that readability research appears to focus only on the verbal attributes of text to measure and improve both reading speed and comprehension. That is, studies in readability may focus on the use of active versus passive voice or the structure of text, while readability formulas tend to focus on measures of word choice and sentence length to determine the readability of text. The physical characteristics of the letters themselves, or the text as a whole, are ignored. In addition, the contribution of visual material, graphs and illustrations for example, to the comprehension of written text is generally neglected in readability research. Studies in these latter areas are usually conducted by experts in the fields of typography and graphics.

Why study legibility and graphic illustration of writing, as it has traditionally been taught, is the process of choosing the right words and structure with which to communicate a written message? John Harris, in his article on the expanding definition of technical writing, provides some insight on the need for a broader view of writing. Harris suggests that the term 'communicator' is more comprehensive in its description of the job of technical writing than is the simple term 'writer' (Harris, 1978:136). He

goes on to recommend

That a communicator, to be good at the job, should be able to choose and use the best medium for the message, the purpose, and the audience. That medium may be written text, photos, drawings, tape, film, or mockup. He should choose the medium on the basis of what is the best medium rather than making the decision by default by writing standard text because that is the one that he knows how to do. (Harris, 1978:136)

This philosophy might well be employed in writing for business and for government as well as in the field of scientific and technical writing. In fact, modern word processing and printing technology may be further expanding the role of the communicator to include the field of typography.

Although not directly involved in the typesetting process, the communicator may now experiment with different typographical formats to observe their effect on the final document because many modern computers can produce typography that approximates the product of automated typesetting machines. Examples of highlighting techniques available for use on one computerized word processing program are shown in Figure 1.

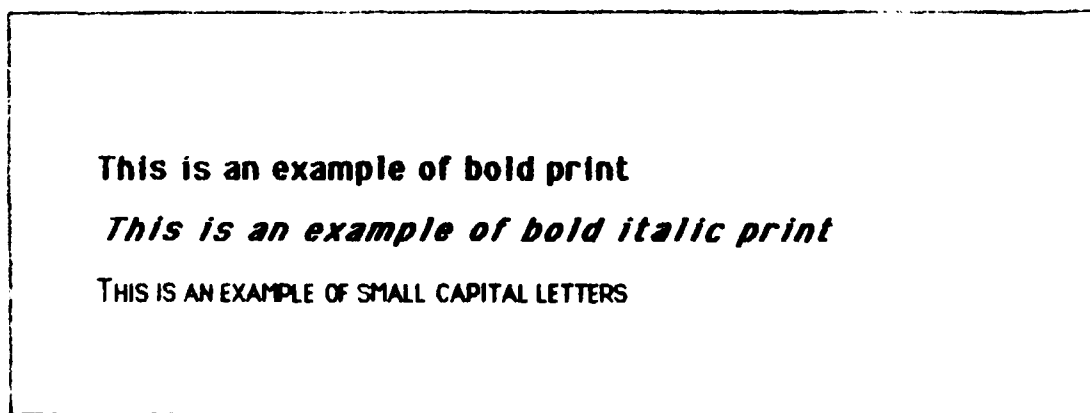


Figure 1. Highlighting Features Available on a Word Processor.

Statistical information has been, and still is, presented in the form of tables, graphs, or diagrams. An author who formerly gave statistical information to a graphics artist for development into a suitable presentation can specify the presentation format he desires. The computer will automatically draw the graph or diagram to scale and, in most cases, label the data points. Thus, the author can quickly determine which presentation best fits his article. The three-dimensional vertical bar chart shown in Figure 2 was produced on a graphics package, although this type of graph can be produced automatically on some systems.

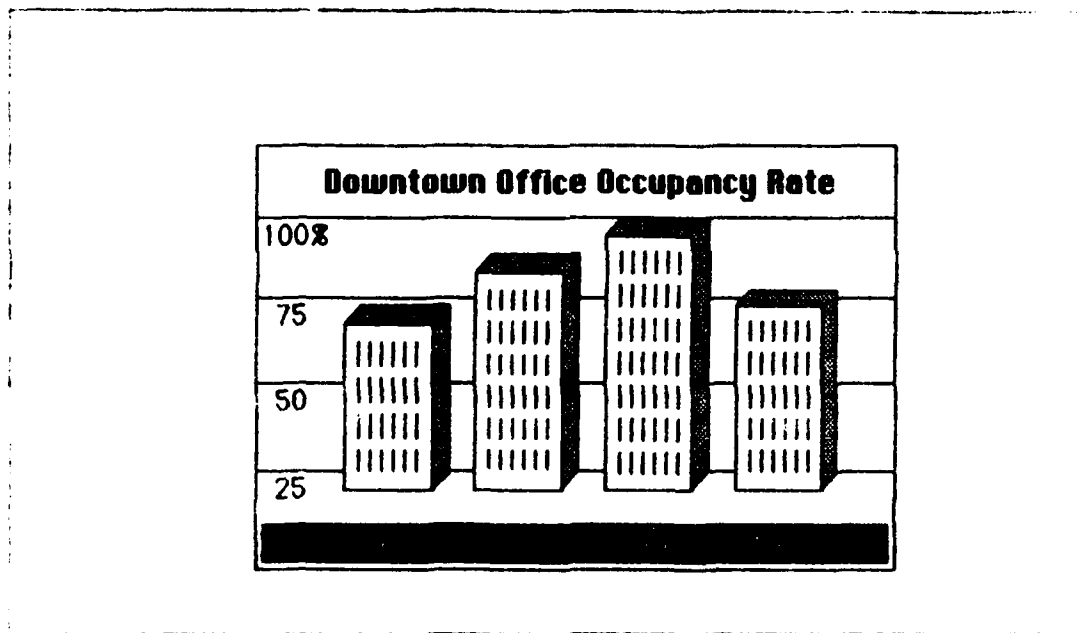


Figure 2. Example of a Three-Dimensional Vertical Bar Chart .

Technical writers can also incorporate illustrations and layouts, once the province of the graphic illustrator, into the text using word processors

with graphics packages. Many modern computer systems possess graphics capabilities that, when used with the appropriate computer programs, can produce high quality illustrations such as those shown in Figure 3. Some word processors even allow for the use of color in text and graphics. In addition, advances in optical scanner technology allow individuals to copy pictures within their text. All of these features allow the author of an article to determine which illustrations contribute to his text and their optimal placement within the text.

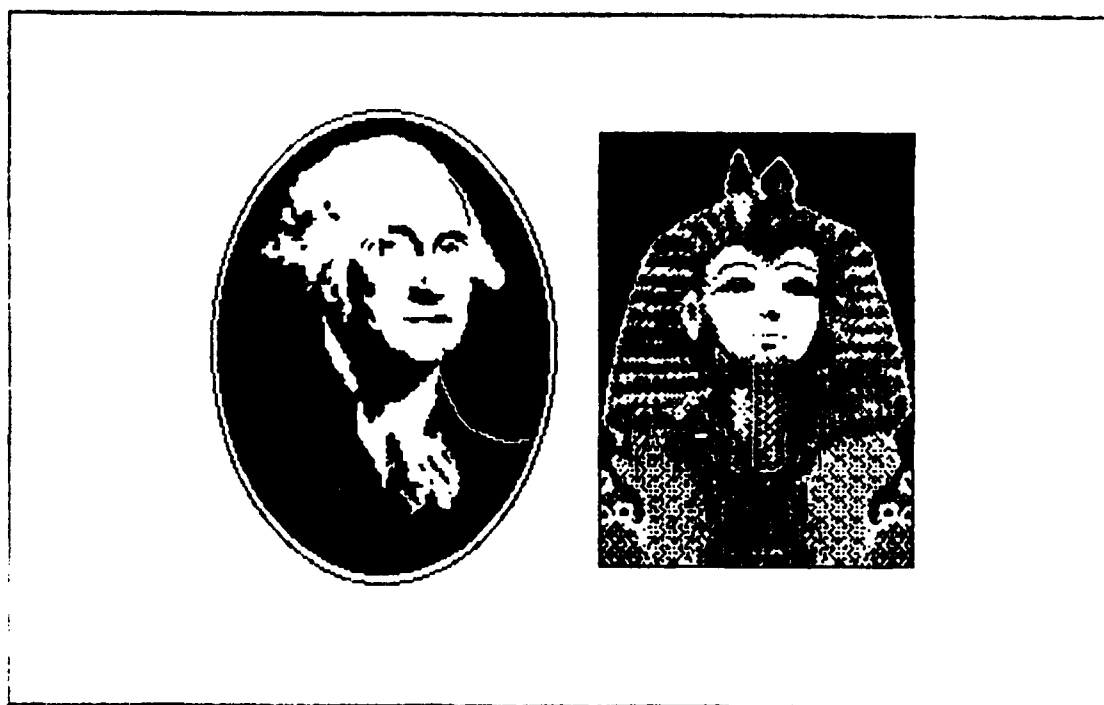


Figure 3. Examples of Illustrations Produced with a Graphic Arts Package.

Perhaps the most significant capability of current word processing programs is the ability to move, or "cut and paste," data and text within a

page or document. This allows the communicator to experiment with different layouts. In fact, computer software is currently available which will allow the user to setup and print newspaper style copy. The only feature which many word processing programs seem to lack is the ability to make fine adjustments to word and line spacing.

Technology exists, therefore, which allows an individual to become the author, illustrator, and editor for his material. By using this technology, a communicator can improve the readability of his material through the use of language, graphics, and typography. Before this improvement can happen, however, the communicator must understand how these diverse fields of research fit into the concept of readability.

The premise of this thesis is that readability results from the synergistic, or combined, effects of language, color, graphics, and typography, and that any research in readability must include research findings in color, typography and graphics if suitable guidelines for written communication are to be developed. Broadening the scope of readability requires the researcher to review numerous articles, including many outside of the researcher's field of expertise. Unfortunately, many researchers do not have the time for such an expansive review of the literature.

As previously stated, over 100,000 scientific journals are published annually. Such numbers prohibit most individuals from the timely review of all the literature on typography and graphics that may have some impact on their work as communicators. Meanwhile, researchers, possibly due to time constraints, may read only those journals in or close to their field of endeavor. Thus, researchers may overlook literature appearing in journals outside their primary field. A synthesis of research findings in color,

typography and graphics, as well as in color, is needed to supplement current readability research and to provide a basis for future research in readability.

Problem Statement

There is no useful synthesis of research on the relationship of color, typography, and graphics to readability, defined in this thesis, as that quality of text which allows the reader, under normal conditions, to easily identify letters, words, and characters in the text and permits the reader to quickly and correctly comprehend the meaning of that text.

Research Objectives

This research has two objectives. First, I identify and present in bibliographic format all research articles, since 1900, which deal with color, typography, and graphics as they relate to readability in the broad fields of education, engineering, and psychology.

Second, those articles which are particularly relevant to readability are summarized in an annotated bibliography.

Methodology

Method of Research. Inasmuch as the purpose of this thesis is to synthesize research on the relation of color, typography and graphics to readability, a thorough search of all relevant literature was conducted. The review focused on those hypotheses which will further additional research in this area.

The literature review in this thesis provides future researchers with a summary of proposed hypotheses relating color, typography and graphics to the concept of readability. An outcome of this summarization process may

be the discovery of new problems and research initiatives by future researchers based on their readings of this summary and of past research.

Description of Sample Population. The articles to be reviewed will come from a broad spectrum of research fields which contain studies of color, typography and graphics: education, educational psychology, cognitive psychology, experimental psychology, communication, advertising, journalism, computer science, graphic arts, commercial art, and ergonomics.

Description of Sampling Plan. Because such a large number of articles are published annually in the areas mentioned above, time did not allow for a thorough review of every article. Only those articles which specifically related research findings about color, typography, and graphics to readability were included

Plan to include articles from one field only or articles from the last ten years only were rejected because they limited the scope of the research too severely and eliminated one major benefit provided here. This thesis establishes the framework for an ongoing effort.

Definitions and Guidelines. Prior to establishing the guidelines to be used in identifying relevant articles, an operational definition for the concept of readability was developed.

Readability. Thomas Huckin defines "writing as 'readable' to the extent that its meaning can be easily and quickly comprehended for an intended purpose by an intended reader operating under normal conditions of alertness, motivation, time-pressure, etc." (Huckin, 1983:91). Combining this definition with the expanded definition of writing presented by Harris, we can form a tentative operational definition of readability as follows:

Writing is readable if the overall presentation of the text allows the reader, operating under the "normal conditions of alertness, motivation, time-pressure, etc.," to comprehend that text quickly and correctly, and to recall at a later time the meaning of that text.

For the purposes of this thesis, the overall presentation of text represents the combined effects of language, color, typography, and graphics.

Typography. Typography, for the purposes of this research, is the study of any factor which may affect the physical appearance of the text. These factors include, but are not limited to, type style, type size, line width, isolation techniques (highlighting or underlining), leading (spacing between words or lines), and the use of justified (even) versus unjustified (uneven or ragged) margins. Typography may also include the use of titles, headings, and indentation as cueing techniques, as well as the use of white (blank) space to affect the appearance of the text.

Graphics. Graphics, on the other hand, includes the use of visual presentations in the form of graphs, tables, diagrams, line drawings, and photographs. While other forms of graphics may exist, this thesis research restricted itself to the aforementioned five visual presentations.

Color. Finally, color was considered as a separate category for this thesis. Although color can be considered an element of typography due to the fact that it changes the physical appearance of the page or pages in which it appears, color research is, and has been, conducted in both the fields of typography and graphics. For that reason, it deserved separate mention.

Articles Reviewed. The articles reviewed were limited to those

focusing on the relationship between color, typography, or graphics and reading ease, speed, or comprehension, which, herein, will collectively be referred to as reading performance. Studies conducted solely to determine reader preference for certain typographical styles or visual presentations and having no relation to reading performance were generally excluded from this study. Comparisons between type styles for reader preference only is an example of the type of study which was excluded.

The study of imagery, when not applied to actual research involving the use of visuals, was also excluded from this research, as were color studies that did not address some aspect of typography or graphics and relate them to reading performance.

The basic guideline for including any research in this thesis effort was the direct applicability of the factors being studied to the task of communicating. While physiological and psychological concepts may be both interesting and important to the principle of readability, they require the communicator to have some specialized knowledge in the area of physiology or psychology. The studies recognized in this thesis allow the reader to identify both the experimental conditions and the results and to make some generalizations upon which guidelines may be based. The reader may also identify some methodological problems and propose new directions for research.

Perceived Problems in the Proposed Study. Two problems that hamper much graduate research are the lack of time and the scarcity of resources. For this study, resources consisted solely of the books and journal articles needed for a careful review of the literature. It was anticipated that some literature of significant interest to this study would be unavailable in the

local area and would have to be ordered.

The time available to the author was spent organizing the research, ordering the needed resources and thoroughly reviewing those articles identified as being particularly relevant to readability. In this manner, a good foundation for future research was established.

Presentation of the Material

Chapter 2 of this thesis discusses prior research in readability including a brief consideration on the development of readability formulas. The research conducted on readability formulas represented an attempt by researchers to measure readability and to develop guidelines based on the findings of their research. Future communicators may wish to expand these formulas to include measures of color, typography, and graphics. The formulas, however, must still contain linguistic measures. Therefore, the user of any formula must still understand how the linguistic measures came about, and Chapter 2 gives that explanation.

Chapter 3 reviews the research on color, typography, and graphics as they relate to readability. Research summaries are divided into these categories: color, graphs/tables/diagrams, typography, or illustrations. Conflicting research findings are pointed out whenever they occur. The chapter ends with some conclusions based on the review of the literature and some recommendations for future research.

Chapter 4 contains both the annotated and nonannotated bibliographies. As in Chapter 3, the articles will be categorized under color, graphs/tables/diagrams, typography, or illustrations.

II. A Literature Review of Past Readability Studies

Readability Defined

Perhaps the simplest definition of readability is "the quality or state of being readable" (Wojcicki, 1979:6). Unfortunately, this definition does not define "readable," which can cover a range of meanings from "the ability to recognize words" to "the ability to comprehend the meaning of the text." A number of specialists in written communications prefer to further qualify their definitions of readability. For example, E. D. Hirsch, Jr., defines readability by the time and effort needed when, "assuming . . . two texts convey the same meaning, the more readable text will take less time and effort to understand" (Hirsch, 1977:85). More recently, Thomas Huckin observes that "writing is 'readable' to the extent that its meaning can be easily and quickly comprehended for an intended purpose by an intended reader operating under normal conditions of alertness, motivation, time-pressure, etc." (Huckin, 1983:91). These three definitions reveal a progression in the field of readability from one which lacks specific definition to one in which goals and conditions are specified.

The Need for Readability Studies

There are two inseparable functions in the process of written communication: reading and writing. According to Rudolf Flesch, "a writer must know how people read, what are the main sources of reading errors, and what can be done to possibly forestall them" (Flesch, 1974:200). That is, if a writer understands the process of reading, he can structure his writing to help the reader avoid the conflicts that usually arise from

reading poorly written material. Flesch cites the benefits of "extra readability" in the following passage from his book, The Art of Readable Writing.

As I said a little while ago, if you do hit the right level, extra readability will usually pay a bonus. Highly readable stories and ads may attract almost twice as many readers as others; highly readable books may be read in almost half the time. On top of this, your readers will understand and remember better what they have read. To be sure, there is much research still to be done on all this, but the basic facts have been proved. There is no doubt any longer that increased readability is worth the added effort. (Flesch, 1974:180)

Early Readability Studies

"People have probably been concerned with readability (or its parallel, listenability) since symbols first were used and recorded" (Klare, 1963:29). George R. Klare cited the work of Irving Lorge when he observed that religious writers, being "the most literate persons of their day," were among the earliest (around 900 A.D.) to concern themselves with the frequency of words in literature (Klare, 1963:29-30). They used a "frequency of occurrence" measure to distinguish between the usual meanings found in literature and the unusual meanings that might appear (Klare, 1963:30).

The most significant occurrence in the pre-formula period, however, was the publication of E. L. Thorndike's book, The Teacher's Word Book, in 1921 (Klare, 1963:30). Thorndike's book tabulated the frequency of words appearing in print. According to Klare, Thorndike's research "not only influenced the teaching of vocabulary in the schools but also provided the basis for the work of Lively and Presser in 1923" in developing the first real readability formula (Klare, 1963:30).

Word frequency was not the only readability variable to be studied during this period. Professor L. A. Sherman and his students appear to be the first to have studied sentence length in a quantitative context (Klare, 1963:31). Among Sherman's findings was the fact that sentence length had been reduced from 50 words during the Elizabethan period to around 23 words at the time of his study in 1893 (Klare, 1963:31). Sherman also found that writers displayed "a remarkable consistency in the pattern of sentence lengths they used" (Klare, 1963:31). Sherman's findings made it possible to analyze a sample of a full text with reasonable assurances to the researcher that the results would apply to the full text (Klare, 1963:31).

An applied psychologist, H. D. Kitson, found a practical use for the research done on sentence length. He used sentence and word length to analyze the readability of advertising copy (Klare, 1963:31). The work of Sherman and Kitson provided a base for the application of sentence length research to future research in readability.

Readability Formulas

In general, a readability formula provides an estimate of the reading level needed to understand the material in the article or message being analyzed. Leon Hull notes that "most of the formulas commonly used to predict readability rely on some measure of sentence length and word difficulty" (Hull, 1979: E-73). Developers of readability formulas conjectured that the manipulation of sentence length and word difficulty would produce changes in reading comprehension. These individuals, many of whom are distinguished educators, hypothesized that the frequency of certain words or phrases could be used to determine a measure of reading level.

For example, the earliest known formula, developed by Lively and Presser, gave weights to words on the basis of their frequency in the sample (Klare, 1963:38). Another formula, proposed by A. S. Lewerenz, used the number of words beginning with each letter of the alphabet to compute his formula (Klare, 1963:40). Lewerenz found that "words beginning with the letters 'w', 'h', and 'b' showed high frequency in simple material, while those beginning with 'i' and 'e' showed low frequency" (Klare, 1963:41). Early readability formulas are discussed in detail in George R. Klare's book, The Measurement of Readability.

As previously stated, readability formulas tend to focus on unit frequency and word difficulty (Klare, 1963:37-80). That is, they measure the frequency at which certain units of measurement, such as words, appeared in the sample text. In addition, they measure word difficulty against some index of difficulty. The specific techniques for measuring readability, as shown in Figure 4, vary from formula to formula.

