FORMATTING VARIABLES AND TYPEFACE VARIATIONS OF DOT-MATRIX PRINT AND THEIR EFFECT ON READING COMPREHENSION AND READING SPEED

by

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(ABSTRACT)

The purpose of this study was to determine whether three typeface variations of dot matrix print [single density, dual density, and photocopied dot matrix type] and two formatting variations [fully justified and left justified] had any effect on the reading rates or reading comprehension of college students when compared to the same typewritten material. A pretest/posttest design with experimental and control groups utilized the Cloze Reading Test and the Nelson Denny Reading Test to measure reading

comprehension and reading rates respectively to college students [N= 240]. Subjects were randomly assigned to the groups to test the effects of the six treatment levels and two control groups of the independent variables [typefaces and type formatting] on the dependent variables [reading comprehension and reading rate]. Four test sessions were used to collect the data and answer the research question: Do either of the three typeface variations of dot matrix print or the two formatting variables have any effect on reading comprehension or reading rates of the subjects when compared to typewriter type? A factorial analysis of covariance [$p. < .05$] was used to analyze reading comprehension; and a two way analysis of variance [$p. < .05$] was used to analyze reading rates. The findings indicated that typefaces or formatting made no significant difference in the reading rate or reading comprehension scores of the subjects tested.

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CHAPTER I

The Research Problem

One of the major impacts of the microcomputer is the development and commonplace use of word processing (Campbell, Marchetti, & Mewhort, 1981; Inglis, 1983; Strawhorne, 1980). Print legibility has been a research topic for almost a century and the microcomputer has created a communication and information revolution (Hills, 1980; Hutchingson, Williams, Reid, and Dudek 1981; Meadows, 1980; Strawhorne, 1980; Yule, 1982). The variety of resulting written materials has sparked a renewed interest in legibility and readability and has caused some individuals to question the quality of computer-generated output (Brooking, 1980; Hope, 1982; Reynolds, 1979; Reynolds, 1980; Strawhorne, 1980; Hartley, personal communication, March 9, 1984). Therefore some individuals have questioned the long-standing conclusions from past legibility studies (Reynolds, 1980).

Academic authors have benefited most from the growth of word processing although microcomputers have caused the role of the educator to become more complex (Hills, 1980; Hope, 1980; Inglis, 1983; Phillips, Burkhardt, Fraser, Pimm, and Ridgeway, 1984). Therefore educators have become information managers, designers, and publishers rather than information disseminators (Bork, 1983; Hills, 1980; Inglis,

1983; Strawhorne, 1980).

The Need For The Study

The proliferation of the use of microcomputers at all levels of education has exacerbated the need to explore further the effects of print legibility on student achievement. An attempt to fully explore all variables and resolve all topical questions would be an unrealistic task (Shebilske, personal communication, June 5, 1984). The focus of the need for this study was that weaknesses and problems which have existed in instructional development have increased as computer technology has continued to revolutionize information processing in the educational community.

Barriers to Computer Use

Increased educational computer use has not been without obvious problems. Major barriers to effective microcomputer use in education have included the shortage of effective instructional software, teacher inability to employ the full potential of the microcomputer, and a general shortage of guidelines for schools using microcomputers (Bean and Hoffman, 1984; Lewyn, 1984; Phillips, et. al., 1984). Additionally, there is a resistance by educators to mesh their curricula with computer technology and to be "force-fed" untested methods of computer instruction against older "proven" teaching methodologies (Inglis, 1983; Lewyn, 1984).

Educators have been generally naive about print legibility and the effect of type design on reading, and have tended to neglect or take for granted the role of graphic communications in instruction (Meadows, 1980; Reynolds, 1980; Waller, 1979; Watts and Nisbett, 1974). This may have had serious implications on reading and readability of printed materials (International Business Machines, 1984). Watts and Nisbett (1974) recognized that "legibility research is not well known to teachers nor even publishers of children's books" (p.33).

Other computer-associated problems are even less obvious to most educators. From the human factor and ergonomic standpoint, there is a need for more communication between computer designers and computer users, especially in the design of aesthetically pleasing typography (Snoberry, Parkinson, and Sissons, 1983; Snydor and Maddox, 1978; Strawhorne, 1980). User confusion has existed because computer standards have often been implemented without having negotiated the design or measured the users' outcome (Inglis, 1983; Thimblely, 1983).

Although computer use by both teachers and students is on the increase, the wide spectrum of computer users generally have learned relatively little about computing (Beebe, 1982; Hirschbul, 1981; Lewyn, 1984; Reynolds, 1980; States, 1980). In 1981, the Apple Computer Corporation

sold 25% of its computers throughout the world to the educational sector (Borrell, 1982). The student-computer ratio has increased from one computer per 400 students to one computer per 65 in the last two years, and 60% of all computing time was spent doing word processing (Hope, 1982; Lewyn, 1984). Thus it has appeared that educators have been uneducated with regard to procedures they have frequently applied in their instructional settings.

The design and appearance of instructional materials are combined with typographical variables to affect legibility (Reynolds, 1979). The scant knowledge among educators about designing effective instructional materials has apparently been a problem which has paralleled those of legibility literacy. The importance of effective instructional design skills are paramount to maximizing computer use among educators, especially since the computer manipulation of page formats is so much easier than that of the conventional typewritten page (Bean and Hoffman, 1984). Ineffective instructional design methods are used by teachers because of a shortage of available guidelines, and the existing instructional design literature is vague and confusing (Hills, 1980; Kerr, 1981; Morrisohn, 1977). As effective computer software and courseware have remained scarce, teachers have designed their own instructional materials and printed "hand-outs" such as learning activity packets (Hills, 1980; Milner, 1980).

Although teacher-designed instructional materials have traditionally been common, teachers do not generally make good designers because they rarely proceed in an organized fashion and do not think as instructional designers (Joyce, cited in Kerr, 1981; Kerr, 1981).

Computer generated images have the potential of lifting instructional management to a new level of efficiency and effectiveness. However, as computer use has increased in the classroom, problems of designing effective instructional material have also increased (Bean and Hoffman, 1984; Becker, 1982; Hirschbul, 1981; Inglis, 1983).

The lack of development of optimally legible dot-matrix, computer-generated type is but one of the numerous shortcomings resulting from the communication gap between scientists/engineers and the product users (Bork, 1983; Snydor and Maddox, 1978). Type designed for normal lithographic offset reproduction, which is the most frequently used printing method, has frequently been used as the basis for designing electronically generated type, although it has not usually been suitable for that purpose (Unger, 1979). Legibility of type designed for electromechanical composition was doubted as early as 1967 (Prince, cited in Watts and Nisbett, 1974). Hirschbul (1981) also expressed doubt about dot-matrix print legibility in the classroom environment. Wrolstad

(personal communication, March 5, 1984) and Hartley (1979) expressed concern that formatting variables were very important to legibility. Similarly, Reynolds (1979; personal communication March 15, 1984) expressed concern over vertical "rivers" which are created with dot-matrix print. The legibility problems may be amplified when computer-printed "originals" are photo-copied for dispersion to a class (Reynolds, 1979; Shebilske, personal communication, June 5, 1984).

The Information Gap

Perhaps one of the most important reasons for conducting this study was that, according to noted legibility authoritries, existing legibility research on dot-matrix type characters was scarce (Reynolds, 1979; Snydor and Maddox, 1978). Although there has been some research on dot-matrix characters, there has remained a need for additional research in dot-matrix technology (Reynolds, 1979; Reynolds, 1980; Riley, 1978; Snydor and Maddox, 1978; Wright, personal communication, March 7, 1984). Design guidelines are sorely lacking in the dot-matrix typographic community (Snydor and Maddox, 1978). A meager amount of research was conducted by either engineers or the behavioral sciencists (Novak, personal communication, March 17, 1984). Thus educators and technologists alike were left with many unanswered questions concerning the appropriate selection and

presentation of computer-generated messages (Wright, 1980A).

Previous legibility research has been in the areas of electronic video display and solid-stroke printed letters. Video display technology, or dot-matrix displays, are closely related to dot-matrix print in that the same typographic design principles have been applied to both areas. Little study has been conducted, however, in the area of dot-matrix <u>print</u> legibility (Snydor and Maddox, 1978).