The four readability formulas to be discussed are those that appear to have or have had widespread use in fields outside of education. They are the formulas of Irving Lorge, Rudolf Flesch, Edgar Dale and Jeanne Chall, and Robert Gunning.

The Readability Studies of Irving Lorge. The attractiveness of Lorge's formula is in the fact that it requires only three elements to compute (Klare, 1963:53). Lorge's original formula measured the number of hard words (x4) and prepositional phrases (x3) in the sample, as well as the average sentence length (x2) (Klare, 1963:54). A hard word is one which does not appear in Edgar Dale's list of 769 easy words (Lorge, 1959:5).

Measure Based on Number of:

Name and Date of Study	Different Words	Words Not Appearing on Some Word List	Personal Words	Sentences	Syllables	Prepositions	Clauses/Prepositional Phrases	Words Per Sentence	Other
1. Lively and Pressey (1923)	✓	✓							
2. Vogel and Washburne (1928)	✓	✓		✓		✓			
3. Doloh (1928)	✓	✓							✓
4. Lewerenz (1930)	✓	✓			✓				✓
5. Johnson (1930)					✓				
6. Ojemann (1934)	✓	✓				✓	✓		✓
7. Dale and Tyler (1934)		✓	✓		✓		✓	✓	✓
8. Grau and Leary (1935)	✓	✓	✓				✓	✓	
9. Lorge (1939)		✓					✓	✓	
10. Yoakam (1939)		✓							✓
11. Flesch (1943,48,50)			✓	✓	✓			✓	
12. Dale and Chall (1948)		✓						✓	
13. Farr, Jenkins, and Paterson (1951)					✓			✓	
14. Gunning (1952)					✓			✓	
15. Stone (1957)		✓						✓	
16. Tribe (1956)	✓	✓		✓					

Figure 4. The Most Commonly Used Measures in Various Readability Studies. (56:74-80)

These measures are then applied to the formula $X_1 = .06 x_2 + 9.55 x_3 + 10.43 x_4$ to determine the readability index (Lorge, 1959:10).

The readability index, according to Lorge, "is an estimate of the reading grade at which the average school child will be able to answer about 55 per cent of the questions concerning detail, appreciation, import, vocabulary, and concept with adequate completeness and correctness" (Lorge, 1959:1).

Lorge found that his formula tends to overestimate the grade level of material read primarily for enjoyment, and underestimate material requiring attention to specific details (Lorge, 1959:1). Yet, Lorge contends that his formula provides a useful estimate of readability for both children and adults. One measure not provided by Lorge's readability formula is that of human interest. This measure is considered in the work of Rudolf Flesch.

Flesch's Measure of Reading Ease and Human Interest. Rudolf Flesch was one of the first to bring readability to the attention of those outside the field of education and psychology (Klare, 1963:56). Because of the attention he brought to his formula, it has become one of the most used readability formulas in existence (Klare, 1963:59). Flesch's formula consists of two basic measures.

First, Flesch's formula measures the reading ease of a sample passage by measuring the number of syllables (w_1) per 100 words, and the average number of words (s_1) per sentence (Flesch, 1951; Flesch, 1974:247-249). The resulting numbers are then applied to the formula $R. E. = 206.835 - .846 w_1 - 1.015 s_1$ to determine the reading ease score (Flesch, 1974:250; Klare, 1963:59).

Second, Flesch's formula measures the human interest level of the text.

Actually, this is "an estimate of the human interest that your presentation (rather than your subject) will have for the reader" (Flesch, 1951:1).

Flesch uses the number of personal words per 100 words (pw) and the number of personal sentences (ps) per 100 words to compute his human interest score (Flesch, 1974:248-249). The resulting computations can then be applied to the formula $H.I. = 3.635 pw + .314 ps$ to find the human interest score (Flesch, 1974:251; Klare, 1963:59).

The Edgar Dale and Jeanne Chall Readability Formula. The Dale-Chall formula consists of two elements of measure. The word factor measures the difficulty of the word (x_1) based on its appearance in Dale list of 3000 words, while the sentence factor consists of the average sentence length in words (x_2) (Klare, 1963:60). These measures are then applied to the formula $Xc50 = .1579 x_1 + .0496 x_2 + 3.6365$ to determine a reading grade score (Klare, 1963:60). Dale and Chall's score reflects the ability of a student to "answer one-half the test questions on a passage correctly" (Klare, 1963:60).

The Gunning "Fog Index". "The Fog Index is the reading grade level required for understanding the material" (Klare, 1963:65). To compute the Fog Index, developed by Robert Gunning, two measures are necessary. The first is the average sentence length computed by dividing the number of words by the number of sentences in the sample (Gunning, 1952:36; Klare, 1963:65). The second measure is the number of sample words containing three or more syllables (Gunning, 1952:36-37; Klare, 1963:65). These are summed and multiplied by .4 to get the Fog Index (Gunning, 1952:37).

Gunning classifies any material scored above 10 as difficult and any above 12 as in "danger of being ignored or misunderstood" (Gunning, 1952:38).

Gunning, like Flesch, Lorge, and others, warns writers against using the Fog Index as a pattern or formula for writing (Gunning, 1952:38). Readability formulas, as viewed by the researchers themselves, are best used as measures of predicting the reading difficulty of a written passage, rather than as a formula for achieving readable writing. Yet, many guidelines for writing have been generated from these readability studies (Flesch, 1951:25-27).

Criticisms of Readability Formulas. Although readability formulas have had some success in estimating reading level, or reading difficulty, some researchers believe that the measures used are not the true determinants of readability (Huckin, undated:90). Some writing specialists believe that traditional readability formulas fall short of being reliable predictors of readability (Huckin, undated:7-8).

One specialist who disagrees with traditional reading formulas, Thomas Huckin, questions the validity of traditional readability formulas because of the absence of a reliable measurement of reading comprehension (Huckin, undated:7). Huckin and others believe that readability research should go beyond manipulation of surface variables and explore the mental processes involved in reading (Huckin, undated:91-92; Klare, 1963:182-90). They think that a better understanding of the mental processes involved will allow a reliable series of guidelines for writing readable literature.

Thomas Huckin has cited "four serious shortcomings" of readability formulas. The first shortcoming is the lack of agreement between readability formulas on reading grade level (Huckin, undated:7). Huckin states that applying two or more readability formulas to the same written passage "frequently yields different readability scores, sometimes differing by as much as 4 or 5 grades" (Huckin, undated:7). He goes on to say, however, that

readability formulas are useful in rank-ordering different texts, or different versions of the same text, according to their degree of difficulty (Huckin, undated:7).

The second shortcoming that Huckin finds in readability formulas is the absence of a factor to measure the reader's prior experience or task dependency and the role these factors play in reading comprehension (Huckin, undated:8). Huckin cites a study by Bormuth as one in which factors existing in the real world were ignored (Huckin, undated:8).

The questionable reliability of readability formulas is the third shortcoming that Huckin cites (Huckin, undated:8). He finds that "the high correlations between the measured linguistic variables and the comprehensibility of a passage" may be due in part to the use of an inappropriate measure of comprehension (Huckin, undated:8). According to Huckin, a "reliable and independent measure of comprehension" is needed to determine reliability and that formula has not yet been developed (Huckin, undated:8).

The final shortcoming that Huckin cites is the fact that many technical writers are under pressure to "write to a formula" by manipulating the "surface variables" measured by readability formulas (Huckin, undated:9). Huckin feels that writing to a readability formula may enhance readability at the expense of comprehensibility (Huckin, undated:9).

A Cognitive View of Readability.

Huckin finds that "recent studies have shifted attention to those aspects of reading more commonly associated with long-term memory" (Huckin, undated:17). He goes on to state that "task requirements, prior knowledge, and the use of schemata in inferring meaning" are of greater importance to

the processing of text than "strictly the linguistic features of the text" (Huckin, undated:17).

Four concepts that Huckin cites in his article are "schema theory, activated semantic contexts, the levels effect, and the leading edge strategy" (Huckin, 1983:92). According to the schema theory, a reader's experience provides the basis for certain abstract concepts stored in his long-term memory (Huckin, 1983:92). These concepts, or "schemata," may be used by the writer to communicate with the reader. If the writer and the reader share certain schemata, then the writer need not explain each concept in detail (Huckin, 1983:92). The reader will be able to provide the missing details based on his own experience (Huckin, 1983:92). The more experience the reader has with the subject, the more details he will be able to provide (Huckin, 1983:92-93). Or, in other words, the reading comprehension of the text is enhanced in proportion to the amount of prior knowledge that the reader has of the subject area (Huckin, 1983:91-92). To be useful, however, the schemata must become "activated" in the reader's mind (Huckin, 1983:93).

Huckin finds that "semantic contexts (i.e., schemata)" are generally activated when the reader feels that a certain passage or word is "important to comprehension" (Huckin, 1983:93). Studies find that readers have greater recall of material they believe to be "centrally important to meaning" than of material believed to be "marginally important" (Huckin, 1983:93). Again, the reader's prior experience will determine which semantic contexts become activated (Huckin, 1983:93)

According to Huckin,

The nonspecialist reader, not having such knowledge to draw on, must rely much more heavily on how the information is presented in the text.

This dependency on the text means that if certain information is structurally buried in the text, the nonspecialist reader will probably not perceive it as being important; as a result, he or she will pay less attention to it, infer few if any details about it, comprehend it poorly, and recall it poorly. (Huckin, 1983:95)

The final concept to be discussed is the "levels effect." Basically, this theory finds that readers can recall high-level information better than they can recall low-level information (Huckin, 1983:95). That is, since readers "process a text hierarchically," they can recall information placed high in the hierarchy better than they can recall information placed low in the hierarchy (Huckin, 1983:95). Huckin recommends that important material be placed in titles, headings, and topic sentences rather than in the body of the paragraph itself (Huckin, 1983:95).

One final topic to be discussed before leaving Huckin's article is that of reading style. "Reading theorists have identified five different 'styles' of reading" (Huckin, 1983:99). These styles are skimming, scanning, search reading, receptive reading, and critical reading (Huckin, 1983:99). Although they may sound similar, each involves a different reading speed and, therefore, different comprehension rates. Huckin finds that readers generally use most, if not all, of these styles in reading the same piece of text (Huckin, 1983:99). This is another factor that must be considered in exploring readability and the possibility of a true readability formula.

Research on Format. While research by Huckin and others has gone beyond the quantitative approach of earlier readability research, other research studies are going beyond the linguistic focus of readability. Current research in readability has found that readers in the western hemisphere will generally "focus on the top left-hand corner of a page and

proceed down the page along a diagonal to the right" (Laner, 1977:142). Thus, material is usually placed along this diagonal by "publishers and advertisers aware of this principle" (Laner, 1977:142).

Summary and Observations

In reviewing this literature, it could be argued that readability research has progressed from study of vocabulary and word frequency to a study of the elements that increase readability through the enhancement of comprehension. These elements include word and syllable counts, word difficulty, and sentence length among others. While readability formulas have shown a high correlation between linguistic variables and reading comprehension, the measures of reading comprehension used are considered suspect by some researchers. In addition, while linguistic variables have some degree of predictive value in measuring readability, they may or may not represent causal factors in reading comprehension. More research is needed, and is being conducted, on those factors related to better readability through increased comprehension. In addition, once research information is made available, this information must be communicated in a manner useable by those who will apply it.

Yet, while these studies have contributed significantly to the study of readability, they have ignored the influence that physical appearance may have on reading performance. The study of legibility, on the other hand, includes the physical characteristics of letters and text and the influence that they have on perception and reading ease and speed (Tinker, 1963:7-8). However, legibility research, which is synonymous with typographical research for this thesis, generally does not focus on the influence that typographical factors have on comprehension and recall.

Color, meanwhile, has been studied for its impact on reading speed, accuracy, and comprehension. Unfortunately, fewer studies have been conducted on the impact of color on comprehension than have been conducted in the other areas of study in color.

Nonverbal studies which do focus on comprehension and recall are those involving the use of graphics. Studies have been conducted on the use of graphs, tables, diagrams, line drawings, and photographs to improve both recall and understanding of the text in which they are presented. These studies, however, rarely appear to consider the effects that graphics have on reading ease and speed.

It has been suggested previously in this thesis that the study of readability must include research in language, color, typography, and graphics if this research is to be of use to today's communicator. At a minimum, readability research must broaden its focus to include studies on the influence that each of the aforementioned areas has on each factor of reading performance. That is, color, typography, and graphics must be studied for their impact on reading ease, speed, and comprehension. As a first step towards the establishment of a base for future research, a review of past and present research on color, typography, and graphics is presented in the following chapter, with a bibliography of relevant research articles appearing in Chapter 4.

III. A Review of Color, Typographic, and Graphics Research

An Overview of the Chapter

Professor Harris believes that writers, as communicators, must be capable of choosing the most appropriate media for presentation of their ideas based on the needs of the audience rather than on past practices (Harris, 1978:136)¹. Yet, in each form of media, of which text, drawings, and photographs are examples, there are methods of presenting information which improve reading ease, speed, and comprehension more than other methods within that media. However, no medium or method is superior in all cases. Experience and experimentation have generally dictated the medium and methods to be used and the situations in which they will be used.

This chapter introduces the reader, as communicator, to research on presentation methods involving the use of color, graphics, and typography. There are methods of manipulating the appearance of the information that will improve the readability (reading ease, speed, and comprehension) of the message, and the communicator must be familiar with these methods and their conditions of use to use them effectively in written communication. Towards that end, the chapter begins with a discussion of color.

¹Citations in this chapter, with the exception of Harris and Frey, refer to articles which appear in the annotated bibliography. For example, (Tinker, 1963) refers to Tinker's book, *Legibility of Print*, published in 1963. The reader can find complete citations in either the annotated bibliography or the cited references.

Color

In their article, "50 Guidelines for Instructional Text," James Hartley and Peter Burnhill note that "there is no need to use colour on every page simply because it is technically possible to do so. (Hartley and Burnhill, 1978:192). Although modern technology has made the use of color more feasible and more economical than in the past, its use may not add to the readability of text. The purpose of color research is to determine when, and under what conditions, color assists the reader in recognizing the characters (letters, numbers, and special) and understanding the text.

These two goals, recognition and understanding, form the basis for the organization of this section on color. The first subsection deals with the comparisons of certain color combinations to determine their effects on visibility. A discussion of the research that studies the effects of color on learning and comprehension follows. The section concludes with observations on the state of color research as it relates to readability.

Studies in Brightness Contrast. Another noted researcher in the field of legibility, Dr. Miles Tinker, proposes that brightness contrast is "of prime importance" when considering the use of color for print and background (Tinker, 1963:128). In fact, during my review of the literature, most of the research involving comparisons between print and background color has dealt with brightness contrast. Our discussion begins with a comparison of black versus white print since, as Hartley and Burnhill note, "no colour has the contrast value of black on white" (Hartley and Burnhill, 1978:192).

Black versus White Print. Tinker, in his book, *Legibility of Print*, summarizes the research on black print versus white print when he states that, "with the exception of the early investigations of Kirschmann, every

study undertaken has shown a definite advantage for black print over white print" (Tinker, 1963:137). Tinker's statement reflects not only the work he did with Dr. Donald Paterson, but that of Grace Holmes and others as well (Holmes, 1931; Paterson and Tinker, 1931). An example of black print on white and white print on black backgrounds (Figure 5) is provided so that the reader may observe the difference in contrast. Since the type in the example has been enlarged for visibility, the reader is cautioned not to make any judgments on legibility based on this example.

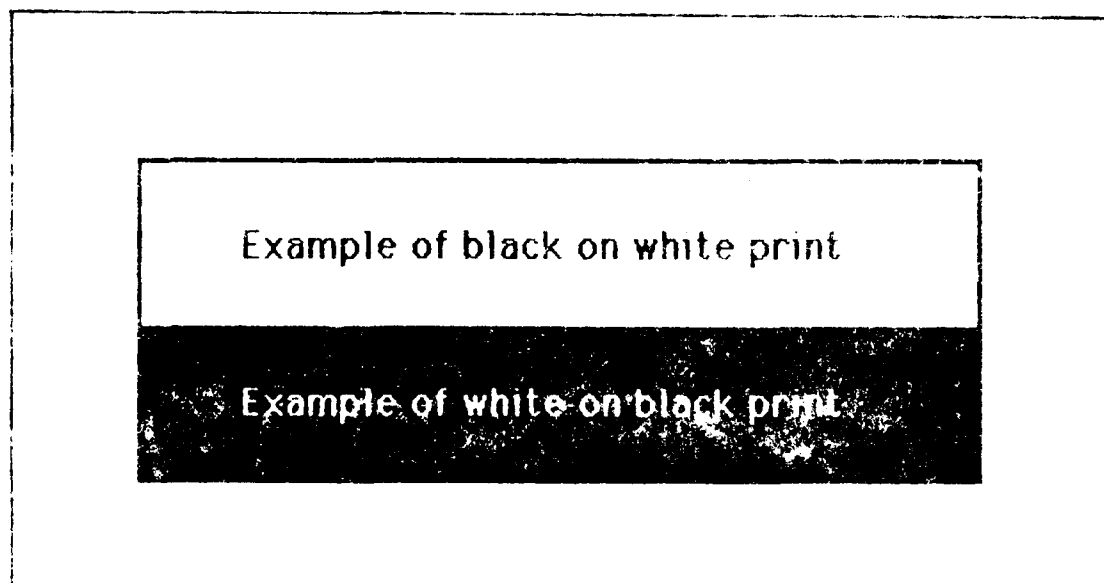


Figure 5. A Comparison of Black-on-White versus White-on-Black Printing.

Research on Other Color Combinations. Interest in the relationship between brightness contrast and reading performance led to further research involving the legibility of different color combinations. F. N. Stanton and H.E. Burtt, for example, focused on paper color as a variable in

reading speed. They studied the effects of paper surface and tint on legibility and conclude that neither factor impacts on reading speed (Stanton and Burtt, 1935).

Other color research indicates that color print does affect legibility and that the most legible color combinations are those providing the maximum brightness contrast between colors (Konz and others, 1972; Miyake and others, 1930; Preston and others, 1932; Sumner, 1932; Tinker and Paterson, 1931a). To achieve this brightness contrast, researchers suggest the use of dark ink on a light background (Sumner, 1932).

While legibility researchers were comparing color combinations in their search for optimal brightness contrasts, other color researchers were questioning the effectiveness of color in improving learning ability.

Color as a Variable in Learning

There appears to be no trend in research findings on the use of color as a learning tool. Roger Dooley and Larry Harkins, for example, find color to be useful in attracting the reader's attention although ineffective in improving learning (Dooley and Harkins, 1970). In another study, William Michael and Robert A. Jones observe no difference in examination scores for groups using colored and white paper (Michael and Jones, 1955). On the other hand, Francis Dwyer, Jr. and J. Kenneth Jones, in separate studies, cite the effectiveness of color in certain situations. Dwyer, observing 261 college students, notes that color illustrations are effective for certain types of visuals, while Jones' experiments with nursery school children reveal an increase in learning when colored letters and words are used (Dwyer, 1971; Jones, et al., 1965). Finally, Natan Katzman and James Hyenhuis indicate that color may improve recall for peripheral, but not central, material, while

Richard J. Lamberski finds the use of color significantly improves recall of instructional material (Katzman and Nyenhuis, 1972; Lamberski, 1982).

Modern research appears to focus on the use of color as it relates to visual displays produced by computer technology. Gerardine DeSanctis, in her article on computer graphics, cites the work of researchers such as Tullis and Christ in concluding that the use of color is situational and, at best, offers no "special advantages" over non-color material. (DeSanctis, 1984). She does, however, find "considerable room for research on the effects of color combinations on user comprehension, decision performance, and so forth" (DeSanctis, 1984).

We need further research studies on color and readability. Although the technology for producing color documents is rapidly advancing, research to date indicates only that use of color in improving the reader's understanding of the material is somewhat questionable. One general conclusion appears to be that the effective use of color depends on the material to be used and the circumstances surrounding its presentation. But which materials and what circumstances have yet to be determined.

Typography and Readability

Overview. Much of the research on typography has been conducted in the area of legibility, which is "the coordination of those typographical factors inherent in letters and other symbols, words, and connected textual material which affect ease and speed of reading" (Tinker, 1963:8). Tinker proposes that "optimal legibility of print 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" (Tinker, 1963:8). This, then, is the focus which has guided past research on typographical factors and their relationship to readability.