There are many misconceptions that past research findings can be generalized or inferred to the more current technologies (Foster and Bruce, 1982). Tinker (1963) stated that all experiments should be conducted by employing actual printing practices. Warford (1972) cited the method of printing and the quality of the impression as two of the primary factors which have contributed to legibility differences. Although Hutchingson (1981) conducted research in dot-matrix display technology, his concern about the generalizations of solid stroke research to dot-matrix technology perhaps best expresses the need for more current studies:

Extensive research by Tinker (1963) has evaluated such issues as vertical versus horizontal layouts and line widths for best reading performance. Cornag and Rose (1967) have reported some 140 studies that have examined

the layout of alphanumeric text materials. This extensive body of data has only limited application in current display technology, because it was based on solid-stroke alphanumeric characters (p.551).

Supporting Documentation

As an effort to fully justify the research efforts and to avoid the possibility of research duplication, inquiries were sent to educational associations selected from the Encyclopedia of Associations (1983), manufacturers of dot-matrix printers which were below the $700.00 price range, and noted authorities on legibility research or visual imagery. Supporting documentation was received from Hartley (personal communication, March 9, 1984), Shebilske (personal communication, June 5, 1984), Easterby (personal communication, June 12, 1984), Reynolds (personal communication March 15, 1984), and Foster (personal communication, March, 15, 1984), who are noted authorities on legibility. Additional support was received from publishers of Reading Research Quarterly and Computing Teacher Journal, vocational educators Chase, (personal communication, November 1, 1983;) Eurich, (personal communication, November 1, 1983;) Ricketts, (personal communications, November 14, 1983;) Samuels, (personal communication, March 15, 1984;) Sava, (personal communication, November 1, 1984;) Steeb, (personal communication, December 1, 1983), and educational

associations including The International Council for Computer Users in Education, The National Association of Elementary School Principals, and The Academy for Educational Development. Only one support letter was received from a computer or peripheral manufacturer (Cockayne, personal communication, November 2, 1983).

Printer Popularity

The major disadvantages of the dot-matrix printer are its noisiness and the appearance of the type (Bernard, 1984A; Bernard, 1984B; Johnson, 1983). Neither of these characteristics have hampered the printers' popularity. Although there have generally been four other technologies-- thermal, ink jet, laser, and daisy wheel-- which have been competing for the computer printer market, their versatility, speed, price and/or reliability have prohibited these technologies from threatening the dot-matrix printer which has dominated the market.

The dot-matrix printer offers reasonably fast speed at approximately 160 characters per second. It has the capability of printing graphics, offers a variety of typefaces at the press of a button, and readily accepts plain single sheet or "fanfold" computer paper (Bernard, 1984A). Furthermore, Bernard (1984B) recognized that dot-matrix printers have developed a reputation for durability and reliability because the print heads have been generally designed to last for about 100 million

characters, or about five years.

Thermal printers are inexpensively priced around $300.00, but do not readily accept plain paper and only produce mediocre quality text (Linzmayer, 1984). Thermal printers are neither bidirectional nor logic seeking. With bidirectional printers, printing occurs as the head passes in each direction. In logic seeking printers, the print head logically moves into proper printing position without delay.

Ink jet printers have been in use for some time, however the quality is somewhat questionable for text material. They have usually printed only 34-40 characters per second and have generally been expensive (Bernard, 1984B). Only one ink-jet printer, Hewlett Packard's Think-Jet, has broken the $500.00 price barrier and has not been available long enough to develop a reliable reputation.

Daisy wheel printers produce a "letter quality" type but produce a printed page in about three times the time it takes to print the same material with the dot-matrix printer (Bernard, 1984B).

Additionally, low cost daisy wheel printers have print quality similar to a manual portable typewriter and do not have the capability of producing both graphics and text material (Bernard, 1984A). Laser printing technology experienced a major breakthrough when Hewlett-Packard

introduced its "affordable" laser printer in the summer of 1984. Laser printing is predicted to be the wave of the future in computer print technology, and although the laser printer has offered amazing advantages such as letter quality print and speed, the price has prohibited widespread use in situations other than offices (Anderson, 1984; Bernard, 1984B).

The popularity and widespread use of dot-matrix printers is because they can do some of what each of the competitive printers can do at a very affordable price (Teja, 1984). Although efforts have been made to improve dot-matrix print quality through increased numbers of pins in the print heads, the low cost printers will not realize these changes for some time (Johnson, 1983). Dot-matrix printer prices range from a few hundred dollars to over three thousand dollars, and the quality of the print is proportional to the price of the printer. The closer the dot-matrix print quality is to typewriter quality, the higher the cost. Johnson (1983) classed moderate quality dot-matrix printers to be priced between $700.00 and $1500.00.

Relevance of Study

Many computers and peripherals, including inexpensive printers, are in use in the educational environment (Borrell, 1982; Lewyn, 1984). Computer and peripheral use will continue to grow and expand in the educational

community because of the low price and popularity of word processing (Bean and Hoffman, 1984; Borrell, 1982; Gates, 1980; Hills, 1980; Lewyn, 1984). Although dot-matrix printers have produced only moderate print quality, they will remain the most popular printer through 1987 because of their low price and their ability to use plain paper (Borrell, 1982; Hope, 1982). Borthwell (cited in Teja, 1984) predicted there will be a future marketplace for each printer category because each has offered advantages and disadvantages (Bernard, 1984B, Teja; 1984).

The printed word, although electronically generated, will continue to be the mainstay in educational communications (Gates, 1980; Hills, 1980; Wright, 1980). The conclusions drawn from this study will remain relevant as long as those peripherals are in existence in the schools.

Problem Statement

The problem of this study was to determine the effects certain typographical variables of dot-matrix print have on student reading performance, when compared to material printed by standard typing methods. Four styles of type and two kinds of formatting were used as treatment levels of the two independent variables, typestyle and formatting. The four typestyles used included single density dot-matrix print, photo-copied single density dot-matrix print, dual density dot-matrix print, and typewriter print. Justified

and unjustified type were the two formatting variables used. The levels of each of the independent variables were tested against two dependent variables, reading comprehension and reading speed.

Purpose of This Study

This study focused on certain variables that have been researched through previous solid stroke alphanumeric legibility studies to see if they differed with dot-matrix print and whether the differences, if any, ultimately affected student achievement. Additionally, this investigation determined if student achievement significantly differed when photo-copied dot-matrix print rather than solid stroke alphanumeric print was used for the composition of instructional materials.

The purpose of this study was to determine if either of the four levels of typefaces or either of the two levels of formatting of dot-matrix print had any affect on the reading rate or reading comprehension of university students.

Research Questions

Six major research questions with respect to the purpose of this study were investigated:

1. Was there any significant difference in the mean reading rate scores of students tested on four different typestyles?

2. Was there any significant difference between the

mean reading comprehension test scores of students tested on four different typestyles?

3. Was there any significant difference between the mean reading rate scores of students who read fully justified dot-matrix print and those who read left-justified dot-matrix print?

4. Was there any significant difference between the mean reading comprehension scores of students who read fully justified dot-matrix print and those who read left-justified dot-matrix print?

5. Was there any difference between the mean reading rates of each of the groups tested on one typestyle and type format?

6. Was there any difference between the mean reading comphension scores of each of the groups tested on one typestyle and type format?

Definitions

For the purpose of this study, the following words and terms were defined for clarity:

Dual-density dot-matrix print (Ddmp): The ability of a terminal or a printer to have produced type characters in regular as well as highlighted bold formats.

Justified Type (Jt): Type set, or formatted, so that both the left and right margins are flush, such as in newspaper columns.

Left Justify [Ragged Right]: Type set so that the

left margin is even [flush] and the right margin is uneven, or "ragged" as in the format of this paper.

Legibility: The ease and accuracy with which a reader is able to perceive the printed word (Orvink, cited in Watts and Nisbett, 1974).

Peripheral Device: A device, such as a printer, mass storage unit or keyboard, that is used as an accessory to a microprocessor to transfer information to and from the processor.

Printer's Measuring System: 6 picas = 1 inch; 12 points = 1 pica; and 72 points = 1 inch.

Readability: A traditional way that the relation of text variables to comprehension has been viewed. Readability research has related the comprehensibility of texts to various factors related to semantics such as word length, difficulty, and frequency (Encyclopedia of Educational Research, 1982).

Reading Comprehension: The reader's ability to understand reading material as measured by the Cloze reading comprehension test.

Reading Speed: The rate at which one has read printed material as measured by the Nelson-Denny Reading Rate test for students from grades nine through sixteen.

Resolution: A measure of ability which has delineated picture detail; also the smallest discernable or measurable detail in visual presentation. Resolution is stated in

terms of modulation transfer, spot diameter, line width, or raster lines.

Solid Stroke Type (Sst): The most common method by which typographical characters have been composed, which have consisted of solid lines as opposed to computer-generated characters formed by a series of dots.

Standard Typewritten Type: Typed material which was composed on an IBM Selectric typewriter using a Roman typeface.

Standard Dot-Matrix Print (Sdmp): The normal or "standard mode" of printing which is most often used for transferring computer information from the computer onto paper, thus creating "hard copy." The standard dot-matrix print is labeled single density print since the printer head on the printer makes only one pass across the line being printed and therefore results in a "lighter than normal" printed copy. For this study, the Sdmp was generated with an Epson FX-80 Dot Matrix Printer.

Type Formatting: Methods employed in type composition by which written material is visually altered by using spatial variables such as margins and line spacing.

Typestyle: The specific typeface design used in typesetting and page composition.

Photo-copied Dot-Matrix Print: Single density dot-matrix print which is reproduced on a typical small office copier.

Limitations

The following limitations pertained to this study:

1. Subjects used in this study were enrolled in Industrial Education and Technology classes in the Winter 1985 Semester at Appalachian State University, Boone, North Carolina.

2. The time period for completion of the test sessions may have affected the external validity of the study.

3. Prior knowledge of the students may have affected the internal validity of the study.

Assumptions

The following assumptions were made with regard to this study:

1. The above-mentioned limitations did not cause unusual investigative results.

2. The subjects were a representative sample of undergraduate students at ASU.

3. The treatments were applied in a time frame suitable for evaluating such research.

4. The measurement of silent reading time was an accurate assessment of the legibility of the typographical variations being tested.

5. The random selection of passages used in the reading tests did not spuriously affect the outcome of the study.

CHAPTER II

Review Of Literature

The investigation focused on three literature areas which were perceived by typographic researchers, Foster (personal communication, June 7, 1984) and Shebilske (personal communication, June 5, 1984), to provide the most relevant information: Solid stroke legibility; computer generated type; and typographic research methodologies. Literature searches through all relevant computer data sources were conducted to assure that the most current and available literature on the topic was fully reviewed. Additionally, all recommendations from resource letters were investigated, including computer searches with the London College of Printing at the London Library and the American Psychological Association.

Solid Stroke Research

Interpretative Precautions

The conclusions drawn from the abundance of solid stroke research are the result of a variety of measurement criteria, methodologies, and interpretations which have resulted in several precautions that should be noted (Snydor and Maddox, 1978).

Readability and legibility are used as synonymous terms in typographic research which have included studies

in both visual perception and/or the comprehension of graphic symbols (Smith and Dechant, cited in Reynolds, 1979; Zachrisson, cited in Reynolds, 1979).

Some researchers, however, have distinguished between legibility and readability. Legibility research has traditionally been involved in typographic variables as defined by the dominant figure Miles A. Tinker (Waller, in Kolers, 1979). Tinker's definition as well as definitions by others including IBM (1984) have commonly centered around Orvink's theme that legibility is "the ease and accuracy with which a reader is able to perceive the printed word" (Orvink, cited in Watts and Nisbett, 1974, p.41).

Readability research is involved in the more complex reader-oriented variables and can be interpreted as a sum total of reader, textual and environmental interactions and elements within a piece of printed material (Dale and Chall, cited in Brooking, 1980; Tinker, 1963). The measurement of readability and the resulting conclusions from such studies were further complicated because reader ability and/or reader interest was an intervening factor in the research (Brooking, 1980; Massaro et. al., 1980; Rye and Sjolander, 1984; Warford, 1972). The most general and common definition of readability is the ease of understanding reading materials where word and sentence characteristics are used as a standard of measurement

(Brooking, 1980; Massaro, et. al. 1980; Warford, 1972).

Research findings were largely inconsistent, conflicting, or broadly interpreted because of several factors:

1. Background levels and/or ages of the subjects tested may have invalidated such studies (Warford 1972).

2. A sound theoretical base was lacking in typographic research (Waller, 1980).

3. The variety of statistical techniques used by the legibility researchers combined with the wide difference in variables caused different results and inclusive data (Ladas, cited in Kolers, 1979; Waller, 1979, cited in Kolers).

4. There has been no single best method for measuring legibility/readability, either qualitative or quantitative, which has resulted in a large amount of reading rate studies (Watts and Nisbett, 1974).

Research Variables

Typographical research variables have been largely grouped into either reader or text variables. Reader variables have traditionally been categorized into psychological and physiological variables, while text variables have focused on typographic variables and text design (Shaw, 1969 cited in Watts and Nisbett, 1974; Tinker, 1963; Waller, 1979; Warford, 1972). It has been a widely accepted concept that these variables must have

interacted for successful reading to have occurred (Brooking, 1980; Reynolds, 1979; Watts and Nisbett, 1974). Typographic variables have received the most renewed attention because of the recent changes in printing methods, such as computer generated print. A secondary reason for the renewed concern was that the abundant amount of solid stroke research had become old and outdated (Reynolds, 1979; Snydor and Maddox, 1978).

Reader Variables

The results of typographical research and the associated psychological and physiological factors have been questionable. Many times the conclusions drawn from the research have not been solely attributed to the treatment applied to the groups (Massaro, et. al. 1980; Haber and Haber, 1981; Reynolds, 1979). This problem has been largely because there has been increased evidence that the reader's perception of learning and the kind of material read has influenced research outcomes (Cunningham and Trierney, 1979; Haber and Haber, 1981; Wright, 1980).

The physiological factors which have affected reading were identified by Reynolds (1979) and others as eye movement, the advancing and regressing of the eye as they move along a line of printed type, eye fixation, and letter and word recognition (Haber and Haber, 1981; Massaro, et. al 1980; Reynolds, 1979, with Foster).

Text Variables

Typographic variables have been largely categorized into spatial and typographic coding (Reynolds, 1979). Spatial coding has involved the layout and formatting of page arrangements, and typographic coding has involved the use of letter characteristics which allow the reader to adopt easier mental and visual structuring of ideas and scanning strategies (Hartley, 1979; Reynolds, 1979). Both have been used most effectively to identify sections of text, such as headings, paragraphs, and sentence length (Reynolds, 1979; Watts and Nisbett, 1974).

Reynolds (1979) emphasized the importance of considering both spatial and typographic factors in research because the exclusion of either may result in false or misleading assessments. Specifically, type characters have been more legible as individual elements than when they were in their completed format (Burnhill, et. al. 1977; Haber and Haber, 1981).

The general findings about spatial factors have been somewhat mixed. Insignificant results were found by Hartley and Burnhill (1975). However, according to Hartley et. al. (1979) and Reynolds (1979) spatial arrangement was the preferred coding method for textual information because it has been most beneficial for learning and a major determinant of reader preference. Research which supported Hartley's and Reynolds' conclusions have included summaries of Frase and Swartz (cited in Hartley, 1980) and

other studies (Anglin and Miller, 1968; Carver, 1970; Coleman and Hahn, 1966; Coleman and Kim, 1961; Cromer, 1970; Epstein, 1967; Hartley and Burnhill, 1976; and Murray, 1976). More recently, Shebilske (1981) concluded that students who read special layouts recalled and remembered text better, were better prepared, and had generally improved learning without requiring appreciably more time studying.

Specific spatial factors have included leading, justification of type, line lengths and columnar formatting, page sizes, and margins. Leading, the spacing between lines of type, has been most recently summarized by Reynolds (1979), who concluded that leading improved legibility, especially in the smaller sizes of type.

Type justification, the manipulation of the right and left margins, has been one of the most frequently explored legibility research topics. The ease with which computers have manipulated margins seems to have had specific implications for electronic text technology, since the two formats have offered such noticable differences in word spacing (Reynolds, 1979; Wright, 1980). Wright (1980) similarly agreed that the differences in the two have affected linguistic factors, which determin how easily information is subdivided into factors relating to words, sentences, and paragraphs. Past research, however, has frequently failed to conclude that justified or unjustified

type has been a significant structural difference in a layout, because many of the studies did not use type composition methods which were consistent with the methods used to generate printed material (Tinker, 1963; Watts and Nisbett, 1974).

Although line lengths have varied broadly without affecting legibility, the interaction of line length on typesize formatting variables has affected legibility in a number of ways (Reynolds, 1979). Several reading problems associated with line lengths were identified. Generally, short lines of type are severely affected by larger typesizes, and smaller type sizes are severely affected by longer lines (Reynolds, 1979). Researchers have concluded that extremely short lines prevent the maximum use of peripheral vision, optimum eye fixations, and perception times (Reynolds, 1979). However, if lines become too long, the beginning of each line is more difficult to locate because of the increased number of regressions (Reynolds, 1979; Tinker, 1963). Determining the optimal line length is compounded by individual reader variables, such as age and skill (Wendt, 1979). Reading difficulties increase when lines varied greatly from a "normal" length, such as ten to twelve words or sixty to seventy characters, or when the lines were not rational and consistent (Burnhill and Hartley, 1975).