This section summarizes that research, beginning with a discussion of type style, type size, line length, and spacing. It concludes with some observations on the use of typographical cueing.

The Physical Characteristics of Print Cyril Burt, with fellow researchers W. F. Cooper and J. L. Morton, observed that type style, type size, spacing, and line length interacted to produce variations in reading speed and comprehension (Burt and others, 1955). Although these factors appear to be synergistic in their effect on legibility, research has generally been conducted on only one factor at a time. The studies reviewed in the course of my research tend to support this finding.

Type Style Tinker and Paterson, in one of their early experiments, indicated that eight of the ten type styles then in common use were equally legible, although not all were equally desirable to the reader (Tinker and Paterson, 1932). David Robinson, Micheal Abbamonte, and Selby Evans attempted to explain this variance in reader preference for type style based on the presence or absence of serif-form letters. Using a simulation model of the human visual system, they discovered that the presence of serifs somehow enhanced the reader's perception of those characters (Robinson and others, 1971). Examples of serif and san-serif type print are presented in Figure 6.

Special Cases of Print Style In addition to studies on commonly used type faces, research has also been conducted on the use of boldface and italic print as well as on the use of all upper-case versus all lower-case

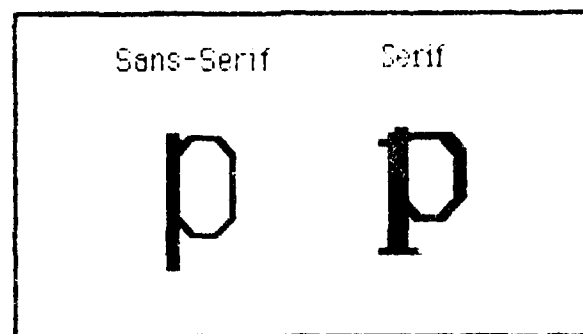


Figure 6. Serif and Sans-Serif Type

letters. The research of Tinker, Hartley, and others, shows that the use of lower-case letters is superior to the use of upper-case letters in almost every situation in which they were compared (Hartley and Burnhill, 1978; Tinker, 1932). In addition, the legibility of bold print appears to equal to that of lower-case letters while the use of italics generally results in a decrease in reading speed (Tinker, 1963:62). Tinker and Hartley recommend italics only for situations which require added emphasis on the word or words (Tinker, 1963:65; Hartley and Burnhill, 1978).

Type size, Spacing, and Line Length. Most research results in the observation that type size interacts with type style and the length of the printed line to produced optimal legibility (Burnhill, 1970; Burt and others, 1955; Poulton, 1972; Tinker and Paterson, 1928, Tinker and Paterson, 1929a). The result of this interaction is that type size varies with the style of type and line length being used in the text. However, one researcher, Howard T. Hovde, contends that type size, as well as spacing, is

unimportant since these typographical factors are secondary to the context of the article (Hovde, 1929 and 1930).

Spacing, either between words or between lines (leading), and the length of the printed line have been the focus of other research studies, including that of Tinker and Paterson, Poulton, and Hartley. As with type size, most researchers suggest that the optimal spacing and line length varies with the style of type used, although some researchers find no significant relationship between these typographical factors and readability (Crossland and Johnson, 1928; Lucklesh and Moss, 1938 and 1941; Paterson and Tinker, 1932; Tinker and Paterson, 1929b and 1931b; Wiggins, 1967). Other researchers, E. C. Poulton and Tinker and Paterson, for example, give the optimal type sizes, line lengths, and leading for the different styles of type compared in their studies (Paterson and Tinker, 1932; Poulton, 1972).

One- versus Two-Column Formats. A special case of line length involves the use of one- and two- column formats for printing. Lloyd Bostian, in a 1976 study, observed that reading speed and comprehension were improved when a single-column was used (Bostian, 1976). He suggested that the amount of white space in the format influenced the results of his study and recommended the use of a single-column format when adequate white space could be provided (Bostian, 1976). In their studies, however, John M. Smith and Maxwell E. McCombs contend that while white space improved reader interest, it had little, if any, effect on reader comprehension (Smith and McCombs, 1971).

In another study on multiple column formats, Hartley, Burnhill, and Lindsey Davies observed 500 grade school children and noted no differences between the reading performance of groups assigned to either a one- or

two-column format (Hartley and others, 1980a). Tinker, on the other hand, found no necessity to conduct legibility studies on multiple-column formats since the same principles of type size and line length applied to all formats (Tinker, 1963:116). However, in his study involving college students and professional typographers and printers, Tinker did note a preference for two-column formats and recommended that the use of this format be increased in the printing of textbooks and journals (Tinker, 1963:118).

Justified versus Unjustified Margins. Another special case of line length is the use of justified versus unjustified margins. In some cases, researchers found no evidence of a relationship between margin width and readability, while other research suggested that the use of justified margins actually degraded reading performance (Davenport and Smith, 1965; Frase and Schwarz, 1979; Gregory and Poulton, 1970). In most cases, however, researchers discovered that readers tended to prefer shorter, more uneven lines (Hartley and Burnhill, 1971).

Typographical Layout. Closely related to the use of the various type styles, sizes, and spacing is the format used to print the text on a page. The four typographical styles generally used in experimental studies are horizontal (conventional), vertical, spaced units, and square pan or double-line block. Spaced unit typography incorporates the use of spacing to separate the text into meaningful thought units, while square pan and double-line block typography use a combination of vertical and horizontal presentation techniques (Tinker, 1963). An illustration of each of these last three styles is shown in Figure 7.

While the research generally indicates the superiority of conventional typography over vertical and specialized typographies, some exceptions to

this conclusion have been noted. J. L. Coffey, for example, observed no difference in reading accuracy between groups viewing either horizontal or vertical alpha-numeric displays, while Irwin Nahinsky concluded that vertical typography improved the reader's comprehension of the text presented in the experiment (Coffey, 1961; Nahinsky, 1956).

Spaced unit:	There was not	a drop of ink	in the house.....
Square pan:	There was not	a drop of ink	
	in the house	for someone had broken.....	
Double-line			
blocks:	There	a drop	in the
	was not	of ink	house
			for someone
			had broken.....

Figure 7. Illustration of Spaced Unit, Square Pan, and Double-Line Block Typography (Tinker, 1963:125).

Results similar to Nahinsky's findings were observed by Edmund Coleman and Insup Kim in a study involving college students. Coleman and Kim discovered that horizontal typography had a slight advantage over the other three styles of typography when conventional testing techniques were used in the experiment (Coleman and Kim, 1961). Yet, when a tachistoscope was introduced into the study, the use of spaced units, square pan, and vertical typography proved to superior to horizontal typography (Coleman and Kim, 1961).

A tachistoscope is an instrument which is generally used to restrict the subject's field of vision to a small area. This allows the researcher to experiment with different typographic factors without the contaminating

influence of images outside the experimental field of vision. Test images are usually presented to the subject between the presentation of blank slides to reduce the influence of the previous image on the current image.

The tachistoscope was again used by Coleman in a follow-up to his earlier study with Kim. In this experiment, Coleman and S. C. Hahn used both vertical and horizontal typography in a reading accuracy test involving elementary school children. This time, the subjects read the horizontal (conventional) typography far more accurately than they read the vertical typography (Coleman and Hahn, 1966). This finding was observed even in experiments involving the use of the tachistoscope (Coleman and Hahn, 1966).

Finally, Tinker noted that reading speed dropped for typographic styles other than the horizontal style, although he suggested that the reading speed for vertical typography could be improved through practice (Tinker, 1963:127). His suggestion may indicate that the uniqueness of the unconventional typographic styles may have influenced the reader's performance significantly.

Whatever the effect of these unconventional typographic styles, their unique qualities can attract the attracted reader's attention. Other typographical factors have also been used to focus attention on material that the communicator wishes to emphasize. Among these are line spacing, indentation, underlining, and the use of headings. These are the subject of our section on typographic cueing.

Typographical Cueing. In their 1979 study, Lawrence Frase and Barry Schwartz noted two typographical factors that affect comprehension. They identified these factors as segmentation cues, which alert readers to

meaningful passages, and spatial cues, which are used to separate text (Frase and Schwartz, 1979). Frase and Schwartz suggested that the use of meaningfully segmented text was critical to reading comprehension (Frase and Schwartz, 1979). One type of cue commonly used to alert readers to these important passages is the underline.

Underlining. No trend seems to be developing in the research on the use of underlining. For example, research studies by C. M. Christensen and K. E. Stordahl in 1955 and Dirk Wendt and Hans Werckerle in 1972 concluded that underlining had no effect on recall or comprehension (Christensen and Stordahl, 1955; Wendt and Werckerle, 1972). Yet, Sally Hartley, Alan Bartlett, and Branthwaite observed that the use of underlining produced an improvement in the recall of underlined material presented to a group of sixth grade students (Hartley and others, 1980a). A study conducted by George Klare, J. E. Mabry, and L. M. Gustafson may, perhaps, explain some of these differences in findings.

Their study was conducted to determine the effects of underlining on reading speed and retention of a 1206-word technical lesson on aircraft maintenance. They observed that readers who were aware of the rationale behind the use of the underline were able to retain more of the underlined material (Klare and others, 1955). On the other hand, readers who were unfamiliar with that rationale were hindered in their efforts to retain the material. Underlining did not affect the reading speed of either group (Klare and others, 1955).

Spacing as a Typographic Cue. The use of spacing as a cueing technique has also been the focus of typographic research. Wendt and Werckerle, in the same study that investigated underlining, noted that the

use of indentation increased the speed of reference work being conducted by the subjects in the study (Wendt and Werckerle, 1972).

In another study, Hartley, Burnhill, and Davies compared the use of indentation and line spacing as techniques for the cueing of paragraphs. Their results indicated that the use of either indentation or line spacing was superior to a format which contained neither (Hartley and others, 1979). In a separate study, Hartley suggested that the use of spatial cueing did affect comprehension even though he was unable to prove the effect statistically (Hartley, 1980).

One other study, conducted by Wayne Hershberger and Donald Terry, provides some insight into the use of multiple cueing, including the use of underlining. In this study, Hershberger and Terry compared simple and complex cueing. Simple cueing consisted of the core and enrichment materials of the text being printed in a different colors. Complex cueing, however, involved underlining, various type sizes, and colors to differentiate the core and enrichment material as well as the four sections of the enrichment material itself. Based on their observations, Hershberger and Terry suggested that the use of simple cueing was enough to improve retention of the affected material. They found that complex cueing offered no significant advantages over simple cueing (Hershberger and Terry, 1965).

Headings as Typographical Cues. Early research by Christensen and Stordahl, J. K. Hvistendahl, and others concluded that headings had little, if any, effect on the recall of text (Christensen and Stordahl, 1955; Hvistendahl, 1968). In fact, Hvistendahl noted that more than one-half of the subjects in his study failed to notice that the heading and the text contained contradictory information (Hvistendahl, 1968). Recent research

by Hartley, et. al. however, indicated that headings did improve both the immediate and long-term recall of text (Hartley and others, 1980b).

Summary. Although much of the research reviewed during the course of this investigation was conducted earlier in this century, the principles developed appear to have withstood the test of time. Further research is needed and should include studies on the effects of typographical factors on reading performance when text is read from a computer display terminals.

Some observations based on the research that has been conducted should be made, however. For example, the synergy between type style, type size, spacing, and line length requires that each factor be studied to determine the necessity for changes in the other factors to maintain optimal readability. That is, no one type style, type size, line length, or method of spacing is constant for all situations if optimal readability is to be maintained.

Research has also indicated that reading performance is not significantly affected by the use of either justified or unjustified margin widths, although most studies concluded that the readers generally prefer the unjustified margin. Again, the use of two-column formats, usually argued on the basis of economical factors rather than typographical factors, does not appear significant to reading performance.

A final comment on type styles: Readers prefer serif letters over sans-serif letters. Readers also prefer to read this print horizontally, although they can adapt to a vertical type if they are allowed to sufficient practice.

Typographical cueing has also been the focus of much research. The use of spacing, which includes indentation, has shown some effectiveness as a

typographical cue, while the use of headings appears to have questionable value as a typographical cue. Research on underlining has produced no definite findings. While some underlining studies have found this technique useful, others have observed no significant differences in recall. An early study by Klare et al. may provide partial explanations for these diverse results.

Finally, more studies are needed along the lines of Hershberger and Terry's research on the use of multiple cues. Researchers must focus future research in this area and take a more holistic view of typography. Factors other than type style, type size, spacing, and line length may combine to produce changes in the optimal readability of prose.

Graphics, Illustrations, and Readability

The importance of graphics in text goes far beyond an esthetic value. The capability of the computer to produce, or copy, illustrations and transfer them to text has sparked a new interest by researchers in exploring the limitations of graphics in text. Yet, past research in this area is extensive and provides us with some good observations on the ability and inability of graphics to improve readability. The use of graphics to improve readability is the focus of this section. We begin by reviewing the research conducted on statistical, or relational, graphics and conclude with a discussion on illustrations in text. For the sake of brevity, the category of statistical graphics, which includes graphs, tables, and diagrams, will herein be included in the term "graphics." The term "illustrations," meanwhile, will be used to indicate the category containing both line drawings and photographs.

The Use of Graphics Illustrations are provided in this section so that

the reader may see the general appearance of the various presentation formats tested. The same data was used in the preparation of the horizontal bar, vertical bar, and circle graphs to allow the reader to see the differences in appearance of the various graphs drawn to the same scale. The line graphs, however, were prepared with a different set of data and, thus, are not directly comparable to the bar and circle graphs.

Graphs. In the earliest study reviewed, Walter Eells measured the reading performance of students using bar or circle graphs. He observed that circle graphs were read more accurately than bar graphs, especially as the number of divisions presented in the graph increased (Eells, 1926). Later research conducted by L. V. Peterson and W. Schramm also concluded that circle graphs were most accurate when comparing parts of a whole (Peterson and Schramm, 1954).

In answer to Eells' experiments, Frederick Croxton and R. E. Stryker observed that circle graphs were superior to bar graphs when presentations of 50-50 and 75-25 relationships were required (Croxton and Stryker, 1927). However, insufficient evidence existed to prove that the use of circle or bar graphs was superior in all cases (Croxton and Stryker, 1927). In an article in that same year, however, Croxton compared his work to that of Eells and observed that bar graphs were generally superior to circle graphs where reading accuracy was concerned (Von Huhn and Croxton, 1927). Figure 8 presents an illustration of a horizontal bar graph and a circle graph. They show the same information presented in a format common to each type of graph. That is, the bar graph represents the number of units on each day, whereas the circle graph represents the proportion of the entire week's production accomplished on a specific day.

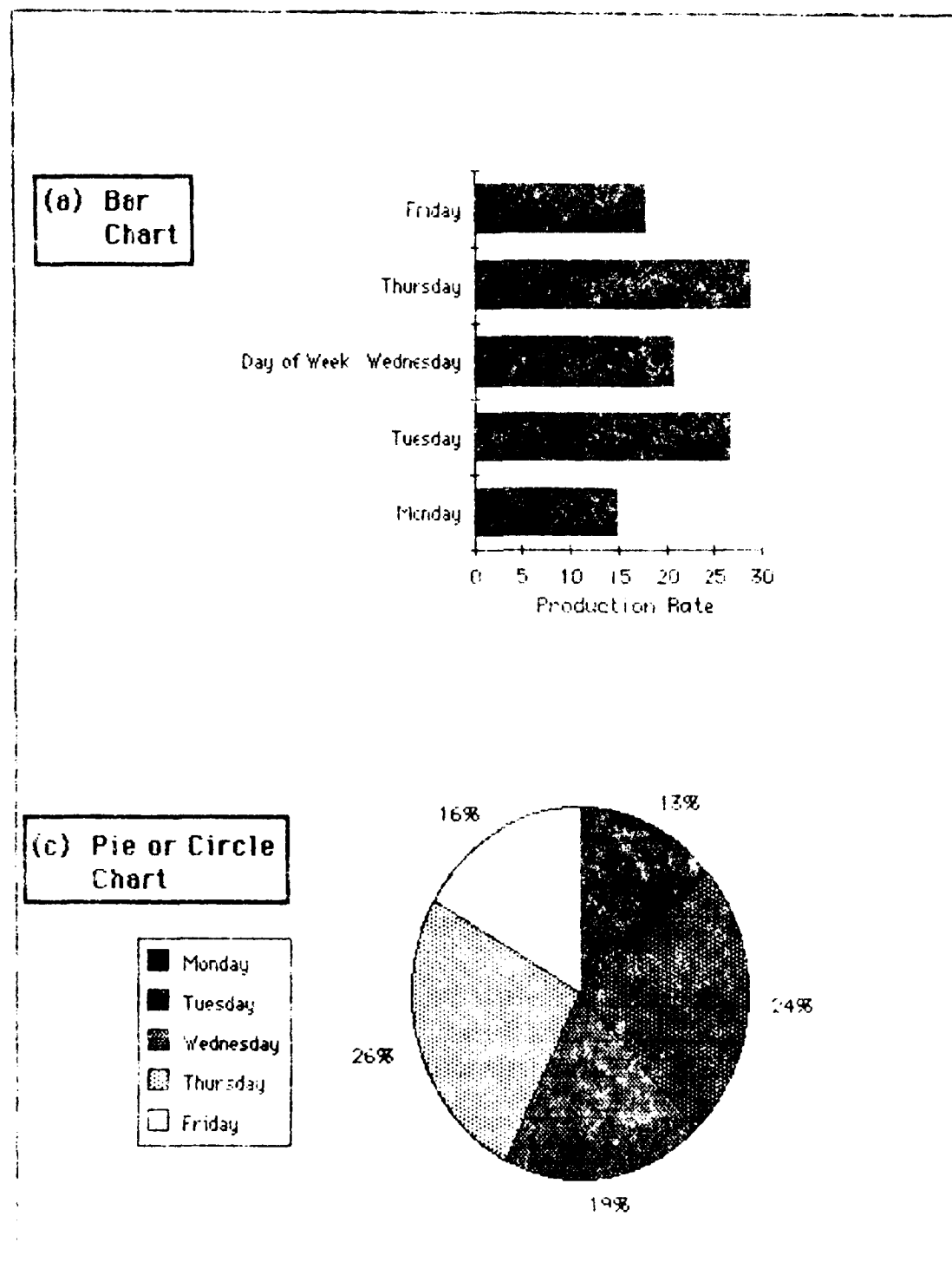


Figure 8. An Illustration Comparing a Horizontal Bar and a Circle Graph.

A later study conducted with fellow researcher Harold Stein reaffirmed Croxton's conclusion on the use of bar graphs. Croxton and Stein also studied the use of square and cubed (three-dimensional square) graphs and discovered that cubed graphs were read less accurately than any of the other graphs (Croxton and Stein, 1932). Examples of both a two-dimensional and three-dimensional bar chart are shown in Figure 9.

Meanwhile, James Graham was investigating a reader's ability to accurately use bar graphs. Graham observed that readers tended to overestimate bar lengths when the bars were short, narrow, or shaded (Graham, 1937). He also noted that coarse scale units and wide spacing between bars caused readers to overestimate bar lengths (Graham, 1937). Finally, he discovered that readers tended to overestimate bar lengths on vertical graphs more so than on horizontal graphs (Graham, 1937). Figure 10 illustrates horizontal and vertical (or column) graphs representing the same bar lengths.

In 1961, Howard Schutz compared the use of various graphical formats in presenting both single and multiple trends. In both cases, he observed that performance using line graphs was superior to both the horizontal and vertical bar graphs (Schutz, 1961). Schutz suggested, however, that as the number of missing data points increased, the differences between the three types of graphs disappeared (Schutz, 1961). Figure 11 presents the reader with an illustration of a horizontal bar graph and a single trend line graph.