Line width is most often the determining factor for

the three general kinds of of formatting, [horizontal, vertical, or columnar]. Formatting is closely related to and perhaps largely dependent on type justification, especially in the publishing industry (Inglis, 1983). There have been mixed conclusions about appropriate formatting. Huey's research in 1898 concluded that the horizontal formatting was read more rapidly and perhaps therefore was best for reading texts (Huey, 1898, cited in Tinker, 1963). Vertical reading, on the other hand was found to have increased the capacity and efficiency of short term memory (Le Poultier-Perron and Drevillon, 1980). Poulton (cited in Reynolds, 1979) found that smaller type in double columns was preferred by publishers over single columns for economic reasons, but it was not suitable for typewritten text and classroom instructional materials (Hartley, 1978). Tinker (1963) even concluded that vertical arrangements could be made at least as efficient as horizontal reading arrangements.

Page size problems have been compounded by the wide variety of page sizes used by printers, publishers and copier technology (Reynolds, 1979). Page size has been largely determined by the other formatting variables such as column numbers, line length, type size, leading, frame margin size and, if the material were to be copied, the desired reproduction size. Traditionally, page size has indirectly but significantly affected legibility, in that

large pages have been harder for the readers to hold and therefore have kept the readers from reading the page at the optimal reading angle (Reynolds, 1979; Tinker, 1963).

Although page size research has appeared to be somewhat outdated and minimal, copier technology has caused some researchers to question the implications the copiers may have on page size (Reynolds, 1979). Copier-associated problems have arisen in that the formatting variables changed when the image was photo copied, especially if the image was reduced or enlarged (Reynolds, 1979).

Perhaps least significant of all formatting variables has been page margins (Reynolds, 1979; Tinker, 1963). Early research by Patterson and Tinker (1940) found no significant difference in the speed of reading of adults when they read printed material with and without margins. More recent arguments, however have contended that especially narrow margins have affected the pages' aesthetic appeal and practicality for holding purposes. Thus, print with excessively narrow margins contributed to visual fatigue in young readers (Burt, Cohn and Dearborn, 1959, cited in Watts and Nisbett, 1974; Reynolds, 1979; Tinker, 1963).

Typographical Factors

Typographic coding, using typographical variations to segment print, has not been as effective on learning as spatial coding. Of the two general methods of typographic

coding, typeweight and typeface, Reynolds (1979) concluded that typeweight, the thickness of the strokes of the characters, has been more obvious and effective for the average reader.

Typeweight has been affected by several individual letter variables, including stroke width, counters, and serifs. These variables must interact with spacing within the letter to affect typeweight, and in turn, legibility. Although Tinker (1963) concluded that all type styles are equally legible, others concluded that optimally designed and aesthetically pleasing individual letter variables are closely related to reader preference and attitude, which therefore affected reading (Brooking, 1980; Reynolds, 1979). The preferred typeweight has been similar to that of boldface type, although it has been more suitable for emphasis than use in continuous text (Reynolds, 1979; Tinker, 1963).

Of the two dimensions of a type character, horizontal and vertical, the width of a letter has been the most often neglected and criticized factor in type design because the width has affected the length of the phrase and the snytactically structured word strings (Hartley, 1979; Reynolds, 1979; Massaro, 1980). Researchers have similarly agreed that as long as the horizontal letter dimension remains constant and at the optimal width, 80% of its height, other variables such as the length and number of

the ascenders and descenders could be manipulated to improve legibility and readability (Cooper et. al., 1979; Massaero, 1980; Prince, 1940, cited in Warford, 1972; Watts and Nisbett, 1974).

Two methods of letter spacing, proportional and monospacing, have been used for printing type. Proportional spacing means that the letters are spaced according to the individual letter size, and monospacing means that the letter spacing is equal, regardless of letter size. Printed material such as that in a textbook typifies proportionally spaced type, and typewritten material typifies monospaced type. Investigations into the effects of letter spacing on legibility have been scarce, but the existing research has suggested that spacing has made no appreciable difference on legibility (Gillilard 1923, cited in Reynolds, 1979). From a subjective standpoint, monospacing received most criticism because it produced uneven texture around narrow letters and has created a generally unpleasant appearance (Reynolds, 1979).

One of the oldest and perhaps most common legibility research topics was the comparison of capital letters as opposed to all lower case or even mixed cases. Early summaries by Watts and Nisbett (1974) as well as more current conclusions discouraged the frequent use of capital letters. Disadvantages to the use of all capital letters are largely related to problems with word unity and eye

movement (Massaero, 1980; Watts and Nisbett, 1974). The advantages to reading lower case letters, on the other hand, are centered on the use of ascenders and descenders in the word recognition process. Word recognition was correlated with the overall letter size and shape (Massaero, et. al. 1980; Watts and nisbett, 1974). According to the Foster and Bruce summary (1982), apparently the only advantage to using uppercase letters was that uppercase words were visible at a greater distance and therefore were more easily identifiable than their lowercase counterparts when the letters were the same height.

Other than tradition and aesthetics, serifed type offered only a few advantages to the reader. Their use and popularity in type design is apparently due to tradition (Reynolds, 1979; Robinson, et. al, 1975). The advantages of reading serifed type are that serifs improve word recognition, increase reader preference, and improve photo-copying capabilities of type (Cooper et. al., 1979; Poulton, 1965, cited in Brooking, 1980; Robinson, 1980; Spencer et. al., cited in Reynolds, 1979).

Problems with numeral legibility have been more individual-related rather than group-related. For educational settings, most effective numeral legibility has depended upon typestyle selection and the task to be performed (Watts and Nisbett; 1974). Specifically, Arabic

numerals were most easily read, and numbers with hanging ascenders and descenders were read more easily when read alone, but made no difference when grouped together (Berger, 1948, cited in Reynolds, 1979; Warford, 1972).

As for punctuation research, the few studies indicated that the most appreciable affect of punctuation on legibility was that larger sizes of the point and the comma generally improved legibility (Prince, cited in Watts and Nisbett, 1974).

Typefaces, both typewriter and typeset copy, have perhaps been one of the most important considerations for the educational environment. Both have been a concern in legibility because of the enormous number and the general shortage of information on the choice of typeface, and they have been significantly different in terms of legibility (IBM, 1984).

Several disadvantages have been noted about typewriter type. More letters are confused with typewritten copy than with typeset copy. Typographical coding is more restricted because of type style and weight (IBM, 1984; Reynolds, 1979).

Typeset copy, on the other hand, has offered unique advantages over typewritten copy, in that the typestyles have been grouped, designed, and recommended for specific purposes such as space saving, emphasis, adverse conditions, creating moods, or to maintain a high level of

readability (Brooking, 1980; IBM, 1984; Tinker, 1963).

An additional concern has been the continuous change in reader preference of typefaces, which has usually been formed early in life (Burt, 1959; Poulton, 1959, cited in Cooper et. al., 1979). Failure to consider typeface as a legibility variable may result in confusion of the idiosyncratic features in the type form itself, the form of the particular characters, or in the design of the character set (Reynolds, 1979).

In the selection of adequate typefaces, selection criteria should include specific purpose of the message, character assembly methods, and availability of methods and typestyles. Image degradation, the amount of image quality which has been lost during the reproduction process, has been an additional factor to be considered (Brooking, 1980; Hartley, 1978; Tinker, 1963; Warford, 1972). Traditional image degradation has occurred because reproduction procedures were less than perfect. Typical design breakdown problems are that fine lines break down, small internal faces fill in, strong contrasts between thick and thin strokes cause a "dazzle" effect, and letters often run together (Reynolds, 1979).

Other factors which affect legibility, largely because of reader preference, are the selection of ink density and paper selection (Reynolds, 1979; Tinker, 1963).

Research Methodologies

Numerous research techniques have been employed to measure the most common dependent variables of reading rate and reading comprehension. Hartley et. al (1975) used the test-retest method to assess the reliability of the most widely used testing methods used in typographical research. Oral reading, scanning/retrieval, silent reading speed, and the Cloze reading comprehension tests were used to test male and female school children and university students. The authors used traditional testing methods where test material was equated for difficulty and typographic specifications were held constant. The authors concluded that specific methods were more useful than others for assessing typographic research and the appropriateness of the method depended largely upon the nature of the variable being assessed.

Of all the methods tested, Hartley et., al. recognized that although oral reading recorded the highest reliability coefficient among university students, .78, it was determined to have very little use in typographic research because it lacked sensitivity to typographic layouts and could have produced artificial results because it was an unnatural reading method. Scanning was found to be most appropriate among university students, reliability coefficient of .88, for assessing technical materials. Silent reading, and particularly the Cloze procedure was determined to be most appropriate for typopgraphic

were untimed for more reliable results; and that more than one test session was administered for greatest generalizability.

Controlling for the precautions has resulted in a recommended procedure in which 250 to 300 word passages were used in conjunction with the Fry Readability graph. This has assured that each passage was well below the readability threshold of the students tested. Additional recommendations were to administer three untimed test sessions (Aulls, 1976).

One hundred fifty-six university psychology students were time-tested for reading speed and reading achievement in a study by Campbell, Marchetti, and Mewhort (1981). The dependent variables were measured against three computer text processing techniques: ragged right format; fixed character spacing; and variable character spacing. The authors distributed one of the three versions of the test booklets to the volunteer students who silently read the passage and then answered a series of questions and a vocabulary test. The results showed that the ragged right formatting and large and unpredictable spaces between words reduce reading speed.

This study very closely paralleled the Campbell, et. al., investigation. However, a Xerox Diablo daisy wheel printer which printed solid stroke type was used rather than dot-matrix printer and reliability of the research

could perhaps be questioned since the students were aware that their experimental session was a test of both speed and accuracy.

Upper and lower case letter legibility of computer screen type was investigated by Foster and Bruce (1982) when they tested two groups, 14 males and 8 females per group, in an experimental room. The times taken to read aloud six randomly ordered passages of nonsense text presented in upper and lower case were compared. The results of the experiment concluded that there was no difference between males and females on either upper and lower case letters. Neither upper or lower case was significant, though the serial order of the presentation of the text was significant in that some passages were read more slowly than others.

Perhaps the most significant factor about their research was that the test material was replicated from an earlier study on print for the partially sighted by Shaw (1971). The test material was composed of semantically anomalous random sentences which had an acceptable sentence structure, or pseudo-texts such as "Hungary bridges describe expensive farmers." Foster, Bruce, and Shaw justified the technique because it reduced the intelligence and comprehension factors which have frequently intervened and therefore resulted in a more accurate test of the actual visual rather than the mental ability of the reader

(Foster and Bruce, 1982).

Several limitations were recognized by the authors. The subjects were more than likely above average readers which caused limited generalization to other groups. The oral reading process employed limited generalizations to the reading of lines of type and would not be appropriate for generalizing to other methods of formatting type, such as lists. Finally, the pseudo-texts may have prejudiced the test in that some words were more meaningful and therefore more easily read than others.

Hartley and Trueman (1981) used reader preference to judge variations in layout, wording, and a combination of both in instructional text. The authors conducted five experiments. Each of the first three utilized 100 college students which compared reader preferences of different complexity levels of typographic and textual variations. The authors concluded that readers made generally crude and global judgements; more difficult and complex tasks resulted in more refined judgements; and previous theories were upheld that subjective judgements were difficult to interpret because of the apparent variety of judges' opinions and test material differences.

In a study conducted for the Compugraphic Corporation, Lewis, Sykes, and Lemieux (1984) used two test instruments to test reading speed, comprehension, and reader reaction of three hundred professional students. Reader reaction

was measured on readability, credibility, and persuasiveness of the documents.

Two test instruments were used: One was written in the form of a memo as a directive from a superior; and the other was written in the form of a proposal as a communication to be passed "up" the chain of command in a typical business structure. Each of the instruments was composed by either an IBM typewriter, a dot-matrix printer, or a computerized phototypesetter.

The typographic versions of both the memo and the proposal increased reading speed by 10 to 27 per cent over the typewritten or dot-matrix method but there was no significant relationship in the document read and the person's score on the comprehension scale. The authors generally concluded that typographic documents were superior to others tested and could be read quicker than the other formats tested without any loss of comprehension. The subjects showed no preference of material which was generated by computer, typewriter, and typesetter when compared on credibility and persuasiveness of the documents.

Two major limitations were pointed out: The subjects used prevented any generalization to populations other than professionals; and the instruments used in the study were intended for a business environment and would more than likely not be suitable for use in an educational

environment.

Waller (personal communication, September 7, 1985) has been conducting ongoing research concerning dot-matrix print legibility with fonts which do not allow for ascenders and descenders to be printed respectively above or below the baseline.

Wendt (1979) used three formatting variables, column width, word spacing between meaningful phrases, and horizontal and vertical structuring to test visual effect of design on secondary school textbooks. Four versions of a lesson from a secondary school physics textbook were used to determine reading times, achievement, and reader preference of 600 German secondary students. The four versions of the lesson included traditional 32 pica columnar spacing, 15 pica double column format, chunked typographic spacing of phrases, and an optimally designed, according to graphic designers, visualized version of the lesson.

The results yielded no evidence which allowed the author to recommend superiority of columnar versions or word spacing although the optimally designed version took the shortest reading time and resulted in the largest knowledge gain of either of the four versions. The success of the optimally designed version of the test was attributed to the overwhelming reader preference which affected reader motivation. Wednt's study was significant

because he used the normal classroom situation to test typographic variables against three determinants which were reader preference, reading time, and achievement.

Computer Generated Type

Of the two methods of computer screen type generation, vector generated and dot-matrix, the dot-matrix type has received most attention and gained popularity because it has been generally the least expensive to electronically create and its legibility has been more frequently questioned (Shurtleff, cited in Snydor and Maddox, 1978; Reynolds, 1980). Problems have been compounded because original dot-matrix type that was designed for computer screens has been carried over for inexpensive dot-matrix printer use (Takeuchi et. al, 1982).

Similarities With Solid Stroke Type.

Computer type legibility has focused on the similarities and differences which have existed between video screen type and dot-matrix print, and whether research conclusions in either of these areas were applicable to the voluminous solid stroke research studies.

Maddox, et. al. (1979) differentiated between the traditional type and electronic text:

> The dot-matrix characters used in the computer output systems are quite different in appearance from their conventional stroke counterparts in that stroke characters are composed of continuous line segments.

> It has been recognized for some time that certain characteristics of stroke alphanumeric characters affect their relative legibility. Much research has been undertaken to ascertain which stroke font is the most legible under certain conditions. However it has not been satisfactorily demonstrated that the conclusions from solid stroke font research are directly transferable to dot-matrix fonts (p.89).

Display luminance, luminance contrast, element or dot shape, dot size, ambient luminance, refresh rate, and display chrominance were seven video display variables which were identified by Snydor and Maddox (1978). Only four of those seven had application to dot-matrix print displays: contrast; element or dot shape, dot-size and inter-element spacing. Reynolds (1979) similarly suggested that there were significant differences between video displays and computer printouts: the video display consisted of a constantly flickering light source and character sets were limited and not necessarily the same as those encountered on computer printouts or computer printing.

Design Limitations

The design problems and limitations associated with dot-matrix type characters have been blamed on several factors (Jonassen, 1982; Unger, 1979). There have been more design restrictions with dot matrix characters than

conventional type characters (Jonassen, 1982; Snydor and Maddox, 1979; Wright, 1980). The fixed nature of the character grid for dot-matrix characters has restricted the design of the letters in that the characters are uniformly spaced regardless of their width. This resulted in character designs in which the narrow letters had become isolated, and caused an aesthetically unpleasant appearance, and a general uneven texture in a body of text especially when both upper and lower case letters were used (Jonassen, 1982). Additionally, the complete versatility of electronic typefaces such as slanted, compressed, and extended type has compounded design problems in that one type design has not proven to be suitable for all style possibilities. The overall appearance of the typeface and the texture of the page is affected by the electronic text versatility (Hope, 1982; Unger, 1979). Jonassen (1982) reiterated this point by calling for a complete redesign of some letters.

Traditionalism in type design has prevailed. The new typefaces have usually been designed along the same procedures and methods derived for adapting hot metal typefaces to film setting and are still designed to look like Roman characters. The practice has remained for the designer to anticipate photographic film's reproduction distortion by exaggerating the details such as the extensions of and cutting out of corners (Unger, 1979).

This increased the likelihood of individual letter confusion (Jonassen, 1982; Unger, 1979).

There has been a shortage of usable design data on dot-matrix type. The resulting dot-matrix letter forms were crude (Jonassen, 1982); there was a limited range of possibilities in terms of typographic variations; and screen characters differed from those in the printed page (Jonassen, 1982; Reynolds, 1979). Snydor and Maddox (1978) perhaps best recognized that the shortage of data created a challenge for the designer of dot-matrix print:

> When the designer was confronted with meeting satisfactory specifications for readability and legibility, a rather surprising fact surfaces. A volumnuous body of experimental knowledge exists on the effect of certain display parameters on readability. Most of these experimental data exist for [solid] stroke characters, and suitable design data for dot-matrix displays are quite scarce (p. 258).