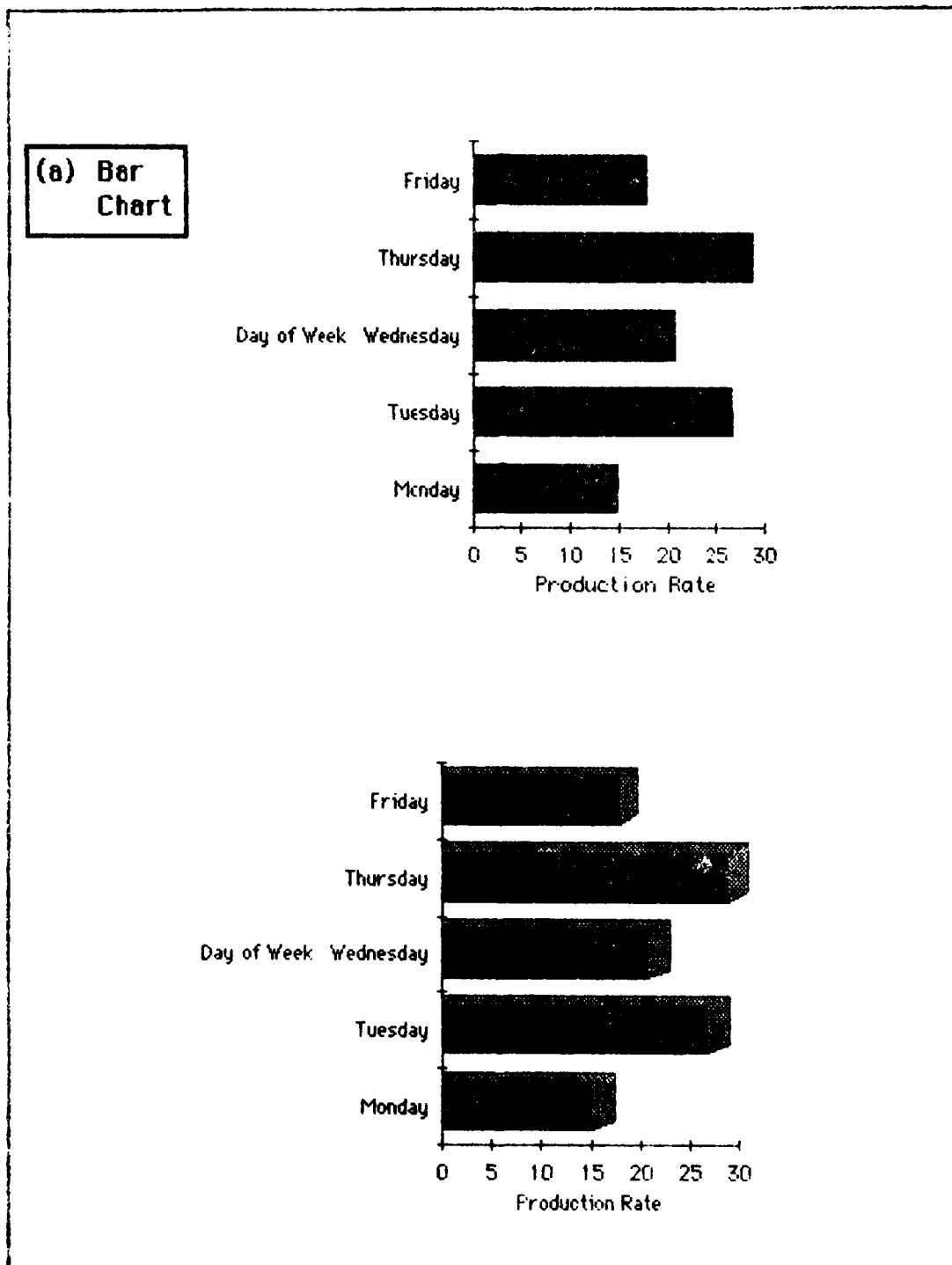


Figure 9. Illustration of Two- and Three-Dimensional Bar Graphs.

Neither has the placement of labels on a graph been neglected in research. R. Milroy and E. C. Poulton measured readers' speed and accuracy on graphs with different locations for labels (indicating what the line, bar, or circle segment represents). In the experiment, the lines were either labelled directly or the line labels were placed inside the area of the graph or in the general area of the graph heading. Based on their observations, Milroy and Poulton recommended that functions be labelled directly for greatest accuracy (Milroy and Poulton, 1978). Figure 12 illustrates the use of the direct labelling of functions and labelling inside the area of the graph.

Tables. Tables, in the meantime, have not been neglected by psychologists and statisticians. For example, Launar Carter studied the ability of college science students to use tables and graphs. He defined the best designed table as one which included all the relevant data points for all major and minor arguments, or categories, in the problem (Carter, 1947). He observed that when student performance on this table and on simpler tables and graphs was compared, students used the best designed table with greater speed and accuracy (Carter, 1947).

In another study, B. K. Peterson suggested that the use of text supported by either graphs or tables was superior to narrative alone in improving reading speed and retention (Peterson, 1983). She noted, however, that text which used both tables and graphs tended to confuse the reader and resulted in lower recall performance scores than those for text with either tables or graphs (Peterson, 1983). Figure 14 illustrates the same information in both tabular and graphic form.

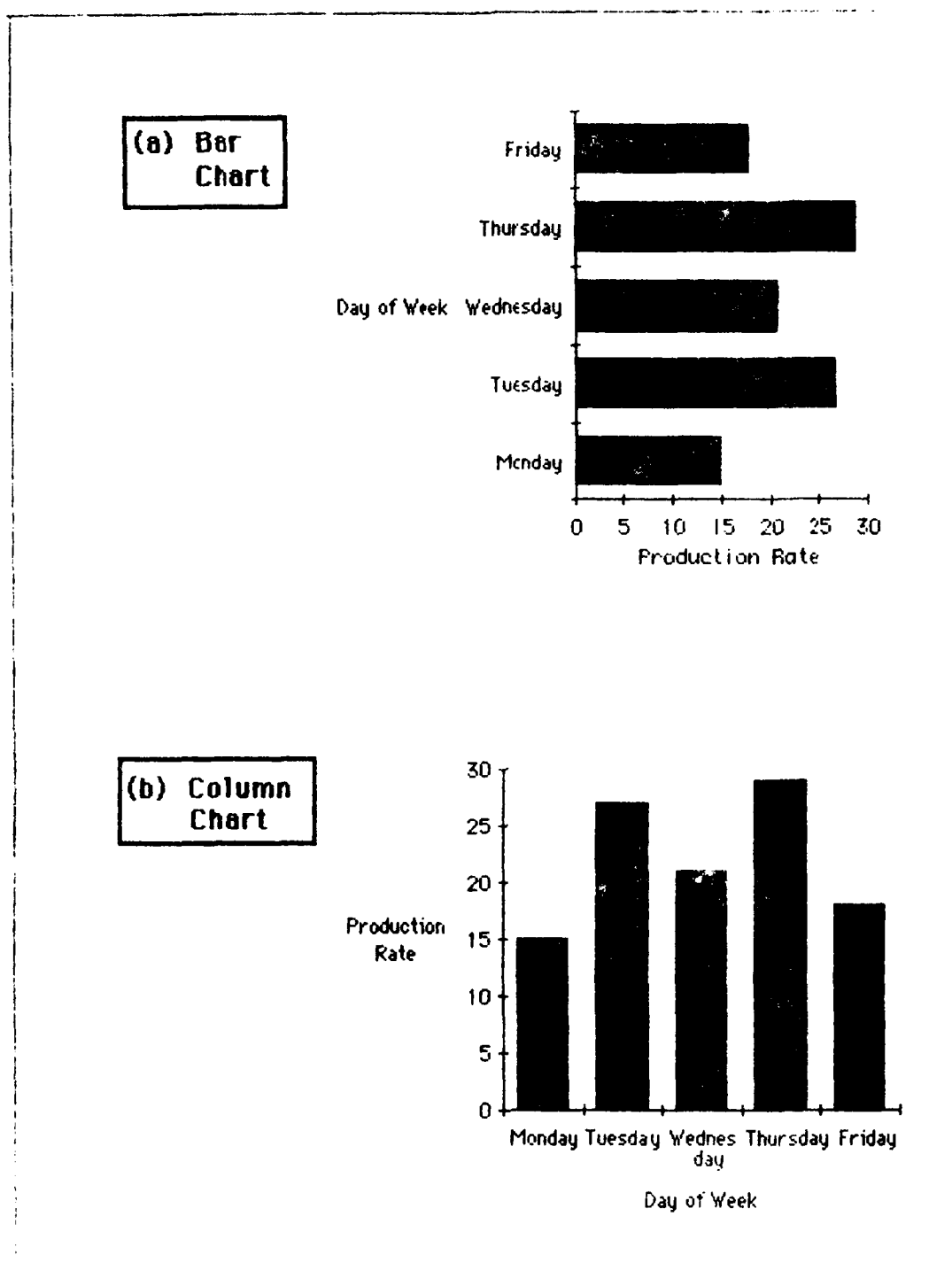


Figure 10. Illustration of Horizontal and Vertical (Column) Bar Graphs

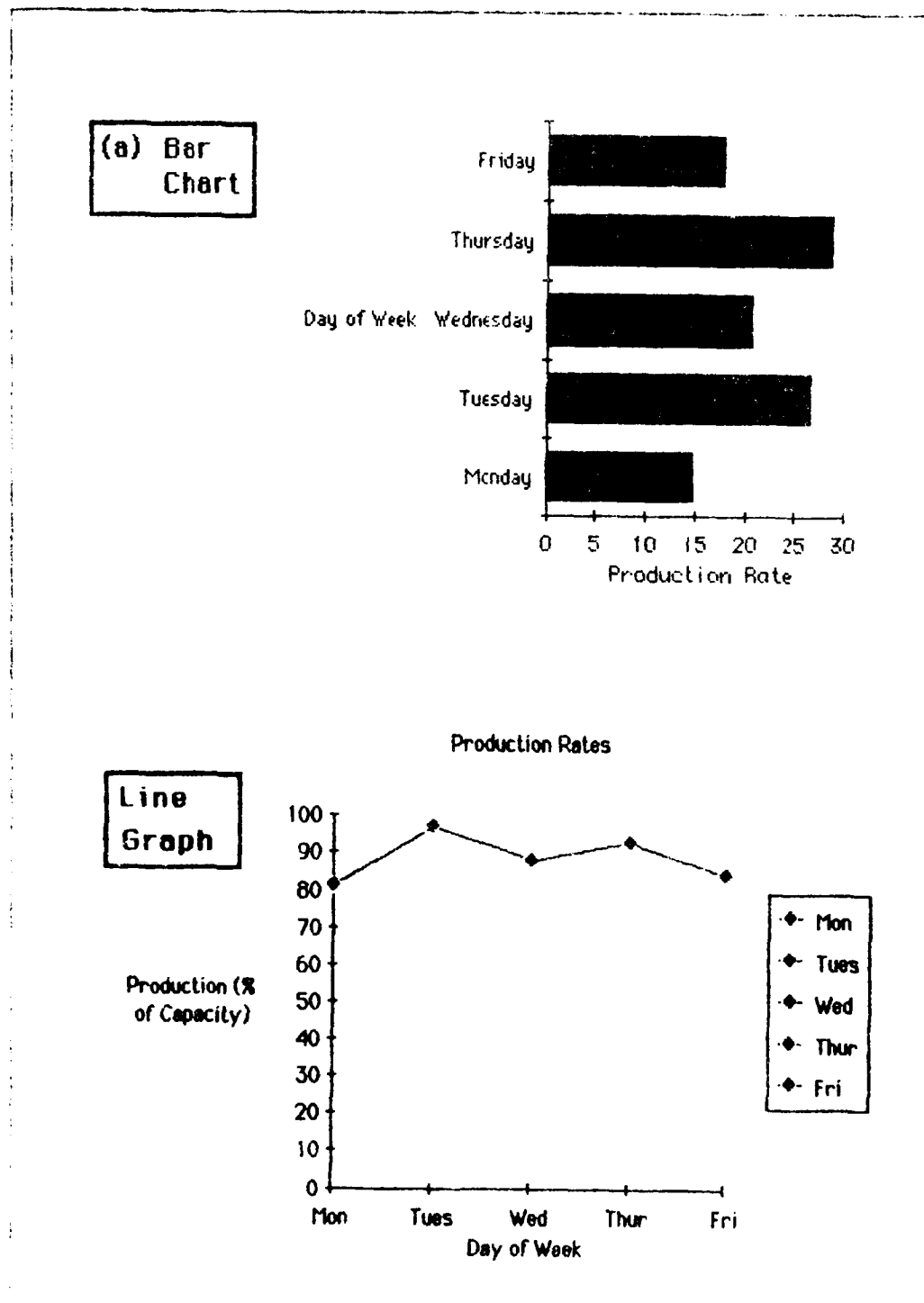


Figure 11. Illustration of Horizontal Bar Graph and Line Graph.

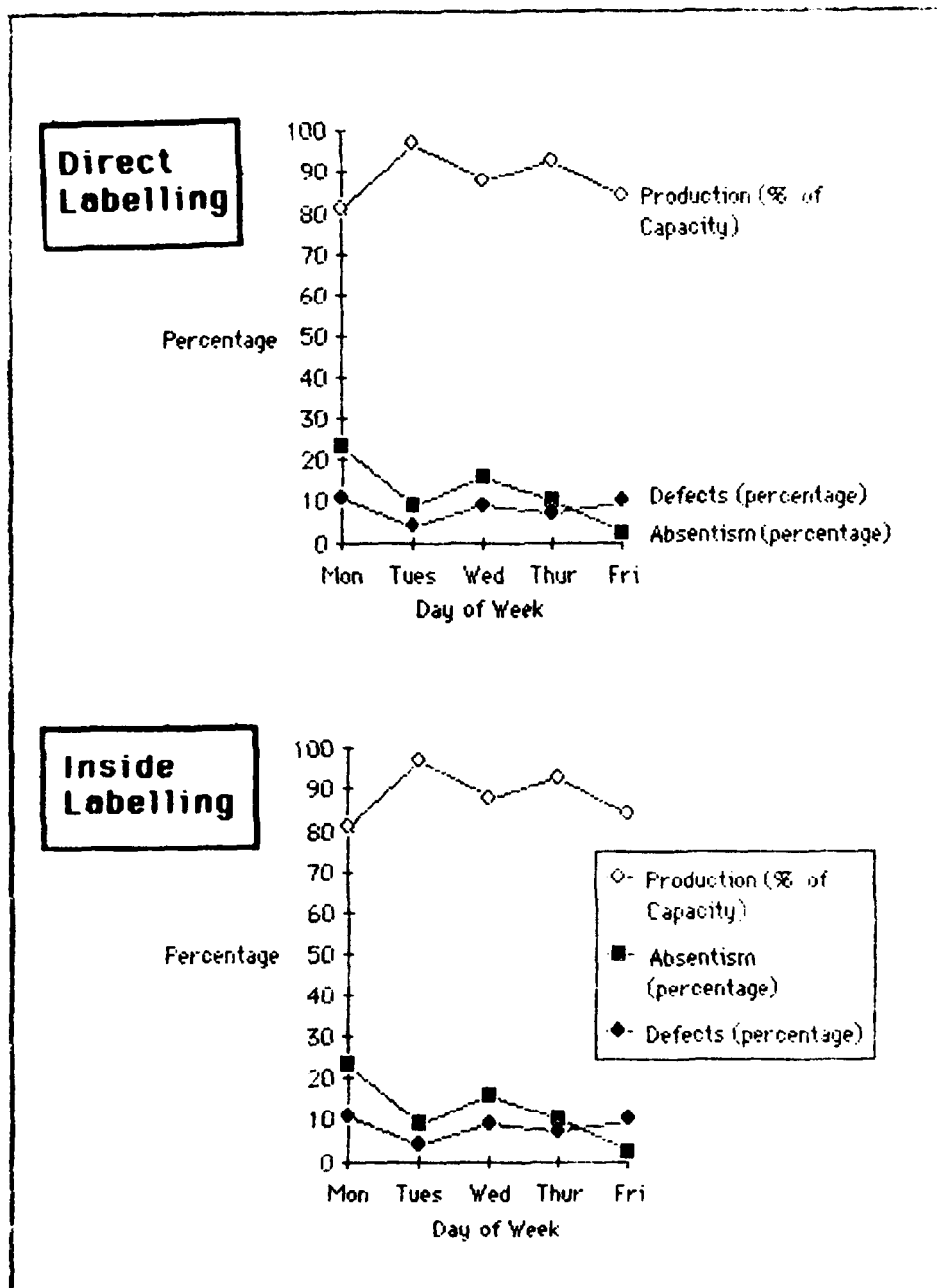


Figure 12. Illustration of Direct Labelling and Inside Labelling

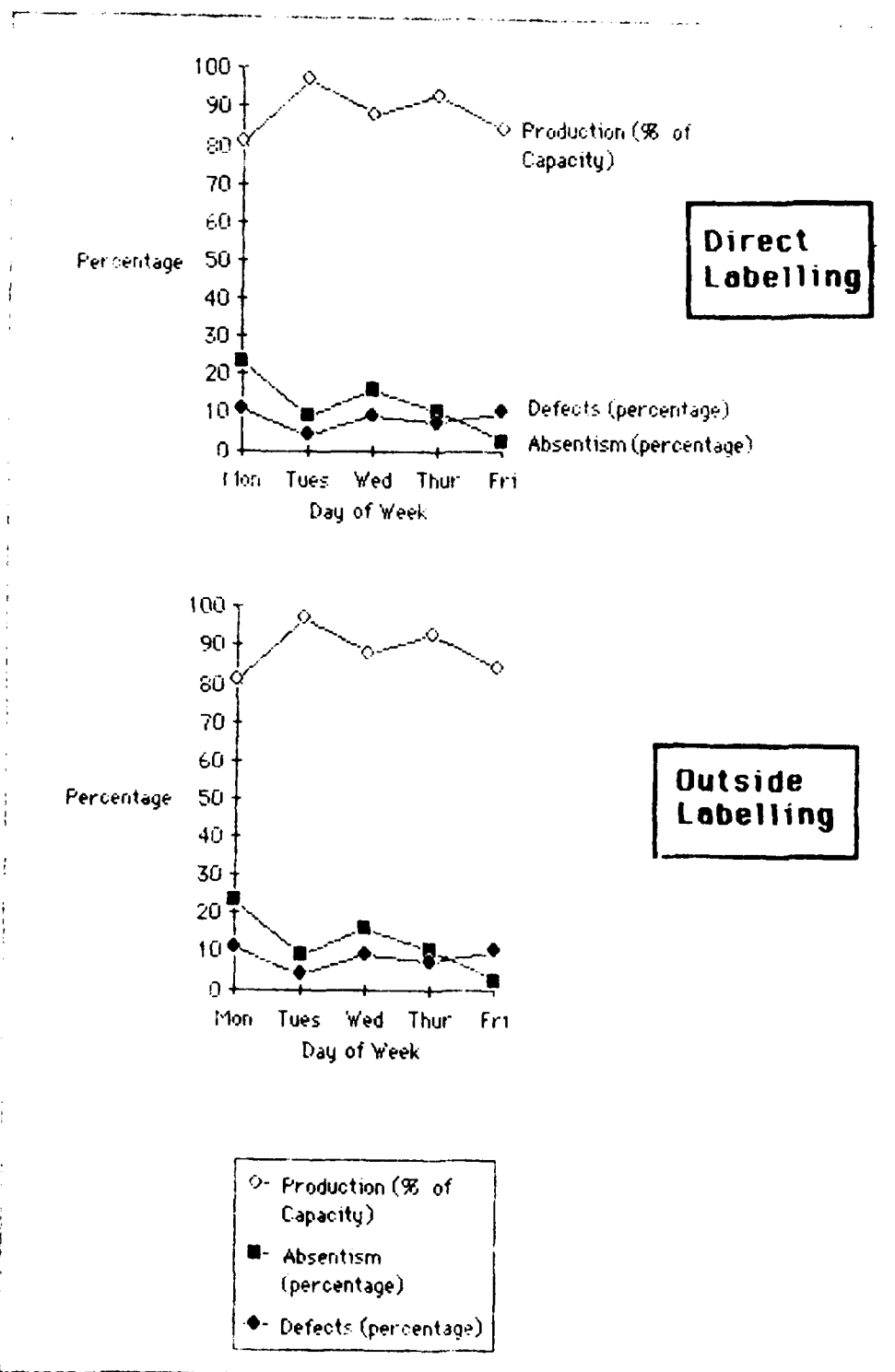


Figure 13. Illustration of Direct Labelling and Outside Labelling

Diagrams. Samuel Weintraub, in reviewing past research on graphs and diagrams, noted that research on reading diagrams was far less extensive than research on reading graphs (Weintraub, 1967b). In one of the few studies conducted, Magdalen Vernon observed no improvement in the reader's understanding of the material presented in diagrams alone (Vernon, 1953b). She recommended that diagrams, when used, be accompanied by narrative, but she also suggested that tables may be a better way of presenting factual data (Vernon, 1950).