Dot-Matrix Characteristics

Several characteristics of dot-matrix type were studied in the video display community. The characteristics which most significantly affected legibility were dot size, dot shape, dot resolution, matrix area, spacing, and image degradation and hardware. Snydor and Maddox (1978) concluded that optimal dot sizes were

task-related in that smaller, 1.0mm dots were better for contextual material than larger, 1.2mm dots. The authors concluded that the more square the dot, the better the observer performed reading and search tasks; and eliptical dots were poorest of all variations for legibility. Snydor and Maddox's study concluded that search tasks were optimized by using large elements which lead to more rapid identification of symbols, and that smaller

elements were more suitable for continuous reading since they minimized the number of eye fixations.

Vartabedien (1971) and a similar study by Ketchel and Jeremy (1968) concluded that element shape interacted with and was a determinant of a subject's performance, and that eliptical elements were inferior to circular elements. Vartabedian's study evaluated four concerns of dot-matrix type. Symbol generation methods, which consisted of dot-matrix vs. solid stroke type, and the common 5 x 7 and 7 x 9 matrix sizes were two concerns. The authors also studied the use of circles and elongated dots in character makeup, and symbol orientation. Response time and accuracy were the performance measures used to measure the recognition of letters. The resulting conclusions were that the 7 x 9 circle dot-matrix was superior to all other fonts; vertically elongated dots adversely affected legibility; the 7 x 9 dot-matrix was far superior to 5 x 7 matrices; and the dot-matrix construction of letters was

far superior to stroke matrix letter construction.

The concerns about the resolution of a printed page are similar to those with a video display. Resolution, the number of picture elements or pixels contained on a display, is a major consideration in dot element design (Snydor, 1980; Unger, 1979). Dot resolution has been constrained by the size of the display, the spacing between the elements and occasionally element shape, and the amount of contrast required.

One alternative to maximizing resolution without increasing dot size has been the overlapping of a smaller dot size to make a thicker stroke of a letter. Although overlapping dot elements has increased resolution on either a screen or a printed page, there is contrasting research as to whether dots are more easily read when they are overlapped or when there is a space between the characters (Snydor and Maddox, 1978).

The overlapping technique was simulated with dot-matrix printers by offering normal printing options including double strike and emphasized print which generally resulted in increased print character resolution but at the same time sacrificed half the printer speed (Kater, 1983; Takeuchi, 1982). Therefore, the optimal dot-matrix print quality has been a combination of the emphasized and the double strike modes (Gemini 1983, Kater, 1983).

Several studies have been performed to determine the optimal active area of a matrix. Active area was defined as the area of the matrix used to generate a character. Snydor (1978) indicated that the closer a dot matrix character resembled a solid stroke letter, the better the legibility and readability. Snydor (1980) further concluded that the active area was perhaps best interpreted as the ratio of the element size to spacing between the elements. The authors also concluded that readability of letters and words increased proportionally with the ratio of the element size, and that interelement spacing should not have been any more than 50% of the element width. Similar studies by Vandervolk, Herman, and Hershberger (1975) showed that the greater percent of active area, the better observer performance.

Jonassen (1982) and Reynolds (1980) recognized that problems for computer generated information were more prevalent than conventional type. Computer generated displays were considerably restricted due to inflexible word spacing as well as line spacing, which sometimes caused line-to-line letter fusion. Other problems with inflexible line and word spacing include difficult justification, uneven word spacing, and increased hyphenation (Jonassen, 1982). These problems are less severe with the printers, however, because a variety of printing pitches such as normal, emphasized mode, double

strike, and italics are usually offered as well as proportional and disproportional spacing (Kater, 1983).

One of the typographer's roles has been to consider and incorporate a degradation factor into type design. The degradation factor is defined as the amount of image quality that type characters lost as they were reproduced. Characters are most frequently degraded through variations in contrast and spatial frequency, and the problem is more prevalent with single density computer text (Shurtleff, 1974, cited in Snydor and Maddox, 1978). If image degradation has been adequately incorporated into type design, fatigue rate of the reader is reduced (Charmon and Heron, 1979; Charman and Tucker, 1977; Johnson, 1976; Owens, 1980 cited in Kintz, 1982).

Computer type design is further complicated by other design concerns. User satisfaction, the type font's ability to interface with a number of kinds and qualities of hardware and affordability, were among the constraints designers have addressed (Crowell, 1979; Reynolds, 1980; Strawhorne, 1980; Takeuchi, et.al., 1982; Unger, 1979). The wide range in variety and capacities of equipment has resulted in a limited number of monospaced character sets which consist of a single font of lower case, upper case, numerals and special characters and the absence of a universally acceptable type font (Reynolds, 1980; (Phillips et. al., 1984; Takeuchi, et. al., 1982).

Reynolds (1979) and Russell (1976) similarly concluded that sans serif letters were most suitable for computer recognition. The recommended x-heighth of character fonts for computer displays has been between .001 and .002 of the screen size (Phillips, Berkheardt, Coupland, Fraser, Pimm, Ridgeway, 1984). Computer printouts have optimally been between 60 and 70 characters long when upper and lower case letters were used in a normal fashion (Reynolds 1980).

Font Optimization Studies

Although there has been considerable research on determining optimal type for the computer screen, Snydor and Maddox (1978) recognized that font selection decisions by manufacturers have not been based on the body of knowledge about legibility but rather on the expediency of production. Additionally, the size of the grid and the corresponding letters vary from manufacturer to manufacturer (Gemini, 1983; Jonassen, 1982; Kater, 1983). The usual method employed to perform dot-matrix research is to vary several display parameters of the dot-matrix characters while holding the remainder of the variables constant (Snydor and Maddox, 1978). Most research focused on the control of a minimal number of variables to maintain managability of the investigation (Snydor and Maddox, 1978).

Early research by Shurtleff and Owen (1966, cited in Snydor and Maddox, 1978) used speed and accuracy as

performance measures to compare the legibility of dot-matrix characters to standard Leroy characters and concluded that 10 lines per symbol vertical height was a minimum legibility standard for CRT display. Giddings (1972, cited in Snydor and Maddox, 1978) studied height of characters on CRT displays and concluded no relationship between character size and legibility, although optimum character size was determined to be 4.75 mm. Huddleston (1974) conducted two studies which compared and evaluated the effect of character size on the legibility of British and American styled fonts and concluded that the British fonts were more legible.

Perhaps one of the most reputable and significant studies involving dot-matrix font optimization studies was performed by Snydor and Maddox in 1978 (MacDonald Ross, personal communciation, June, 1984). As an effort to provide some design criteria for dot-matrix displays they compared four different alphanumeric fonts with five different matrix sizes for single character legibility. Two of the fonts used in the experiment, the Lincoln Mitre and Huddleston fonts, are a standard in the industry and were designed to provide maximum luminance. Two more fonts, the Maximum angle and Maximum dot fonts, were designed in accordance with theoretical vision perception principles (Maddox et. al., 1977). Snydor and Maddox concluded that the Lincoln Mitre and Huddleston fonts were both superior

to, but not significantly different from, the maximum dot and maximum angle fonts. The 5 x 7 matrix produced more errors than any of the other sizes. As the matrix size was increased, significantly fewer errors occurred. The general conclusions indicated that the larger the number of dots in the matrix, the better the legibility, and the smaller the character within these, the better the legibility. The main benefit for reducing the character size was that it proportionally reduced the space between the dot elements. The Snydor and Maddox study was limited in that it examined only single character presentation legibility, it did not include single case and lower case letters and symbols, nor did the study offer conclusions based on contextual advantage or disadvantage.

Geyer and Gupta (1981) used the tachioscopic method of letter stimulus and presentation to test and compare the recognition and confusion of dot-matrix letters and solid stroke letters. Nine upper case letters were used to test single dot, filled dot, and solid stroke font styles. The most significant differences resulted between the single dot characters and the other two characters. The major weakness of their study was that generalizations could not be made to real situations because there were only nine letters used in the recognition process, and the method of image presentation made it difficult to compare to other studies.

One of the few studies on subjective image quality and observer performance of dot-matrix video displays was performed by Riley and Barbato (1978). The authors studied image degradation and how various dot sizes affected legibility. Riley used four groups of undergraduate students in an artificial testing situation to test varying degrees of element degradation of five different 5 x 7 matrix fonts. Variations of element degradation were controlled by the removal or addition of certain dots within the matrix of a character. While there were some differences found among characters, no differences were found among the fonts or between the manner of degradation. Perhaps the most significant contribution of the study was that it established a technique for determining and evaluating the relative importance of each matrix spot in character generation.