The Ability to Use Graphs. Vernon, in experimenting with graphs, concluded that the use of graphs did not significantly improve the reader's ability to understand and recall the data presented in the graphs (Vernon, 1946). She observed, however, that few of her subjects had studied the use of graphs in their educational training (Vernon, 1946). She suggested that the inability of individuals to use graphs properly may be the result of a lack of training in this area (Vernon, 1946). Weintraub also expressed this sentiment when he cited the importance of the teacher in the development of graph-reading skills (Weintraub, 1967).

Summary. Research conducted by Eells, Croxton, Stryker, and others early in this century generally revealed that while circle graphs were better for comparing parts to a whole, readers were able to read data with greater accuracy using the bar graph (horizontal and vertical). Further research by Graham indicated that, among bar graphs, vertical (or column) bar lengths tended to be overestimated by the reader. When Schutz compared bar graphs to line graphs, however, his research indicated that line graphs were superior to bar graphs for presenting both single and multiple data trends.

Sales Trends

<u>Year</u>	<u>Sales (in millions)</u>
1970	15
1971	17
1972	19
1973	25
1974	29
1975	33
1976	34
1977	31
1978	24
1979	21
1980	18
1981	19
1982	24
1983	27
1984	26

Sales Trends

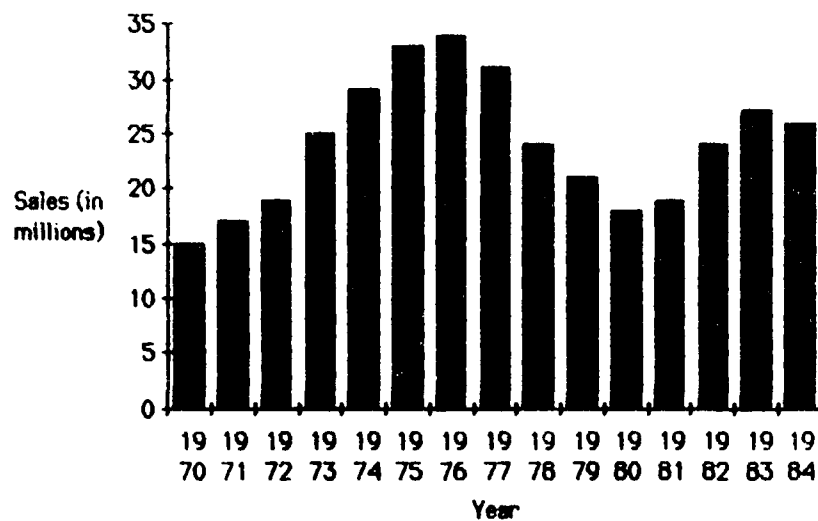


Figure 14. Sales Data Represented in Both Tabular and Graphic Forms.

On the other hand, the use of tables, according to Carter, tended to be as effective as graphs if the table included all relevant data points for each relationship being represented in the graph. Tables were also cited by Vernon as being superior to diagrams for factual data. In reference to diagrams, Weintraub observed that experimentation on the use of diagrams is less extensive than experimentation conducted on the use of graphs. Vernon also cites the importance of supporting any graphic technique, including diagrams, with narrative.

Finally, both Vernon and Weintraub cite the importance of education in preparing readers to use supporting devices such as graphs and tables. The relationship between graphics instruction and the speed and accuracy of their use, then, is an important variable and merits further consideration in any study involving graphics usage.

Meanwhile, study on the use of graphics continues. According to DeSanctis, readers tend to prefer realism in both illustrations and graphs (DeSanctis, 1984). This brings to mind a popular presentation technique used in one of the major weekly news magazines, U. S. News and World Report. For example, in relating the rising trend in budget deficits, the magazine superimposed a colored line graph on a color photograph of a mountain range. Since news magazines enjoy popularity among a substantial number of readers in this country, it might be worthwhile to study the reader's ability to read this new type of format and to understand the concepts that are being presented in the graph.

The future also presents a challenge in the study of graphics. The computer has made the use of graphics commonplace in most business, scientific, and educational circles. Graphics presentations, however, are

generally limited to the use of two-dimensional and psuedo-three-dimensional (an illusion of three-dimensional) presentations. Advances in laser technology and in the study of holograms, or three-dimensional pictures, present a potential to produce true three-dimensional graphics (Frey, 1983:G&P-18) Research, therefore, will be needed to study the effects of three-dimensional graphics on a reader's speed and accuracy of use as well as on the individual's understanding of the material presented.

Three-dimensional graphics, however, is not the only focal point for future study. Present technology has advanced to a point where an individual with a home computer can now scan photographs and print them into a text file. Where once individuals were writers and, then, word processors, they now have the ability to change typography and include graphics in text. This ability has propelled the communicator into the role of editor and, commonly, publisher. Therefore, if the tools of technology are to be employed effectively, the communicator must be able to judge the useability of the output.

The ability to make this judgment requires a prior knowledge of the principles, based on research, behind the use of color, typography, and graphics. Having discussed color, typography, and relational graphics, we now turn to our final discussion on the use and effectiveness of illustrations in text.

Illustrations and Readability. The relationship between illustrations and reading traces its origins to the dawn of mankind and the use of illustrations to communicate. However, the alphabet brought about written language as we perceive it today. Yet, illustrations are part and parcel of written publications. While many illustrations are used for their esthetic

appeal, many others are used to illustrate a concept. The reality of the adage "one picture is worth a thousand words" has been studied and debated throughout the years and is still being studied even as writing is transitioning to communicating in Harris' sense of the term.

This section presents a summary of that research. Research on illustrations generally falls into one of two major categories. The first category includes research on the impact that illustrations have on a reader's recall of the information presented pictorially. Our discussion begins by summarizing the research conducted in this area.

A discussion of several theories advanced to explain the superiority of illustrations over text alone and to explain the differences between the effectiveness of the different types of illustrations concludes the research summary. As with the previous sections, a summary and recommendations for further research complete this section.

Picture-Memory Studies. Much of the research into a reader's ability to remember illustrated material indicates that the reader is capable of retaining far more information than early research indicated. For example, Lionel Standing, Jerry Conezio, and Ralph Haber present dramatic evidence of a reader's retentive capabilities for illustrated material. In their experiment, Standing and his fellow researchers presented subjects with over 2500 pictures shown at intervals ranging from five to ten seconds. Subjects were then presented with a second series of photographs and asked to identify those photographs viewed in the initial presentation (Standing and others, 1970). Research results indicated that the subjects were capable of correctly identifying a significant number of the photographs for

periods up to three days following the initial presentation (Standing and others, 1970).

These results were again observed in Raymond Nickerson's studies. In one experiment, he observed that individuals could identify a photograph appearing a second time in the series even when as many as 200 photographs were observed between the identical photographs (Nickerson, 1965). Follow-up studies by Nickerson indicated that these illustrations could still be identified by the subjects for periods up to a year following the original experiment (Nickerson, 1968).

Research conducted Marilyn Haring, Kent Dallett and Sandra Wilcox, and Elihu Katz, Hanna Adoni, and Phina Parness also indicates that readers have a far superior retentive capability for illustrations than exists for words (Dallett and Wilcox, 1968; Haring, 1982; Katz and others, 1977). On a smaller scale, David Corsini, Kenneth Jacobus, and S. David Leonard observed that the 40 preschoolers in their study were able to recognize pictures over long periods of time (Corsini and others, 1969). They suggested, however, that the ability of the children to translate those images into words was degraded by changing experimental conditions (Corsini and others, 1969). This ability to translate the information provided by the illustrations into some meaningful concept is the focus of the following discussion on pictorial comprehension studies.

Pictorial Comprehension. The value of illustrations to the process of learning has been a topic of much debate. While one group recognizes the contributions of illustrations in text to the learning process, another group proposes that the use of illustrations may actually degrade learning performance.

For example, Philip Brody, Seth Spaulding, and the research team of Haring and Maurine A. Fry all indicated in separate studies that illustrations could aid the student in learning the concepts presented in the text (Brody, 1982; Haring and Fry, 1979; Spaulding, 1955 and 1956). S. Jay Samuels, however, held an opposing view on the usefulness of illustrations. In research studies in 1967 and 1970, Samuels indicated that illustrations may actually hinder the reader (Samuels, 1967 and 1970). In fact, in his 1967 study, Samuels observed that individuals with less developed reading skills actually learned more from non-illustrated text (Samuels, 1967). Finally, a 1984 study by Robyn Saunders and Robert Solman concluded that the use of pictures did not aid kindergarten students in the acquisition of the vocabulary words presented in the study (Saunders and Solman, 1984).

Most studies on illustrations, however, indicate that illustrations are useful for retention of specific information but are ineffective in improving the reader's understanding of the concepts involved. Karl Koenke and Wayne Otto's study, for instance, revealed that pictures were useful in aiding an elementary school student's retention of specific facts, but they were not beneficial in increasing the child's knowledge of the concept (Koenke and Otto, 1969).

Magdalen Vernon also arrived at this conclusion in her experiments in the early 1950's. In addition to questioning the use of illustrations to improve comprehension, Vernon went on to suggest that the use of graphs may be superior to the use of illustrations when relationships were being discussed (Vernon, 1953a and 1954). Finally, William Miller's studies on 600 elementary school students revealed that, although the pictures had interest

value, the use of illustrations had little value as a tool for improving comprehension (Miller, 1938).

Pictorial versus Verbal Coding Systems. Many studies have focused on the reader's ability to recognize and recall the information presented by illustrations. The psychology of the human information processing system has been the subject of many of these experiments. For example, previous theory on information processing suggested that two encoding systems existed, verbal and perceptual. Research by Herbert Clark and William Chase, however, suggests that only one encoding system exists, not two, and that it processes data regardless of its source (Clark and Chase, 1972).

On the other hand, Arnold Powell and Rena Wynn retained the dual-coding concept and suggested that pictures are processed on both systems (Powell and Wynn, 1976). Research by Alinda Friedman and Lyle Bourne, though, indicated that pictures may have a head start in this encoding process because they are more distinguishable from one another than are words (Friedman and Bourne, 1976).

Another explanation is forwarded by Susan D. Denberg. She suggested that text and illustrations each provided the reader with incomplete information on the subject. By combining these two incomplete views, the reader was afforded a larger view of the subject, hence better understanding (Denberg, 1977). Similar results were observed by David Stone and Marvin Glock, who suggested that the use of both narrative and illustrations provided the reader with a certain amount of redundancy in the information presented (Stone and Glock, 1981).

While these theoretical studies are of general interest, more practical research compares the impact of simple (fewer lines, less detail) versus

realistic illustrations on recall and comprehension.

Simplicity versus Realism in Illustrations. One major study in simplicity versus realism was conducted by Frederick Dwyer. He presented one of three different types of illustrations of the human heart (simple line drawing, shaded, detailed drawing, and photograph) or an oral description of the human heart to 108 college freshmen. Upon analyzing the results of recall testing for new ideas or terms, Dwyer concluded that the use of the oral description proved to be superior to the use of illustrations (Dwyer, 1967). Among the illustrations, however, Dwyer observed that the simple line drawing was more effective in improving the student's ability to learn the new material (Dwyer, 1967). Figure 15 presents two examples of shaded, detailed drawings. The illustration on the right also illustrates how a photograph copied electronically into text might look in print.

Simple drawings were also shown to be superior to detailed drawings and photographs in studies conducted by Russel Coulter, Marcie Coulter, and John Glover (Coulter and others, 1984). Thomas Nelson, Jacqueline Metzler, and David Reed, however, observed no significant differences between the various types of illustrations (Nelson, 1974). Meanwhile, T. A. Ryan and Carol Schwartz, upon measuring the speed of processing various types of illustrations, concluded that line drawings required more time for processing than was required for shaded drawings and photographs (Ryan and Schwartz, 1956).

One final observation in the use of illustrations is necessary. Research indicates that illustrations by themselves offer no assistance to the reader when understanding is required (Vernon, 1954). Illustrations must be supported with some form of verbal narrative (Vernon, 1954).

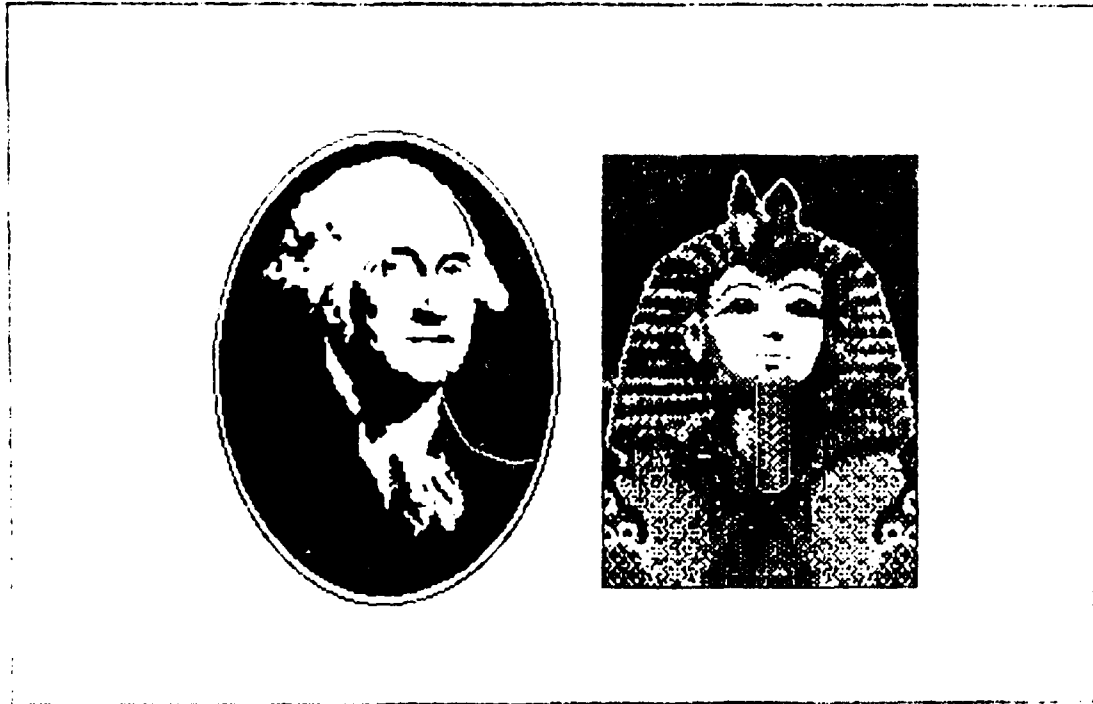


Figure 15. Example of Shaded, Detailed Line Drawings.

Summary. Illustrations, according to the evidence, are effective in supporting text, not replacing it. While readers may be capable of retaining specific facts represented pictorially for long periods of time, it is the responsibility of the communicator to explain in narrative how those facts relate to the concepts being presented in the text.

Several theories have been advanced to explain why readers can remember facts presented pictorially longer than they can retain the same facts presented verbally. These include the concept of dual-encoding in the human information processing system and the reader's ability to rapidly distinguish illustrations from one another.

Finally, simple drawings tend to be processed slower than more detailed drawings and photographs. Yet, simple drawings appear to be superior to more detailed drawings when general identification with the object is required.

As mentioned previously, the use of three-dimensional graphics, to include illustrations, is possible and requires further research. In line with this, more research needs to be conducted on simplistic versus realistic illustrations. Although technology allows us to insert photographs into text, research may indicate that the use of such detailed illustrations is ineffective in aiding the reader's comprehension of the material. If this proves to be true, then the communicator may waste time, effort, and money in attempt to introduce realism where it is not needed.

Conclusions

Technology has advanced the art of writing to include areas not traditionally taught in a basic writing course. The communicator has the ability to introduce color, graphics, and even typographic changes into a piece of text. Yet, research indicates that the perceived benefits of using these tools may not be reflected in the reader's understanding of the subject presented in the text.

The purpose of this thesis has been to introduce the readers to the fields of color, typography, and graphics so that they may use these techniques effectively. The reader must remember, however, that the most effective way to use some techniques is to avoid using them in certain situations. More precisely, to add color and graphics to text simply because it is technically possible to do so may, at some point, actually hinder the reader's ability to read and understand the text.

Color. Color research, for example, has shown that the most legible color combinations are those having the brightest contrasts in color. Therefore, using a color combination such as white lettering on a light blue background may not be as effective as using the standard black on white print. If the purpose of the text is to attract the reader's attention, however, then the use of color combinations with less brightness contrast may be justified.

Color may also be used to emphasize certain words or phrases within the text. Research has shown that color is effective in improving recall of the material presented in color. Research, however, has also shown that color is not entirely effective in improving the reader's comprehension of the subject. Therefore, in a lesson on aircraft maintenance, the communicator may wish to color code the parts and names of the aircraft according to their function (mechanical, electrical, and hydraulic) while printing the narrative itself in standard black on white print.

Another point should be emphasized. The use of color coding and graphics does not replace the use of narrative. One general conclusion brought out by research in these two areas is that the communicator must state his reasons for including color or graphics in text. In the example above, the communicator should state the purpose of color coding the names and parts: to identify mechanical, electrical, and hydraulic functions. Otherwise, the reader may not make this assumption on his own.

Graphs/Tables/Diagrams. The same reasoning applies to the use of statistical graphics and illustrations. To be consistent with our first two observations, graphs, tables, and illustrations should be used only when they are directly related to the subject matter, and, then, their purpose should be

explained to the reader in narrative. In addition, the communicator must evaluate the type of graph he wishes to use for his presentation.

Research has indicated that if the communicator wishes to present a simple relationship between a part and its whole, especially for 50-50 and 75-25 relationships, then the circle graph is most appropriate. On the other hand, bar graphs are more appropriate for presenting more complex relationships that require reading data points from the graph itself. Horizontal bar graphs, according to research, appear to enjoy a slight advantage over vertical bar, or column, graphs in this respect. Yet, when the subject requires the presentation of a large number of data points and the reader must identify these points with accuracy (as in many engineering tables), then a table including all relevant data points is, perhaps, more appropriate.

Tables, on the other hand, may not be appropriate for displaying trends, especially multiple trends. To present this type of information, the communicator may wish to consider the use of line graphs or, in some limited cases, vertical bar graphs. The functions represented by line graphs (production and defects in our earlier illustrations) should be labelled directly or, at least, in the area of the graph. The communicator should also remember that, unless a great deal of accuracy is required, the graph should be kept simple. That is, the communicator should only use enough data points to adequately represent the relationship between the major arguments.

Illustrations. Simplicity is also desired in illustrations unless detail is critical to the discussion of the narrative. Using our aircraft maintenance example, a discussion on the general location of certain pieces of equipment

may best be served by a simple outline of the aircraft with an illustration of the equipment displayed in the area it is located. However, when an example of its exact location is required, such as in many technical orders, a photograph may be more appropriate.

While research has shown that pictures improve the reader's recognition and recall of material presented pictorially, it has not provided conclusive evidence that pictures aid reading comprehension. On the other hand, research has also shown that readers use the incomplete information provided by the illustration to complement the incomplete information provided by the text. On other occasions, illustrations and text provide redundant information, thereby providing the reader with a common focal point between the information presented in the text and the information presented in the illustration.

If illustrations can provide both complementary and redundant information to the reader, then the ineffectiveness of illustrations used to aid reading comprehension may be due to a lack of reader training in the use of illustrations. This problem is also noted in research on the use of statistical graphics. Early research on the use of statistical graphics indicated that the subjects who were unable to use graphs effectively had little or no training in the use of graphs. I am not aware of any research comparing the effectiveness of illustrations on improving reading comprehension before and after the readers' have been trained on the use of illustrations to complement text.

Typography. The presence of color and graphics is immediately obvious to the reader, and the communicator can explain his use of these techniques to the reader. Less obvious to the reader, however, is the use of typography

to improve readability. Outside of the use of headings and underlining, little research has been conducted on the use of typography to improve reading comprehension. Most research has been conducted on the use of typography to improve reading ease and speed.

For example, research has shown that the use of serifed letters is preferred over the use of sans-serifed letters. While subjects generally based their preferences on the appearance of the lettering, research using computer simulation the structure of the human visual system indicates that serifed letters may be processed faster and more accurately by the reader than sans-serifed letters.

Meanwhile, other research indicates that subjects increase their reading speed without degrading their performance when unjustified margins are used. This observation holds true for either one- or two-column formats. On the other hand, research indicates no differences in speed or ease of reading between the different type styles in common use. Research does indicate that type style, type size, and the length of the printed line interact in producing optimal legibility. That is, no one style of type, size of type, or length of line is suitable for all occasions. These factors appear to vary from article to article.

This brings about one final observation on the use of typography. Even while researching the effects of one or a combination of these typographical factors on reading performance, many researchers observe that the typography used in articles is based more on economical considerations than psychological or physiological considerations. That is, the type style, type size, spacing, number of columns, and use of justification is usually

determined by the size and shape of the journal in which the article appears as well as by the editorial policies of the journal.

Future Research. Two areas in particular need further research. First, researchers should look at the composition as a whole, rather than as separate collections of words, colors, typographic styles, and illustrations. For example, more research along the lines of Hershberger and Terry's study on simple versus complex cueing is necessary in order to study the synergistic effects of color, typography, and language.

Another area of research that needs to be addressed is the impact of computerized word and graphics processing on written communication. More specifically, the use of computer display terminals to present written communication and the effects of dot-matrix (or the formation of letters by the arrangement of a series of dots) printing should be evaluated for readability.

This bibliography pulls together most major research relating color, typography, and graphics to readability from the fields of education, journalism, and psychology. It represents only a beginning, however. Other fields which have contributed to readability research are linguistics, physiology, business, and ergonomics. Other factors relating to readability are reader fatigue and stress. Although not directly under the control of the communicator, the effects that reader fatigue and stress have on readability are important to the concept of 'knowing the reader'. Research in this area must be added to the material here to complete the comprehensive document needed by communicators. This document provides a format and a rationale.

IV. Bibliography

Annotated Bibliography

Color

Booth, George and Herbert A. Miller (1974) "Effectiveness of monochrome and color presentations in facilitating affective learning."
AV Communication Review, 22: 409-422.

Booth and Miller conducted their study by presenting color and monochrome slides to a group of second, fourth, and sixth grade students. From their findings, Booth and Miller concluded that monochrome presentations may be best suited for tasks requiring ideation. Color, however, may be an effective force in promoting levels of valuing in older students.

Dooley, Roger P. and L. E. Harkins (1970) "Functional and attention-getting effects of color on graphic communication."
Perceptual and Motor Skills, 31: 851-854.

Dooley and Harkins conducted a study to determine the effectiveness of color as aid to learning and reader attraction. They concluded that while color was effective as an aid in gaining the attention of the 45 adults participating in this study, the use of color did not improve the learning performance of the subjects to any great degree.

Dwyer, Francis M., Jr (1971) "Color as an instructional variable."
AV Communication Review, 19: 399-416.

Dwyer's studied involved the use of illustrations of varying type and color composition to determine their effectiveness as a learning aid. Analysis of the data generated by the 261 college students involved in the study revealed that color does play an important role in the instructional effectiveness of certain visuals. However, the data did not

support the view that visuals improve comprehension in each case to which they are applied.

Holmes, Grace (1931) "The relative legibility of black print and white print."
Journal of Applied Psychology, 15: 248.

In her study, Holmes concluded that printing black on white resulted in better legibility than printing white on black.

Jones, J. Kenneth (1965) "Colour as an aid to visual perception in early reading."
British Journal of Educational Psychology, 35: 21-27.

In a study to determine the effect of color on visual discrimination, Jones concluded that a significant number of the 110 nursery school children involved were more interested in and performed better on those experiments using color letters and words.

Katzman, Natan and J. Nyenhuis (1972) "Color vs. black-and-white effects on learning, opinion, and attention."
AV Communication Review, 20: 16-28.

Katzman and Nyenhuis observed that the use of color increased recall for peripheral material when visual images existed but did not improve recall of central material. Results of their study did not support the use of color to improve recall of any non-pictorial material.

Konz, S., Chanla, S., S. Sathaye and P. Shah (1972) "Attractiveness and legibility of various colours when printed on brown cardboard."
Ergonomics, 15: 189-194.

They observed that, in general, black print was more legible than blue print, while blue print was more legible than green print. Red print appeared to be the least legible color print examined. Overall, they recommended the use of the brightest color contrast available.

Lamberski, Richard J. (1982) "The instructional effect of color in immediate and delayed retention." Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Research and Theory Division, Dallas TX.

Lamberski discovered that recall was superior for the group of subjects using instructional materials that utilized color. The rate of decline in recall, however, was equal for both black-and-white and color presentations.

Michael, William B. and Robert A. Jones (1955) "The influence of color of paper upon scores earned on objective achievement examinations." Journal of Applied Psychology, 39: 447-450.

Students between the ages of 18 and 26 participated in a study to determine the impact of paper color on examination scores. Michael and Jones discovered no significant differences between the examination scores of the two groups.

Miyake, R., J. W. Dunlap, and E. E. Cureton (1930) "The comparative legibility of black and colored numbers on colored and black backgrounds." Journal of General Psychology, 3: 340-343.

The researchers discovered significant differences in legibility in eight of the twelve color combinations studied. They concluded that the use of color, especially the color red, did have an effect on legibility and recommended further study in this area.

Paterson, Donald G. and Miles A. Tinker (1931) "Studies of typographical factors influencing speed of reading: VI. Black type versus white type." Journal of Applied Psychology, 15: 241.

The findings from this study show that the use of black on white in printing increases reading efficiency more than the use of white on black.

Preston, K., H. P. Schwankl, and Miles A. Tinker (1932) "The effect of variations in color of print and background on legibility."
Journal of General Psychology, 6: 459-461.

Preston et al. concluded that brightness contrast is necessary for improved legibility.

Stanton, F. N. and H. E. Burtt (1935) "The influence of surface and tint of paper on speed of reading."
Journal of Applied Psychology, 19: 683-693.

Tinker and Paterson's experiments on reading speed formed the basis for Stanton and Burtt's study to determine the effects of printing surface and color on reading speed. They concluded that the paper tint and surface do not impact on reading speed.

Sumner, F. C. (1932) "Influence of color on legibility of copy."
Journal of Applied Psychology, 16: 201-204.

Sumner compared the use of different colored letters and backgrounds to determine their effect on legibility. Like other researchers in this area, Sumner called for maximum brightness contrast when using colored letters and background. He suggested using a grey background for colored lettering. He also recommended the use of dark lettering and light colored backgrounds when reading will be done under daylight conditions.

Tinker, Miles A. and Donald G. Paterson (1931b) "Studies of typographical factors influencing speed of reading: VII. Variations in color of print and background."
Journal of Applied Psychology, 15: 471-479.

Tinker and Paterson investigated the use of color combinations to increase the speed of reading. Comparing ten different color combinations, they found that the most effective combinations were those that provided the brightest contrast between colors.

Graphs/Tables/Diagrams

Carter, Launar F. (1947) "A study of the best design of tables and graphs for presenting numerical data."
Journal of Applied Psychology, 31: 640-650.

Carter conducted this study to determine the effect of an increasing number of points and lines on the ability of 68 college science students to use tables and graphs. Carter also compared the best designed graph against the best designed table generated in this study. He discovered that tables which included all data points relevant to the major and minor arguments of the problem were faster to handle and more accurately used than simpler tables.

Croxtan, Frederick E. and Harold Stein (1932) "Graphical comparisons by bars, squares, circles, and cubes."
Journal of the American Statistical Association, 27: 54-60.

This study extended Croxtan's previous experiments with Stryker to include the use of squares and cubes. They discovered that the bar graph was still more effective than any of the other graphs studied. Subjects performed least well on the cubed graph, while no significant differences were noted between the use of the circle and square graphs.

Croxtan, Frederick E. and R. E. Stryker (1927) "Bar charts versus circle diagrams."
Journal of the American Statistical Association, 22: 473-482.

Croxtan and Stryker observed that circle graphs were clearly superior to bar charts in a presentation of 50-50 and 75-25 relationships. They also noted that many of the 807 students viewing the 27 graphs appeared to prefer the circle chart over the bar charts, although this could not be confirmed statistically. Insufficient evidence existed to confirm the superiority in all cases of either circle or bar charts.

Culbertson, H. M. and R. D. Powers (1959) "A study of graph comprehension difficulties."
AV Communication Review, 7: 97-100.

Based on the data gathered from 100 students enrolled in an agricultural short course, Culbertson and Power observed that horizontal and vertical graphs were better suited for situations where the subject was required to evaluate or compare specific quantities.

DeSanctis, Gerardine. (1984) "Computer graphics as decision aids: directions for research."
Decision Sciences, 15: 463-487.

DeSanctis reviewed past research on the use of graph and tables in decision-making. She observed that research comparing graphs and tables often indicated the better mode of presentation without investigating the reasons for the difference. She concluded her research by questioning the contribution of graphics to decision-making.

Eells, Walter C. (1926) "The relative merits of circles and bars for representing component parts."
Journal of the American Statistical Association, 21: 119-132.

In comparing the reading ease, speed, and accuracy of bar graphs and circle, or pie, graphs, Eells concluded that circle graphs could be easily and as quickly read as bar graphs. Eells' study also concluded that circle graphs were read more accurately than bar graphs, especially as the number of subdivisions presented in the graph increased.

Graham, James L. (1937) "Illusory trends in the observations of bar graphs."
Journal of Experimental Psychology, 20: 597-608.

Graham's experiments with bar graphs included the study of factors which influenced on the perception of bar graphs: bar width, scale size, spacing between bars, shading, color or brightness, and vertical or horizontal presentation. Graham discovered that those bar graphs that tended to be overestimated were those which were short in length, narrow in width, or shaded. He also found that the use of coarse scale

units, wide spacing between bars, or vertical presentation caused the 50 undergraduate subjects to overestimate bar lengths.

Gross, Alan G. (1983) "Primer of tables and figures."
Journal of Technical Writing and Communication, 13: 33-55.

Cross compared the use of tables, graphs, and drawings in text to improve reading comprehension. He observed that graphs and tables were useful to the reader if they were accompanied by a narrative explaining the importance of the data.

Milroy, R. and E. C. Poulton (1978) "Labelling graphs for improved reading speed."
Ergonomics, 21: 55-61.

Milroy and Poulton compared readers' speed and accuracy of reading data from graphs where functions were labelled directly, with labels below the function line but within the graphic presentation, and with labels presented in the general area of the graph heading. They found accuracy to be the greatest for those graphs which were directly labelled.

Peterson, Becky K. (1983) "Tables and graphs improve reader performance and reader reaction."
Journal of Business Communication, 20: 47-55.

Peterson studied the relationship between the method of statistical presentation and the retention and reading time of the material. Based on his observation of 625 business students, Peterson concluded that retention and reading time for narrative with accompanying tables is significantly better than that for narrative alone. He also noted that retention for narrative with associated tables and graphs was lower than that for narrative with tables or narrative with graphs.

Peterson, L. V. and W. Schramm (1954) "How accurately are different kinds of graphs read."
AV Communication Review, 2: 178-189.

The authors found the circle graph to be most accurate when used to compare parts of a whole. They also noted that when subjects were required to compare parts to a whole, they tended to underestimate the larger parts while overestimating some of the smaller parts.

Schutz, Howard G. (1961a) "An evaluation of formats for graphic trend displays."
Human Factors, 3: 99-107.

Schutz compared the use of line, vertical bar, and horizontal bar graphs in three different sizes. He also studied their use when irrelevant points were added or essential information was deleted from these graphs. In his experiment, Schutz tested ten professional level employees on their time and accuracy in using these graphs. Based on his observations, he concluded that under the experimental conditions, the use of line graphs was superior to both the vertical and horizontal bar graphs. However, as the number of missing points increased, the difference between the graphs decreased.

Schutz, Howard G. (1961b) "An evaluation of methods for presentation of graphic multiple trends."
Human Factors, 3: 108-119.

Schutz continued his experiments involving the use of line, vertical bar, and horizontal bar graphs. In this experiment, Schutz compared their use in presenting multiple trend information under the same experimental conditions imposed above. For comparisons of information, Schutz preferred the line graph. He also noted that the use of color improves point reading performance only slightly.

Tinker, Miles A. (1960) "Legibility of mathematical tables"
Journal of Applied Psychology, 44: 83-87.

Tinker's study involving 120 college students sought to determine

the readability of tables where changes were made in type face and size as well as changes in column and row arrangements. He observed that, with the exception of type face, the changes did affect on the readability of the table. He then provided some recommendations for the presentation of mathematical tables in text.

Vernon, Magdalen D. (1953b) "Presenting information in diagrams."
AV Communication Review, 1: 147-158.

Vernon suggested that diagrams alone did not improve understanding and should be supported with verbal narrative. She believed that although diagrams may generate more student interest, tables are a better method of presenting factual data.

Vernon, Magdalen D. (1950) "The visual presentation of factual data."
British Journal of Educational Psychology, 20: 174-185.

Except for using grammar school children instead of adults as subjects, this study is similar to Vernon's 1946 study. Again, using graphs to present data did not improve comprehension of that data. According to Vernon, only words can directly express relationships and reasons.

Vernon, Magdalen D. (1946) "Learning from graphical material."
British Journal of Psychology, 36: 145-158.

After observing that graphs were ineffective in aiding the reading comprehension of many of her subjects, Vernon suggested that individuals need the knowledge and the skills to use graphs effectively. According to Vernon, many individuals lack this skill. She suggested that traditional education presented relationships and meanings in verbal format and that few students were taught to properly assess graphically presented information.

Von Huhn, G. and Frederick E. Croxton (1927) "Further studies in graphic use of circles and bars."
Journal of the American Statistical Association, 22: 31-36.

Von Huhn discussed and critiqued the experiments of Walter Eells. He cited the limitations in Eells' study due to his one-sided treatment of the experimental setting. Croxton compared Eells' study to his own studies which showed that performance on bar graphs was generally superior to that for circle graphs.

Weintraub, Samuel (1967) "What research says to the reading teacher: Reading graphs, charts, and diagrams."
Reading Teacher, 20: 345-349.

Weintraub reviewed and summarized the research on the reading of graphs and diagrams. He found that the research on reading diagrams was less extensive than that for reading graphs and cited the importance of the teacher in the development of graph-reading abilities.

Typography

Blaiwes, Arthur S. (1974) "Formats for presenting procedural instructions."
Journal of Applied Psychology, 59: 683-686.

Blaiwes observed no significant differences in the performance of 38 college students who were required to use either logical trees, coding, or short sentences to perform a series of instructions on a simulated communications console. Blaiwes recommended the use of short sentences when memorization is required.

Bostian, Lloyd R. (1976) "Effect of line width on reading speed and comprehension."
Journalism Quarterly, 53: 328-330.

In comparing one- and two-column formats, Bostian discovered that reading speed and comprehension were increased in the single column format with a 30-pica line length. He suggested that the improved performance was due to the increased white space in the format and

recommended the use of single column formats if adequate white space could be provided.

Burnhill, Peter (1970) "Typographic education: headings in text."
Journal of Typographic Research, 4: 353-365.

Burnhill's article addresses the use of spacing before and after paragraphs and presents the results of a study to determine a mathematical basis for grouping linguistic elements.

Burt, Cyril, W. F. Cooper, and J. L. Morton (1955) "A psychological study of typography."
British Journal of Statistical Psychology, 8: 29-57.

Burt and his colleagues conducted their experiments to determine the effects of type face, type size, contrast, spacing, line length, and margin width on reading speed and comprehension. They found that each of these factors interact to produce variations in reading speed and comprehension.

Carver, Ronald P. (1970) "Effect of a "chunked" typography on reading rate and comprehension."
Journal of Applied Psychology, 54 (3): 288-296.

Carver conducted his study to determine the effect of "chunking" meaningfully related groups of words on reading efficiency. Based on his observation of 104 college students, Carver concluded that the grouping of meaningfully related passages has no effect on reading efficiency if the individual is reading at a normal level.

Christensen, C. M. and K. E. Stordahl (1955) "The effect of organizational aids on comprehension and retention."
Journal of Educational Psychology, 46: 65-74.

Christensen and Stordahl compared the comprehension of text with organizational aids (headings, underlinings, outlining, summary) to text without these aids. They found no significant differences in comprehension.

Coffey, J. L. (1961) "A comparison of vertical and horizontal arrangements of alpha-numeric material- Experiment 1."
Human Factors, 3: 93-98.

Coffey experimented with horizontal and vertical presentations of alpha-numeric material to determine which format would enhance reading speed and accuracy. Based on his results, Coffey concluded that the advantages of displaying this information horizontally rather than vertically, and vice versa, were insignificant.

Coleman, Edmund B. and S. C. Hahn (1966) "Failure to improve the readability with a vertical typography."
Journal of Applied Psychology, 50: 434-436.

Coleman and Hahn conducted a series of three experiments with elementary school children to compare the effectiveness of using vertical typography with the use of the conventional horizontal typography. In these experiments, reading accuracy with horizontal (conventional) typography was clearly superior to that of vertical typography, even in the experiments using the tachistoscope.

Coleman, Edmund B. and Insup Kim (1961) "Comparison of several styles of typography in English."
Journal of Applied Psychology, 45: 262-267.

In this experiment, Coleman and Kim studied the use of different typographic styles: vertical, horizontal, spaced units (the separation of meaningful segments of horizontally presented prose through the use of spacing), and the square pan (which incorporates the use of horizontally spaced units and vertical typography). Using 267 undergraduate students as subjects, Coleman and Kim discovered that the use of horizontal typography had a slight, insignificant advantage over the other types studied when conventional testing techniques were used. Yet, when a tachistoscope was used, spaced units, square pan, and, in particular, vertical typography were all significantly more effective than horizontal typography.

Crossland, H. R. and G. Johnson (1928) "The range of apprehension as affected by inter-letter hair-spacing and by the characteristics of the individual letters."

Journal of Applied Psychology, 12: 82-124.

Crossland and Johnson studied the effects of inter-letter spacing and letter shapes on legibility. They found that the use of inter-letter spacing had little effect on the legibility of the letters.

Cutler, T. H. (1930) "The effectiveness of page size in magazine advertising."

Journal of Applied Psychology, 14: 465-469.

Cutler concluded that increasing the page size of an advertisement did not improve the retention or attraction of that advertisement over similar advertisements in a smaller size.

Davenport, John S. and Stewart A. Smith (1965) "Effects of hyphenation, justification, and type size on readability."

Journalism Quarterly, 42: 382-389.

Davenport and Smith discovered that the use of hyphenation, justification, and type size had no significant effect on newspaper readability under the experimental limitations presented in the article. They suggested, however, that increased exposure to the use of these factors or the reader's proficiency in the subject area could affect the results of this study.

Frase, Lawrence T. and Barry J. Schwartz (1979) "Typographical cues that facilitate comprehension."

Journal of Educational Psychology, 71 (2): 197-206.

Frase and Schwarz cited segmentation cues, or those devices which alert the reader to meaningful passages of prose, and spatial cues which are used to separate text as two typographical factors influencing comprehension. They observed that line length and margin neatness have no influence on reading efficiency or comprehension. Frase and Schwartz suggested that the most critical factor in reading comprehension was the use of meaningfully segmented material and recommended the use of indentation to increase reading performance.

Glynn, Shawn M. (1978) "Capturing readers' attention by means of typographical cueing strategies."
Educational Technology, 18: 7-12.

Glynn's study focuses on the nonverbal means of cueing the reader's attention to certain decision or learning criteria. In particular, her article highlights the use of underlining strategies to cue attention.

Gregory, Margaret and E. C. Poulton (1970) "Even versus uneven right-hand margins and rate of comprehension in reading."
Ergonomics, 13: 427-434.

Gregory and Poulton's experiments on adult readers focused on reading comprehension and its relationship to justified and unjustified text. Although no differences were noted between reading comprehension for long, justified passages and short, unjustified passages, Gregory and Poulton concluded that the use of justification on short passages tends to make reading less efficient.

Hartley, James (1981) "Eighty ways of improving instructional text."
IEEE Transactions on Professional Communication, P-C 24, 1: 17-27.

This article, presents some suggestions for the improvement of instructional material. It provides a series of guidelines on the use of prose materials, graphic materials, and the various typographical devices commonly used in printing. The article incorporates many of Hartley guidelines so that the reader may compare his style against that of other articles in the journal.