Summary

The review of the literature suggests that the new methods of information processing have shifted typographical decision making responsibilities from that of the typographical designer to the author who most often has not had a background in design. Given the fact that many authors and especially educators have been traditionally unaware of the effect of typographical variables on legibility and/or readability, the current innovations in information processing may have magnified an already

existing problem.

The existing solid stroke research, although volumnuous and valuable, has been riddled with inconsistencies ranging from problems of clearly defining legibility and/or readability to inconsistencies in the use of type generating equipment and research methodologies. These inconsistencies, coupled with the fact that many past experiments were conducted in a purely experimental environment and utilized currently obsolete type-generating methods has left some doubt as to the reliability of any generalizations from the conclusions-- especially when considering the instructional applications.

The areas of solid stroke research which may have had the most relevant application to computer generated information, were areas in which the most serious shortages have existed. Specific shortages of past solid stroke research fell in the area of of spatial factors and spatial coding. Hartley (1979) and Shebilske (1982) have recognized a need for more spatial research because of the increased spatial problems with computer text (Reynolds, 1979; personal communication, March 15, 1984).

Electronic text fonts, although similar in the construction of alphanumeric font design, have had only limited application to dot-matrix print. The considerable amount of literature that has existed on electronic text legibility has provided excellent groundwork for dot-matrix

print research. However, the findings from computer screen studies have not been directly applicable to dot-matrix print because of the many dissimilarities in the image generation characteristics and reading situations (Operbeck, cited in Reynolds, 1979).

Typographic characteristics of dot-matrix print differed from any of the previously studied typestyles or fonts. The review of the literature has not answered questions concerning the legibility of dot-matrix print, especially in the areas of character density, typestyle, and ability of the type to be reproduced.

Character density has varied greatly from character to character on a dot-matrix printer because of the nature of the printing process. However none of the fastest and most economical single pass dot generations observed by this investigator appear to have met the density criterion of solid stroke letters specified by Poulton (cited in Reynolds, 1979).

Individual dimensions of each letter have been further affected by character density. The optimal individual character dimensions cited by Tinker, Prince, Watts and Nisbett, and others could be seriously questioned if those criteria were tested against dot-matrix print.

As image degradation has been a factor which most solid stroke type designers have incorporated into design, it appears to have been almost overlooked with dot-matrix

print characters. The characteristic weakening of the density of a photo-copy may have further affected the individual character densities and type legibility if the image were reduced or enlarged.

Finally, while Coe and Spencer (cited in Reynolds, 1979), recognized that only a few experiments have been done this century using realistic reading situations such as lists of words by Twyman (cited in Kolers, 1979), the current trend of typographical research has been to shift towards actual rather than experimental situations, especially when the research pertains to education. A void has existed, however, between the experiments conducted by behavioral scientists and the experiments which have been conducted in the ergonomic and human factor sectors. Foster and Bruce (1982) recognized the importance of distinguishing between the experiments which have involved subjects reading text materials and those in which the subjects were involved in identifying single character or individual words, such as visibility studies. Additionally, Simcox (1983) concluded that research in graphic communications was rarely a primary focus of an investigation, but an extension of a conceptual framework designed for some other purpose and has rarely examined the process of information communication from a user's viewpoint (Waller, 1979).

CHAPTER III

Research Design and Procedures

This study was conducted to determine if either of the dependent variables, reading rates and reading comprehension, were affected by the independent variables, typefaces and type formatting. Two levels of formatting [justified and "ragged right"] and three levels of dot-matrix typefaces, [single density dot-matrix print, dual density dot-matrix print, photocopied dot-matrix print] were used. Additionally, two control groups were administered the same tests in each of the two formats which were composed in solid stroke type produced with an IBM typewriter.

Subjects

The two hundred-forty subjects for this study were students enrolled in Industrial Education classes at Appalachian State University during the Winter Semester, 1985. Each student was randomly assigned a test treatment and each student received the same treatment in each posttest session. Students were selected from these classes to participate in one of the eight treatment groups. Only subjects who had normal vision or corrected vision were asked to participate.

Group Treatments

University classes and normal classroom conditions in

the Department of Industrial Education and Technology were selected to participate in the investigation. Flourescent lighting was used in all test situations, and the groups read the tests from an optimal reading distance. Class rosters were used as a basis to randomly assign the subjects to the treatments. The 30 subjects in each group were assigned a specific test number such as A-1 or B-29 as an effort to control for groups as well as posttest procedures.

Research Design

A randomized group, pretest-posttest design with experimental and control groups was used to measure the dependant variables against the independant variables. The general paradigm for the research design has been illustrated in Table 1.

Table 1

General Design Paradigm for Study
[Randomized Groups, Pretest-Posttest Design]

Group		Pretest	Independent Variable	Posttest
(R)	(E)	Y1	X [treatment]	Y2
(R)	(C)	Y1	--- [no treatment]	Y2

A factorial design [see Table 2] was used as the specific design of the study. Each of the cells represented one of the eight treatment levels. Treatment levels were coded as Test A, B, C, etc. for clarification.

Table 2

Factorial Design Illustrating
Typographic Variables To Be Explored
[Six Treatments With Two Control Groups]

Typeface	Type Formatting: Ragged Right [Rrf]	Justified [Jt]
Single DMP	Group A [n=30]	Group B [n=30]
Dual DMP	Group C [n=30]	Group D [n=30]
Photo Copied DMP	Group E [n=30]	Group F [n=30]
Selectric Typewriter	Group G [n=30]	Group H [n=30]

Statistical Hypotheses

Three hypotheses on reading rate and three hypotheses on reading comprehension were tested.

Reading Rate. The null hypotheses for testing reading rate were stated as follows:

1. There was no significant difference between the mean scores of the reading rate tests across the two levels of type formatting, justified type and ragged right margin.

Ho: U1 = U2 =. . .Urow

Ha: U1 = U2

2. There was no significant difference among the mean scores of the reading rate tests across four levels of

typeface design: Single density dot-matrix print; dual density dot-matrix print; and photo-copied single density dot-matrix print; and typewriter print.

Ho: U1 = U2 = . . .Uc

Ha: U1 = U2

3. There were no significant interactions among the mean scores of each of the six treatment groups and the two control groups tested that could not be explained by the differences among the population means for either typefaces, typeformatting, or both.

Ho: all [Urc - Ur - Uc + U] = 0

Ha: Urc - Ur - Uc + 0 = 0

Reading Comprehension. Reading posttest means were adjusted using the pretest means as a covariate. The hypotheses for these adjusted means were stated as follows:

4. There was no significant difference between mean reading comprehension scores of two levels of type formatting when adjusted for pretest performance.

Ho: U1 = U2 =. . .Urow

Ha: U1 = U2

5. There were no significant differences among the mean comprehension scores of four levels of typeface variations when these means were adjusted for pretest performance.

Ho: U1 = U2 = . . .Uc

Ha: U1 = U2

6. There were no significant interactions among the adjusted means of each of the eight groups tested that could not be explained by the differences among the population means for either typefaces, typeformatting, or both.

Ho: all [Urc - Ur - Uc + U] = 0

Ha: Urc - Ur - Uc + 0 = 0

Test Instruments

Two seperate instruments were used to measure reading rate and reading comprehension. The measurement of comprehension focused on appropriate application of the Cloze Reading Test as recommended by Hartley et. al (1975). The Cloze Procedure has been validated and tested for reliability by Buros (cited in Aulls, 1976). Hartley, (et. al., 1975) also found the Cloze Reading Test to have a reliability coefficient of .83 in typographic research and to be the most reliable method of all for testing reading comprehension in typographic research.

A seperate speed of reading test was administered since one of the stipulations for administering the Cloze test was not to time the test (Aulls, 1976). Passage I from the Nelson-Denny Reading Test [Form A] was used for testing reading rate. Silent reading speed tests have been shown to be a moderately reliable measure, [.96 among males and .53 among females], of reading speed among university students and have been used with more confidence in the

classroom situation than the alternative oral reading approach (Hartley, 1975). In Hartley's study, differences in the males' and females' reliability scores were attributed to testing procedures, in that the two sessions which were used for the data collection reflected completely different attitudes of the subjects.

The first passage of the Nelson-Denny comprehension test was recommended for the measurement of reading rate because compensation has been made to assure that the difficulty of the passage was such that it should not have affected the rate measurement for the test's target age group, which was grades 9 through 16. The reliability of the initial reading rate test was determined to be .93 as computed by the equivilant forms method of testing for reliability (Nelson and Denny, 1960.).