Hartley, James and Mark Trueman (1981). "The effects of changes in layout and changes in wording on preferences for instructional text."
Visible Language, 15: 13-31.

Hartley and Trueman presented 100 university students with combinations of original and revised layouts and original and revised text. Combinations with changes in both layout and text were found to be superior to those combinations where either layout or text were changed.

Hartley, James, Sally Bartlett, and A. Branthwaite (1980a) "Underlining can make a difference- sometimes."
Journal of Educational Research, 73: 218-224.

The authors reviewed previous studies involving the use of underlining and present the results of their study conducted using 55 sixth grade children. They discovered that the children experienced a significant increase in the retention of underlined material for periods up to seven days.

Hartley, James, Jillian Kenely, Gwenda Owen, and Mark Trueman (1980b).
"The effect of headings on children's recall of prose text."
British Journal of Educational Psychology, 50: 304-307.

Results of this study involving 175 children revealed that paragraphs with headings were more effective than those passages presented without headings or presented with title only. Paragraphs with headings were shown to have significantly affected both immediate and long-term (14 day) recall.

Hartley, James (1980) "Spatial cues in text."
Visible Language, 14: 62-79.

Hartley reviewed the work of Frase and Schwartz and evaluated their method of experimental methodology. Using two different methodologies in his experiment, Hartley observed that spacing, although not verified statistically, did have some effect on comprehension and recall of prose. He emphasized that content and purpose must be considered along with design when preparing text.

Hartley, James and Peter Burnhill (1978) "Fifty guidelines for Improving Instructional text." Contributions to an Educational Technology, Vol. 2., edited by J. Hartley and I. K. Davies. New York NY: Nichols Publishing Co.

Hartley and Burnhill present fifty guidelines based on their research in color and typography. Included in the article are guidelines on type style, type size, spacing, highlighting, and color.

Hartley, James, Peter Burnhill, and Lindsey Davies (1978) "The effects of line-length and paragraph denotation on the retrieval of information from prose text."

Visible Language, 12: 183-184.

Five hundred grade school children were presented with example of one- and two-column pages with one of four paragraph denotation techniques: no spacing and no indentation, indentation but no spacing, spacing but no indentation, spacing and indentation. Hartley et al. found no significant difference in reading performance between one- and two-column formats. They also concluded that formats using paragraph indentation but no line spacing did not yield significantly different results from those formats using line spacing but no indentation. Both formats were superior to a format with no spacing and no indentation.

Hartley, James, Susan Fraser, and Peter Burnhill (1974) "A selected bibliography of typographic research relevant to the production of instructional materials."

AV Communication Review, 22: 181.

Hartley, Fraser, and Burnhill categorized their bibliographic entries into the six major areas: basic texts, general overview articles, bibliographies, fifteen research categories, measurement and methodological problems, and standards and print production.

Hartley, James and Peter Burnhill (1971) "Experiments with unjustified text."

Visible Language, 5: 265-278.

Hartley and Burnhill conducted a series of three experiments involving unjustified line endings based on grammatical constraints and hyphenation as well as the use of double column pages with differing column widths. Their findings lead them to conclude that line length does not affect reading speed or comprehension. In fact, Hartley and Burnhill found that their subjects preferred shorter, more uneven lines.

Haskins, J. B. and L. P. Flynn (1974) "Effect of headline typeface variation on reading interest."
Journalism Quarterly, 51: 677-682.

The authors discuss their research on the use of masculine and feminine headline typefaces on reader interest. They discovered no differences between these typefaces on reader interest.

Hershberger, Wayne A. and Donald F. Terry (1965) "Typographical cueing in conventional and programmed text."
Journal of Applied Psychology, 49: 55-60.

Among the objectives of their study was the comparison of complex versus simple cueing techniques. Simple cueing consisted of separating core material from enrichment material through the use of colored ink. Complex cueing involved the use of underlining in addition to different type sizes and ink colors to separate each of the four categories of core material from each other and from the enrichment material. Hershberger and Terry concluded that while the use of simple cueing resulted in improved learning ability, the use of complex cueing offered no significant advantages over the use of simple cueing.

Hovde, Howard T. (1930) "The relative effects of size of type, leading and context, Part II."
Journal of Applied Psychology, 14: 63-73.

A continuation of Part I, Hovde's research findings suggest that context is more important in determining legibility than the sensory content of type. Because these typographical factors appear to be secondary to context in determining legibility, Hovde makes no recommendations concerning type size or leading.

Hovde, Howard T. (1929) "The relative effects of size of type, leading and context, Part I."
Journal of Applied Psychology, 13: 600-629.

Hovde begins by reviewing some historical notes on research in legibility. His study compares changes in type, leading, and context on reading speed and reader preference.

Hvistendahl, J. K. (1968) "The effects of subheads on reader comprehension."
Journalism Quarterly, 45: 123-125.

Hvistendahl studied the use of subheads to determine if they had an effect on recall or merely provided the reader with a mental pause in the processing of text. In one experiment where the subhead and the text contained contradictory information, he observed that less than one-half of the subjects noted the error. His overall conclusion is that the use of subheads does not improve recall.

Klare, George R., James E. Mabry, and Levarl M. Gustafson (1955) "The relationship of patterning (underlining) to immediate retention and to acceptability of technical material."
Journal of Applied Psychology, 39: 40-42.

Klare and his fellow researchers conducted this experiment to study the relationship between patterning, underlining in this case, and reading speed, acceptability, and retention of a 1206-word technical lesson on aircraft maintenance. They found that for able readers, those capable of understanding the rationale for underlining certain passages, retention was improved. For less able readers, the process of underlining actually hindered retention because the readers were not familiar with the rationale behind underlining. Reading speed and acceptability of the material were not affected by the underlining process.

Luckiesh, M. and Moss, F. K. (1941). "The effect of line length on readability." Journal of Applied Psychology, 25: 67-75.

Luckiesh and Moss compare five different line lengths and find the 13 pica length superior to the others studied. This line length is comparable to the line length commonly used in newspapers.

Luckiesh, M. and Moss, F. K. (1938) "Effects of leading on readability." Journal of Applied Psychology, 22: 140-160.

Using various degrees of leading in their experiments, Luckiesh and Moss show that readability increases when leading is used. They suggest that 3-point leading appears to be optimal for readability.

Nahinsky, Irwin D. (1956) "The influence of certain typographical arrangements upon span of visual comprehension." Journal of Applied Psychology, 40: 37-39.

This study compares comprehension spans for three different typographical arrangements: conventional, square pan, and spaced unit. Nahinsky concluded that the vertical visual span of the square pan type appeared to be the distinguishing factor in the increased comprehension noted when this type was used.

Paterson, Donald G. and Miles A. Tinker (1932) "Studies of typographical factors influencing speed of reading: VIII. Space between lines or leading." Journal of Applied Psychology, 16: 388-397.

Paterson and Tinker studied the use of leading, or the spacing between lines, and its effect on reading speed. Using a 10-point type size and an 80-mm. line length, they noted that the passages with 2- and 4-point leading were read faster than passages in solid set text (no leading).

Poulton, E. C. (1972) "Size, style, and vertical spacing on the legibility of small typefaces."
Journal of Applied Psychology, 56: 156-161.

In this experiment, Poulton used a 6.6-point type size and applied it to different type faces to determine those combinations which are most legible. The 6.6-point type size used by Poulton was found to be the optimal size for legibility in his previous experiments. Based on his findings, Poulton makes some recommendations on the proper type size for each type face tested.

Poulton, E. C. (1969) "Skimming lists of food ingredients printed in different sizes."
Journal of Applied Psychology, 53: 55-58 (1969).

Poulton observed the ability of 72 housewives to search lists of ingredients for a target word when type size and lighting conditions are varied. Poulton concluded that the increased age of the subjects, which ranged from 22 to 65, was a significant factor in the results.

Poulton, E. C. (1969) "Skimming lists of food ingredients printed in different brightness contrasts."
Journal of Applied Psychology, 53: 498-500.

In a continuation of his experiments with housewives, Poulton compared inks of varying density to determine the effects of brightness contrast on list searching ability. Poulton used a different set of housewives, ranging between 29 and 72 years of age, for this particular experiment. He concluded that ink densities producing the brightest contrast between print and background improved reading speed and accuracy.

Rickards, John P. and Gerald J. August (1975) "Generative underlining strategies in prose recall."
Journal of Educational Psychology, 67: 860.

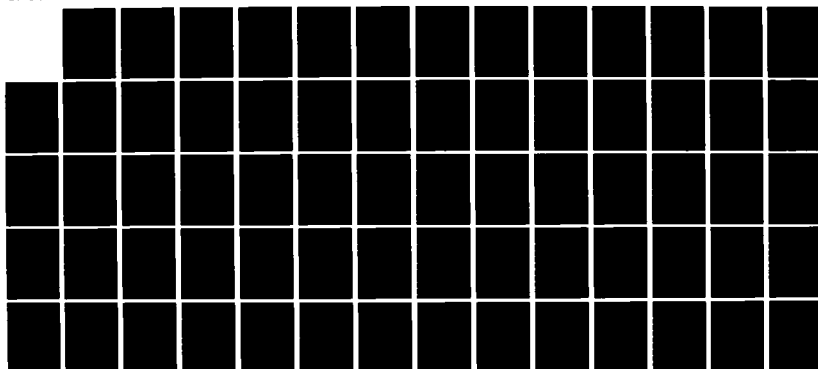
Rickard and August's study compares the use of experimenter versus subject generated underlining. Subjects who were allowed to underline any one passage in the paragraph retained that information and

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A SYNTHESIS OF RESEARCH ON COLOR TYPOGRAPHY AND
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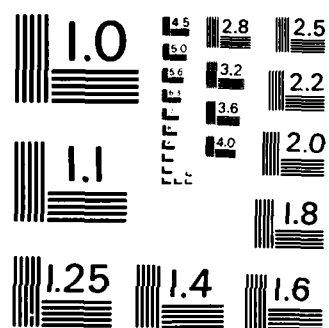
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MICROCOPY RESOLUTION TEST CHART
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associated material better than those subjects required to underline only the most important passage in the paragraph.

Robinson, David O., Michael Abbamonte, and Selby H. Evans (1971) "Why serifs are important; the perception of small print."
Visible Language, 5: 353-359.

The researchers propose a physiological model to explain the continued preference for serif-form letters over sans-serif letters. They also discuss the results of a study that compared serif versus sans-serif letters using a computer simulation of the human visual processing system.

Siskind, Theresa G. (1979) "The effect of newspaper design on reader preferences."
Journalism Quarterly, 56: 54-61.

Siskind discusses reader acceptance of four different formats involving traditional and modern layouts. He found no preference for modern over traditional formats.

Smith, John M. and Maxwell E. McCombs (1971) "The graphics of prose."
Journalism Quarterly, 48: 134-136.

This study focused on the use of white space on reader interest and comprehension. Specifically, Smith and McCombs compared reader performance on text using little white space and text with larger amounts of white space. They concluded that while white space improved reader interest, it did not improve reader comprehension.

Soar, Robert S. (1951) "Readability of typography in psychological journals."
Journal of Applied Psychology, 35: 64-67.

Soar studied 72 undergraduate students under 12 experimental conditions to determine the effect of height-width proportionality and stroke on numeral visibility. Soar's recommendation for the most visible

height-width ration was 10 : 7.5. He found no significant relationship between height-width and stroke on the visibility of numerals.

Tinker, Miles A. (1966) "Experimental studies on the legibility of print- an annotated bibliography."
Reading Research Quarterly, 1: 68-118.

Tinker reviews research on print legibility and provides a summary of the literature following each area of interest.

Tinker, Miles A. (1963) Legibility of Print. Ames IA: Iowa State University Press.

Tinker's book brings together the research that has been conducted in the field of legibility, including Tinker's series of experiments with Dr. Donald Paterson. An annotated bibliography is also contained within the book.

Tinker, Miles A. (1932) "The influence of form of type on the perception of words."
Journal of Applied Psychology, 16: 167-174.

Tinker's experiments compare the use of all lower-case letters to all capital letters. Results reveal that lower-case letters are read faster than capital letters and that readers prefer lower-case letters to capital letters.

Tinker, Miles A. and Donald G. Paterson (1932) "Studies of typographical factors influencing speed of reading: IX. Reduction in size of newspaper print."
Journal of Applied Psychology, 16: 525-531.

The purpose of this experiment was to compare the speed of reading type face at normal page size to reading speed when page size was reduced by 30, 50, and 80 percent. Results found that reading speed was not affected by page reductions of up to 50 percent.

Tinker, Miles A. and Donald G. Paterson (1932) "Studies of typographical factors influencing speed of reading: X. Style of type face." Journal of Applied Psychology, 16: 605-613.

In this study, Tinker and Paterson concluded that the 10 type faces in common use in printing were equally legible. They expressed concern about comparisons of type face without consideration for size, line length, leading, and other typographical factors.

Tinker, Miles A. and Donald G. Paterson (1931a) "Studies of typographical factors influencing speed of reading: V. Simultaneous variation of type size and line length." Journal of Applied Psychology, 15: 72-78.

Tinker and Paterson combined the factors used in their first two experiments on type size and line length and simultaneously change them for this study. Results from the observation of 400 college students show that adjustment in both type size and line length is necessary to bring about an optimal arrangement for maximum reading speed.

Tinker, Miles A. and Donald G. Paterson (1929a) "Studies of typographical factors influencing speed of reading: II. Size of Type." Journal of Applied Psychology, 13: 120-130.

This experiment is part of a series of experiments conducted by Tinker and Paterson on the effect of various typographical factors on reading speed. In addition to presenting their findings for this study, Tinker and Paterson critique the methodology used in previous type size experiments. Results from experiments using an 80-mm. line length show that the 10-point type size yields a faster reading speed than any other type size studied.

Tinker, Miles A. and Donald G. Paterson (1929b) "Studies of typographical factors influencing speed of reading: III. Length of line." Journal of Applied Psychology, 13: 205-219.

In an experiment similar to the previous study on type size, Tinker and Paterson found that the desired line length for a 10-point type size is between 75- and 90-mm., with 80 mm. being the optimum line length.

Tinker, Miles A. (1928) "Numerals versus words for efficiency in reading."
Journal of Applied Psychology, 12: 190-199.

In this study, Tinker compares reading speeds for numbers presented in either numerical form or written in text. Results from his study lead to the recommendation that numerals be presented in Arabic form for more compactness in printing and increased reading speed.

Tinker, Miles A. and Donald G. Paterson (1928) "Influence of type form on speed of reading."
Journal of Applied Psychology, 12: 359-368.

This study compared the reading speeds for individuals using text printed in either all lower-case, all capital, or all italic letters. According to the results of the study, the reading speed for lower-case letters was significantly faster than that for all capital letters. However, the reading speed for italics was only slightly less than that for lower case letters.

Wendt, Dirk and Hans Werckerle (1972) "On effects of indentation and underlining in reference work."
Visible Language, 6: 167-171.

Wendt and Werckerle explored the theory that indentation and underlining helped isolate key words, thus making them easier to recognize. Using 252 10-12 year olds in their research, they discovered that indentation does indeed make reference work faster. However, they also concluded that underlining had no effect on isolating or making words recognizable.

Wiggins, Richard H. (1967) "Effects of three typographical variables on speed of reading."
Journal of Typographic Research, 1: 5-18.

Wiggins' article discusses early typographical research and presents the results of his research on line length and margins.

Wright, Patricia (1977) "Presenting technical information: A survey of research findings."
Instructional Science, 6: 93-134.

Wright presents an extensive review of research findings in subjects dealing with headings, tables and graphs, illustrations, format, and word choice.

Illustrations/Pictures

Bernard, Robert M., Chris H. Peterson, and Mohamed Ally (1981) "Can images provide contextual support for prose?"
Educational Communication and Technology, 29: 101-108.

In their study, Bernard et al. presented contextual organizers, either pictorial and verbal, to the experimental groups while the control groups received neither organizers or illustrations. An analysis of the responses from the 104 undergraduate students concluded that the use of contextual organizers did result in increased recall of the material presented. However, no significant differences were noted between the use of verbal and pictorial organizers.

Bradford, Annette N. and David B. Bradford (1983) "Practical and empirical knowledge of photo-illustrations: what is and is not known."
Journal of Technical Writing and Communication, 13: 259-268.

Bradford and Bradford concluded that the use and layout of photo-illustrations was dictated more by tradition than by empirical research. Their article provides a summary of empirical research on photo-illustrations and presents 11 guidelines for the use of photo-illustrations.

Brody, Phillip J. (1982) "Affecting instructional textbooks through pictures." The Technology of Text: Principles for Structuring, Designing, and Displaying Text, edited by D. H. Jonassen. Englewood Cliffs, NJ: Educational Technology Publications.

Brody's article reviews the manner by which text is affected by illustration and provides guidelines for the use of pictures in textbooks. Brody concluded that illustrations have significant potential for the improvement of learning through reading.

Brown, Maurice A. (1978) "Graphic aids in reporting technical information." Journal of Technical Writing and Communication, 8: 237-241.

Brown describes the use of graphic aids in communicating facts and ideas. Graphics, according to Brown, should be simple, clearly designed, and supported by textual information.

Clark, Herbert H. and William G. Chase (1972) "On the process of comparing sentences against pictures." Cognitive Psychology, 21: 472-517.

Clark and Chase proposed a theory for the process involved in comparing sentences against pictures, and they test this theory in four separate experiments. Although previous theory stated that individuals had separate verbal and perceptual encoding systems, the results of this study did not support that view. Instead, Clark and Chase proposed that individuals possessed a common "interpretive" system that handled data regardless of the source of that data.

Cohen, Peter A., Barbara J. Ebeling, and James A. Kulik (1981) "A meta-analysis of outcome studies on visual-based instruction." Educational Communication and Technology, 29: 26-36.

Cohen et al. conducted a meta-analysis of 74 studies involving visual-based undergraduate instructional media to include filmstrip,

video-tape, and television. They found no significant differences in attitudes, achievement, or course completion among the students.

Corsini, David A., Kenneth A. Jacobus, and S. David Leonard (1969)
"Recognition memory of preschool children for pictures and words."
Psychonomic Science, 16: 192-193.

In their memory studies involving 40 preschool children, Corsini et al. observed that preschoolers retained pictures better than words. However, they caution that the ability to translate those images to words may become degraded as conditions change.

Coulter, Russel G., Marcie L. Coulter, and John A. Glover (1984) "Details and picture recall."
Bulletin of the Psychonomic Society, 22: 327-329.

These researchers studied 75 undergraduate students to determine if the amount of picture recall was inversely proportional to the amount of detail in the photograph. They concluded that recall for outline only illustrations was better than that for name only labels and detailed drawings, though only slightly better when compared to the latter.

Curren, Thomas E. (1977) Survey of technical manual readability and comprehensibility (Technical Report No. NPRDC-TR-77-37). Navy Personnel Research and Development Center, San Diego CA.

Curren presented a review of problems in technical manual readability and recommended some methods to address these problems, including the comprehensibility of graphics presentations.

Cury, Robert (1979) "Visual graphic aids for the technical report."
Journal of Technical Writing and Communication, 9: 287-291.

Besides presenting facts and figures in a condensed and summarized form, Cury concluded that graphics also provided the reader with a short mental pause from verbal processing.

Dallett, Kent and Sandra G. Wilcox (1968) "Remembering pictures versus remembering descriptions."
Psychonomic Science, 11: 139-140.

Dallett and Wilcox presented forty 100-word descriptions or a series of pictures to test the free recall, retention, and rate of forgetting of a group of undergraduate psychology students. Based on the results of their experiments, they concluded that free recall did improve in the group presented with the pictures. However, the retention and rate of forgetting for words and pictures were equal in most cases.

Denberg, Susan D. (1977) "The interaction of picture and print in reading instruction (abstracted report)."
Reading Research Quarterly, 12: 176-189.

Denberg suggested that beginning readers integrated the incomplete information provided by the text with the incomplete information provided by the picture. He further suggested that pictures increased the tendency of the reader to use the incomplete information provided by the prose rather than to ignore it.

Donald, D. R. (1983) "The use and value of illustrations as contextual information for readers at different progress and developmental levels."
British Journal of Educational Psychology, 53: 175-185.

Donald's study involved a comparison of the recall capabilities of a group of 120 students from grades 1 to 5 who were tasked with reading a 320-word passage either with or without illustrations. Donald's study concluded that while illustrations performed a significant role in the development of early reading skills for good readers, the effects of illustrations declined as the reading age increased. Results for poor readers were less conclusive than those for good readers, although illustrations were considered to have some effect on reading behaviors.

Duchastel, Phillipe (1978) "Illustrating instructional texts."
Educational Technology, 18: 36-39.

Duchastel reviewed the attentional, explicative, and retentional roles of illustrations in text. He emphasized the need for the educational

technologist to develop a strategy for using illustrations in their proper context and to coordinate this effort more closely with the graphics designer.

Dwyer, Francis M. Jr. (1970) "Exploratory studies in the effectiveness of visual illustrations." AV Communication Review, 18: 235-248.

Dwyer conducted this study to determine the effectiveness of slides, television, and programmed instruction as teaching tools. While Dwyer concluded that color visuals may enhance the learning of specific objectives at specific grade levels, his overall finding was that the use of visuals did not automatically improve learning achievement.

Dwyer, Francis M. (1967) "Adapting visual illustrations for effective learning." Harvard Educational Review, 37: 250-263.

In his experiment, Dwyer presented 108 college freshmen with descriptions of the human heart using either narrative only or narrative with one of three types of illustrations. He then tested the students on their ability to locate various parts of the heart and their knowledge of medical terminology and the functions of the heart. Based on his observations, Dwyer concluded that the abstract linear (simple) drawing was more effective in learning enhancement than either the shaded, detailed illustration or the photograph. The oral description, however, was superior to all three illustrations when learning of terms or the development of new views of the material was required.

Friedman, Alinda and Lyle E. Bourne (1976) "Encoding the levels of information in pictures and words." Journal of Experimental Psychology: General, 105: 169-190.

Although pictures yield faster inferences than words when both require the same semantic information, Friedman and Bourne found no differential access to memory representations between pictures and words. Friedman and Bourne did suggest that pictures have a head start in the encoding process since they are more distinguishable from one another than are words.

Haring, Marilyn J. (1982) "Picture enrichment of delayed recall: Support from a unique source."

British Journal of Educational Psychology, 52: 104-108.

Haring's study tasked 100 elementary school students with reading a 360-word essay that contained illustrations for the experimental group and text only for the control group. Based on experimental results, Haring concluded that pictures do have a significant effect on the recall of details even after a delay in testing.

Haring, Marilyn J. and Maurine A. Fry (1979) "Effect of pictures on children's comprehension of written text."

Educational Communication and Technology Journal, 27: 185-190.

Haring and Fry reported that pictures did enhance recall of the main ideas in passages read by grade school children and that this effect was relatively long-term in nature. They also suggested that pictures did not have to be detailed to induce this effect.

Katz, Elihu, Hanna Adoni, and Pnina Parness (1977) "Remembering the news: what the picture adds to recall."

Journalism Quarterly, 54: 231-239.

While concluding that pictures did not detract from the retention or comprehension of the news, the researchers found no evidence to support a conclusion that pictures enhanced comprehension.

King, William A. (1975) A comparison of three combinations of text and graphics for concept learning (Technical Report No. NPRDC-TR-76-16).

Navy Personnel Research and Development Center, San Diego CA.

King discussed his research involving the use of animated graphics, still graphics, and text only. King concluded that his research was consistent with other research which found that graphics are useful for identification rather than comprehension.

Koenke, Karl R. and Wayne Otto (1969) "Contribution of pictures to children's comprehension of the main idea in reading."
Psychology in the Schools, 6: 298-302.

Pictures, while aiding students in the retention of specific facts, do not increase the child's general knowledge of the concept. This was the conclusion of Koenke and Otto's study which involved the presentation of three different 198 word passages to the 180 third and sixth grade students involved in the experiment.

Kunen, Seth and Duncan, Edward M. (1983) "Do verbal descriptions facilitate visual inferences?"
Journal of Educational Research, 76: 370-373.

The authors concluded that subjects who visually inspected the pictures and generated a verbal description of that picture were more likely to recognize that picture up to a week later.

Levie, W. Howard and Richard Lentz (1982) "The effects of text illustrations: a review of the literature."
Educational Communication and Technology, 30: 195-232

In their article, Levie and Lentz reviewed 55 research studies that involved comparisons between reading performance using illustrated text and text alone. Based on their review, Levie and Lentz propose nine basic guidelines for using illustrations in text.

Lupker, Stephen J. and Albert N. Katz (1982) "Can automatic picture processing influence word judgements?"
Journal of Experimental Psychology: Learning, Memory, and Cognition, 8: 418-434.

Lupker and Katz demonstrated that pictures can have a positive influence on word processing in some situations while interfering with that process in situations where the picture is incompatible with the text.

Miller William (1938) "Reading with and without pictures."
Elementary School Journal, 38: 676-682

Miller's study involved the presentation of illustrated and nonillustrated text to 600 elementary school students. Test results indicated that performance of students using only verbal information was equal to that of students using text with illustrations. Miller concluded that the use of illustrations, while possibly possessing some interest value, may not be necessary as a teaching tool for reading comprehension.

Mueller, G. A. (1979) The effects of a contextual visual on recall measures of listening comprehension in beginning college German. Unpublished masters thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base OH.

Mueller concluded that visuals enhance listening comprehension depending upon the proficiency of the individual in the subject area.

Nelson, Thomas. O., Jacqueline Metzler, and David A. Reed (1974) "Role of details in the long-term recognition of pictures and verbal descriptions." Journal of Experimental Psychology, 102: 184-186.

Nelson et al. conducted their study to determine the effect of extra detail on long-term memory. The researchers presented a group of 136 undergraduate students with text that included verbal description, unadorned line drawings, detailed line drawings, or photographs. Results indicated that students presented with pictorial representations had a higher recognition rate than those presented with verbal descriptions only. However, no significant difference was noted in recognition between the pictorial representations.

Nickerson, Raymond S. (1968) "A note on long-term recognition memory for pictorial material." Psychonomic Science, 11: 58.

Nickerson extended his previous study to account for periods of up to one year and discovered that pictures, even when briefly presented, did

have a significant potential for improving retention of the pictorially presented information.

Nickerson, Raymond S. (1965) "Short-term memory for complex meaningful visual configurations: a demonstration of capacity "
Canadian Journal of Psychology, 19: 155-160.

Subjects were presented a series of photographs and were required to identify those photographs appearing more than once in a demonstration of capacity rather than an explanation of the process. Nickerson discovered that individuals could identify identical photographs even when as many as 200 other photographs appeared between them.

Niekamp, Walter (1981) "An exploratory investigation in factors affecting visual balance."
Educational Communication and Technology, 29: 37-48.

Niekamp begins his article by reviewing previous visual studies on position, form, size, and tone. There was substantial indication that individuals give images appearing in the upper half of the visual field more weight than those appearing in the lower half. However, no evidence was discovered which would give either the right or left visual fields dominance over the other.

Paivio, Allan, T. B. Rogers and Padric C. Smythe (1966) "Why are pictures easier to recall than words?"
Psychonomic Science, 11: 137-138.

This study required the undergraduate students involved to observe either pictures or their noun labels in color or black and white. Results from memory tests indicated that pictures were more easily retrieved from both short- and long-term memory than were their noun counterparts. No differences were noted between the use of color and the use of black and white.

Paivio, Allan and Dan A. Yarmey (1966) "Pictures versus words in stimuli and responses in paired-associate learning."
Psychonomic Science, 5: 235-236.

Based on the observations of 84 undergraduate students, Paivio and Yarmey concluded that the use of pictures to stimulate recall proved superior to the use of words

Peeck, J. (1974) "Retention of pictorial and verbal content of a text with illustrations."
Journal of Educational Psychology, 66: 880-888.

Students using illustrated text were found to have higher retention rates for that information presented in illustrations when compared to students using text alone. However, for information presented in text only to both groups, no significant differences in retention were noted.

Powell, Arnold, and Rena Wynn (1976) "Memory span, organization, and transformations in recall of pictures and words."
Psychological Reports, 39: 395-399.

In their experiments, Powell and Wynn concluded that paragraph comprehension was more closely associated with picture memory while the immediate memory span was more closely associated with words. They presented a case for the dual processing of pictures. That is, pictures are processed both verbally and through imagery.

Powell, Arnold, James Havnaer, and Wendall Wiggins (1972) "Organization and recall of pictures and words in children."
Psychonomic Science, 29: 385-387.

Subjects reading paragraphs with pictures scored higher in recall and clustering than those subjects reading text alone. Powell et al. concluded from their experiments that pictorial stimuli are less influenced by the encoding process than words.

Rigney, Joseph W. and Kathy A. Lutz (1976) "Effect of graphic analogies of concepts in chemistry on learning and attitude."
Journal of Educational Psychology, 68: 305-311.

The use of graphics to supplement the verbal text resulted in an improvement in student learning and attitude.

Rudisill, Mabel F. (1952) "Children's preferences for color versus other qualities in illustrations."
Elementary School Journal, 52: 444-451.

If elementary school students are presented with pictures of identical content, the students will prefer the pictures presented in color. However, if the black and white picture appears to be more realistic than the color picture, the student will prefer the former. Rudisill concluded that children, when choosing between these factors, prefer realism over color in pictures.

Ryan, T. A. and Schwartz, C. B. (1956) "Speed of perception as a function of mode of representation."
American Journal of Psychology, 69: 60-69.

Ryan and Schwartz conducted a study on the speed of perception as it relates to illustrations presented as either photographs, shaded drawings, line drawings, or cartoons. Study results show that line drawings required the longest processing time for perception while cartoons required the least. No significant differences in processing times were found for photographs and shaded drawings.

Samuels, S. Jay (1970) "Effects of pictures on learning to read, comprehension and attitudes."
Review of Educational Research, 40: 397-407.

According to Samuels, illustrated text was no better than non-illustrated text in affecting reader comprehension and attitude. Samuels, in fact, suggested that the use of pictures may have actually hindered the reader.

Samuels, S. Jay (1967) "Attentional processes in reading: "The effects of pictures on the acquisition of reading responses."
Journal of Educational Psychology, 58: 337-342

Those subjects classified as poor readers were found to have learned more when pictures were not present. No differences were noted among the better readers. Samuels proposed that the use of pictures diverted the reader's attention from the information presented in the text.

Saunders, Robyn J. and Robert T. Solman (1984) "The effect of pictures on the acquisition of a small vocabulary of similar sight words."
British Journal of Educational Psychology, 54: 265.

The use of pictures did not aid the kindergarten students involved in this study in the acquisition of the vocabulary presented.

Shepard, Roger N. (1967) "Recognition memory for words, sentences, and pictures."
Journal of Verbal Learning and Verbal Behavior, 6: 156-163.

Shepard discovered that recognition memory for words, sentences, and pictures is substantially higher than previously reported. On recognition memory tests, subjects asked to identify pictures presented during sessions a week earlier performed as well as subjects who were asked to identify words or sentences that had been presented immediately prior to the test.

Spaulding, Seth (1956) "Communication potential of pictorial illustrations."
AV Communication Review, 4: 31-41.

In this study, Spaulding's research shows that illustrations which are not based on the reader's past experience have little educational value and may even be distracting to the reader.

Spaulding, Seth (1955) "Research on pictorial illustration."
AV Communication Review, 3: 35-45.

In his article, Spaulding reviews past literature on the size, type, and location of illustrations and presents eleven generalizations based on the literature. His major findings are that illustrations do aid the reader in understanding prose and that headlines are effective only if they add something to the text.

Standing, L., Bond, B., Hall, J., and Weller, J. (1972) "A bibliography of picture-memory studies."
Psychonomic Science, 29: 406-416.

Standing and his associates present a bibliography of 685 studies involving picture memory. This bibliography includes studies that involve pictures directly or involve the use of imagery, or the mental formation of images based upon verbal text.

Standing, Lionel, Jerry Conezio, and Ralph Haber (1970) "Perception and memory for pictures: Single trial learning of 2,500 visual stimuli."
Psychonomic Science, 19: 73-74.

Subjects in this study were presented with over 2500 pictures shown at intervals between five and ten seconds. These subjects were then tested for recall up to three days following the initial presentation. Based on their observations, the researchers concluded that the limits for picture memory were substantially higher than those for words.

Stone, David E. and Marvin D. Glock (1981) "How do young adults read directions with and without pictures?"
Journal of Educational Psychology, 73: 419-426.

In their study which had undergraduate students serving as experimental subjects, Stone and Glock discovered that the students who used illustrations produced more accurate performance than those students using text alone. Other experimental results suggested that the decision to use either narrative only or a narrative and illustration depended upon the type of information to be presented.

Stone, David E., C. K. Pine, G. R. Bieger, and Marvin D. Glock, M. D. (1981) Methodological issues in research on reading text with illustrations. New York State College of Agriculture and Life Sciences, Ithaca Department of Education.

Stone et al. reviewed past research on the impact of illustrations on reader comprehension. They also critiqued the methodologies used in prior research and discussed several theories of perception and comprehension.

Szabo, Michael, Francis M. Dwyer, Jr., and Hermes DeMelo (1981) "Visual testing- Visual literacy's second dimension." Educational Communication and Technology, 29: 177-187.

Szabo and his colleagues suggested that experiments involving visual instruction are better evaluated using visual methods. That is, students who are trained with the use of visuals should not be tested with written (narrative) tests. Their study indicated that the subjects in the visual learning-visual testing scored significantly higher in identifying details than did the control group.

Tversky, Barbara (1969) "Pictorial and verbal encoding in a short-term memory task." Perception and Psychophysics, 6: 225-233.

Tversky suggests that individuals are flexible in the method used to encode incoming information and that neither the verbal or pictorial processes are superior in all cases.

Vernon, Magdalen D. (1954) "The instruction of children by pictorial illustration." British Journal of Educational Psychology, 24: 171-179.

In this study, the subjects were asked to read either illustrated or non-illustrated text and were then tested on their comprehension of the material presented. No significant differences in comprehension were noted.

Vernon, Magdalen D. (1953a) "The value of pictorial illustrations."
British Journal of Educational Psychology, 23: 180-187.

Illustrations did not assist the students involved in this study in comprehending the text, although it did aid them in remembering the specific facts highlighted by the illustrations. In fact, Vernon suggested that the use of graphs may be superior to the use of illustrations when relationships and explanations are involved.

Weintraub, Samuel A. (1967) "Illustrations for beginning reading."
Reading Teacher, 20: 61-67.

After reviewing previous research on the use of illustrations in the instruction of beginning readers, Weintraub concluded that illustrations do serve a useful purpose and should not be entirely eliminated from early reading texts.

Related Readings

Color

- Carter, R. C. (1982) "Search time with a color display: Analysis of distribution functions."
Human Factors, 24: 203-212.
- Christ, R. E. (1975) "Review and analysis of color coding research for visual displays."
Human Factors, 17: 542-570.
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edited by J. Money. Baltimore, MD.: The John Hopkins Press.
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Sight-Saving Review, 8: 123-134.

MacLean, W. P. (1930) "A comparison of colored and uncolored pictures."
Educational Screen, 9: 196-199.

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Otto, W. (1967) "Color cues as an aid to good and poor readers' paired-associate learning."
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Schiller, G. (1935) "An experimental study of color and type in advertising."
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Proceedings of the Fourth International Conference on Information Systems. Chicago: Society of Information Management.

Graphs/Tables/Diagrams

Brinton, W. C. (1916) Graphic Methods of Presenting Facts. New York NY: Engineering Magazine.

Burnhill, Peter, James Hartley, and M. Young (1976) "Tables in Text."
Applied Ergonomics, 7: 13-18.

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AV Communication Review, 11: 32-39.
- Fienberg, S. G. (1979) "Graphical methods in statistics."
American Statistician, 33: 165-178.
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Perceptual and Motor Skills, 29: 320-322.
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Journal of Educational Psychology, 39: 27-34.
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Journal of Experimental Child Psychology, 20: 341-355.

Appendix: List of Journals Researched

Acta Ophthalmologica

African Social Research

Alberta Journal of Educational Research

American Journal of Psychology

American Psychological Association Experimental Publication System

American Psychologist

American Statistician

Applied Ergonomics

Archives of Psychology

AV Communication Review (preceded by Audio-Visual Communication Review, 1953-1963, and superseded by Educational Communication and Technology Journal, 1978-Current)

British Journal of Educational Psychology

British Journal of Statistical Psychology

Bulletin of the Psychonomic Society

Bulletin of the British Psychological Society

Canadian Journal of Psychology

Child Development

Cognitive Psychology

Decision Sciences

Developmental Psychology

Educational Communication and Technology Journal (preceded by
Audio-Visual Communication Review, 1953-1963, and AV
Communication Review, 1964-1978)

Educational Research Bulletin

Educational Screen

Educational Technology

Elementary English Review

Elementary School Journal

Ergonomics

Harvard Educational Review

Human Factors

IEEE Transactions on Professional Communication

Instructional Science

Journal of Applied Psychology

Journal of the American Statistical Association

Journal of Business Communication

Journal of Consumer Research

Journal of Educational Psychology

Journal of Educational Research

Journal of Experimental Child Psychology

Journal of Experimental Psychology

Journal of Experimental Psychology: Human Learning and Memory

Journal of General Psychology

Journal of Mental Deficiency Research

Journal of Optometry and Archives of the American Academy of Optometry

Journal of Reading Behavior

Journal of Research Communications Studies

Journal of Research in Science Teaching

Journal of Social Psychology

Journal of Technical Writing and Communication

Journal of Typographical Research (superseded by Visible Language,
1970-Current)

Journal of Verbal Learning and Verbal Behavior

Journalism Quarterly

Memory and Cognition

MIS Quarterly

Museum News

Occupational Psychology

Perception and Psychophysics

Perceptual and Motor Skills

Programmed Learning and Educational Technology

Progressive Education

Progressive Learning and Educational Technology

Psychonomic Science

Psychological Reports

Psychological Review

Psychology in the Schools

Psychophysics

Psychophysiology

Quarterly Journal of Experimental Psychology

Reading Improvement

Reading Research Quarterly

Remedial Education

Review of Educational Research

Science Education

Scientific American

Sight-Saving Review

The Reading Teacher

Visible Language (preceded by Journal of Typographic Research,
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Logistics Spectrum, 13: 6-16.

Vita

Captain Melvin E. Lamoreaux was born on 9 May 1952 in Jacksonville, Florida. He graduated from high school in Centerville, Ohio, in 1970 and attended Chipola Junior College and the University of Central Florida, where he received the degree of Bachelor of Arts in Psychology in June 1976. Upon being commissioned through ROTC in 1976, Captain Lamoreaux entered the Air Force Reserve program as an intelligence officer and was assigned to Detachment 16 of the Air Force Intelligence Service. Called to active duty in 1979, he entered training for the Minuteman III missile system and was assigned to 321st Strategic Missile Wing at Grand Forks Air Force Base, North Dakota. There he served as deputy missile crew commander, missile crew commander, and Minuteman ICBM flight commander. In 1983, Captain Lamoreaux was selected to serve as a consolidated command post controller for the 319th Bombardment Wing (Heavy) and remained there until he entered the School of Systems and Logistics, Air Force Institute of Technology, in 1984.

Permanent Address: Route 7, Box 333

DeFuniak Springs, Florida 32433

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This thesis provides a foundation for future research on the use of color, typography, and graphics to improve readability. Articles from the broad fields of education and psychology, as well as from the fields of journalism and printing, have been reviewed for research relating color, typography, and graphics to reading ease, speed, or comprehension. The most relevant articles reviewed are presented in an annotated bibliography; the remaining articles are also presented in a bibliographic format.

This literature review indicates that recognition and recall of printed material may be improved through the use of headings, underlining, color, and, especially, illustrations. Current research suggests that individuals can remember pictures far longer than past research indicates. However, researchers are divided on the usefulness of illustrations to improve reading comprehension. On the other hand, reading comprehension can be improved through the use of statistical graphs and tables if the reader is properly trained in the use of these devices.

Those factors which influence the ease and speed of reading but are ineffective in improving recall or comprehension are type style, type size, margin width, line length, multiple column formats, or typographical arrangements other than the horizontal style of printing.

Further research on the interaction between language, color, typography, and graphics is needed. More specifically, research needs to be conducted on the combined use of language, color, typography, and graphics to improve reading ease, speed, and comprehension. Research also needs to be conducted on the readability of written text appearing on computer monitors and in computerized dot-matrix print.

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