Test specimens [Appendix A] illustrate the typographic variations which were tested and that the typographic dimensions and specifications of the materials used for the tests were held constant except for the variables being tested.

Specific dimensions of the instruments were held in accordance with optimal reading conditions for the size of type and continuous text as recommended by Tinker (1963) and Reynolds, (1979): paper size was 8 1/2"x 11"; white bond paper was used; type size was 12 point, or as close as the dot-matrix printer would allow; line spacing was

equivilant to one line space, approximately 12 points. Line length was set up on the word processor to obtain a six inch line length. Typographic composition, however, was different for each treatment group, except for a comprehension pretest which was composed on an IBM Selectric Typewriter.

Dot-matrix print was generated by an Epson FX-80 dot-matrix printer which was interfaced with an Apple IIe Personal Computer which utilized an Applewriter II word processing program. A new ribbon was placed on the Epson printer prior to the printing of the test material for each session. A carbon ribbon was used on the typewriter.

Preparation Of Test Instruments

For the comprehension test, passages were randomly selected from an eighth grade literature book (All In America, 1963) to make up the four comprehension tests. Passages have been verified by the North Carolina State Board of Education that the reading book had not been used in the public schools since "around 1970" (Warren, personal communication, January, 1985). Each passage was screened for readability. The pretest was composed with solid stroke type and each of the posttests were composed in each of the typographic variations.

One of the major concerns of comprehension testing in typographic research has been to control for passage difficulty, and to make sure that the test passages were

below the comprehension level of the subjects. The Fry Readability Graph was used to assure that each of the passages was below the comprehension "threshold," or grade level of reading, for the age group being tested. The Fry Graph has been an accepted method for determining readability by selecting passages, counting the first one hundred syllables in the passages, and determining how many whole and parts of sentence are in those syllables (Aulls, 1976). Once this information had been determined, the points were plotted on the Fry Graph to determine the passages' readability level [see Table 3]. Aulls (1976) recommended a fifth word deletion Cloze test for measuring comprehension. Therefore each passage was between 250 and 300 words in length. Fifty words were deleted from each passage used in the comprehension tests.

Table 3

Readability of Passages
as Measured by the Fry Readability Graph

	Syllables per 100 words	Sentences per 100 words
pretest	135	5.3
session 2	130	7.5
session 3	145	6.3
session 4	135	10.5
AVERAGES	137	7.4

*AVERAGE PASSAGE READABILITY [FROM GRAPH] = 7.2

The reading rate test was reprinted with the authors' permission from The Nelson Denny Reading tests, in each of the eight formats mentioned above. The same typographic variables tested in the comprehension test were tested with the Nelson-Denny test [see Table 2].

Testing Procedures

One of the decisions at the outset of the experiment was to collect data from 30 subjects per cell to obtain as high a statistical precision as possible. A decision was made that if attrition or mortality of the subjects should occur, a minimum of 20 subjects per cell would have been acceptable. The task of collecting the data was accomplished with the assistance of four graduate students. Either the graduate students or the investigator served as a moderator for the testing sessions. Graduate students were briefed about the investigation and appropriate procedures before the administration of the tests. Prior to any actual testing session the graduate student moderators were administered a "dry run" of the actual tests.

Permission for conducting the experiment was obtained from the participating instructors as well as the department chairman. Prior to the first session participating classes were informed of the general purpose of the experiment and subjects were asked to participate. On the first day of testing students were given a detailed

set of instructions. The instructions included a demonstration of the reading rate test and a sample comprehension test. A question and answer period followed.

Administration Of Tests

Data collection was originally to be accomplished during four separate testing sessions, one session to be performed per class session, therefore taking only a minimal amount of time from the participating classes.

The purpose of the first testing session was to collect pretest data from all subjects for analyzing comprehension as well as data which were used in the analysis of the speed of reading for each of the groups. Prior to the presentation of test packets, students were given an explanation of the two tests. Students then received a sealed packet containing the reading rate test and the pretest material. The Nelson Denny reading rate test was administered first because the test could be administered in one minute. At the end of one minute students were asked to stop reading and to circle the last word they read. Students were instructed not to proceed any further until told to do so. The remaining time was spent collecting pretest data by using the Cloze procedure. Students were given a sample comprehension test as part of the instructions to assure that they understood how to take the comprehension test. After answering any questions, the first comprehension pretest session was begun. Each test

packet contained the same comprehension pretest, and students were not aware that the first session was any different from any of the following sessions, although the subsequent tests would be typographically different. Following Aulls' (1976) recommendations on administration of the Cloze test, the comprehension pretest was not timed. Average completion time for the Cloze test was about 30 minutes. Session one was concluded upon the completion of the comprehension pretest.

The last three testing sessions involved collecting posttest data relating to reading comprehension. Specific instructions were included as the first page of the test instrument, and the class rosters were used to assure that the same treatment in each test session was applied to each subject. The procedures for each of the sessions were identical and were similar to the procedures used in administering the comprehension pretest.

At the end of the first four sessions, however, only 27 [11.25%] of the 240 subjects had completed enough test material which could be used for data analysis. The "usable" data was from subjects who had completed a pretest and at least two posttests. The low number of completed instruments was attributed to bad weather conditions which caused interruption of classes that week. Therefore the initial data collection period was extended. The same procedure was performed for the extended period of data

collection.

Five weeks were required to obtain enough scores in each of the eight cells to meet the minimum number of subject requirements [n=20]. At the end of this second phase of the data collection, only 160 [66.6%] of the 240 subjects had been tested. Unsuccessful follow-up attempts by graduate students had influenced the decision to further extend the data collection period. Therefore a decision was made to extend the data collection period as long as the participating instructors would allow, in hopes of increasing the number of subjects in each of the cells and increasing the precision of the analysis. The third phase of the data collection was extended for five additional weeks and ended one week prior to the conclusion of regular classes, at which time two of the instructors had indicated that class time was necessary for the completion of course requirements.

Test Scoring

Grading and scoring of the test material was conducted manually by the investigator and one assistant. The investigator was present at all scoring sessions so that any judgemental decisions, such as interpreting handwriting, could be made by one person and consistancy of scoring could be maintained. Any test returned by a subject without responses, that is, where there was no evidence of having attempted the test, was omitted and was

recorded as incomplete data.

The same procedure used by Nelson-Denny was used to collect the raw scores for the reading rate. The word circled by each student was located by the recorder, and was converted to a numerical "line score" [see Appendix A]. Since the typographic variables caused this line score to differ from the original Nelson-Denny scoring sheet, a "master" scoring sheet was made up with the appropriate line endings marked so that the same scoring technique could be employed [see Appendix A]. Once the line scores were recorded, they were used to determine the mean scores for each group. The mean scores for each group were used in the statistical analysis.

For reading comprehension, students were scored according to the number of correct words they inserted in the blanks. In addition to marking the actual "wrong word" as incorrect, mispelled words, gramatically incorrect words, unanswered blanks, and blanks which had more than one word in the blank were also counted as incorrect. Since there were fifty blanks in each test, the raw score was doubled to obtain a score based on 100% for simplicity of interpretation. The mean scores of the three posttests were used with the covariate pretest means of each group in the statistical analysis.

Although the extended data collection period increased the number of subjects per cell, there was still some

incomplete data in each of the cells for both reading rates and reading comprehension scores. The resulting 10 week data collection period yielded a 96% completion on the reading rates.

On the reading comprehension tests, subjects were omitted from the data analysis if they had not completed either the pretest and at least two of the posttests. The data collection period yielded a total of 208 usable instruments [86%] from the 240 subjects. Table 4 reflects the numbers of subjects per cell used for the analysis.

Table 4

Number of Subjects Per Cell Used in Data Analysis

	Treatments							
Tests	A	B	C	D	E	F	G	H
Reading Rate	30	30	29	30	26	29	29	28
Comprehension	30	25	29	26	23	24	26	25

Statistical Procedures And Analysis

After the completion of data collection, the data were input into the mainframe computer at Appalachian State University and were verified for accuracy. Corrections for typographical errors were made prior to the statistical analysis. The Statistical Package of the Social Sciences [SPSS] was used for the analysis.

A factorial analysis of covariance was used to measure

comprehension across all levels [see Table 5]. The pretest mean [X] for each group were used with the posttest means [Y1; Y2; Y3] to obtain the covariate data used in the statistical analysis of covariance.

Table 5

Factorial Design Illustrating Typographic Variables Which Were Explored [Six Treatments With Two Control Groups]

	Type Formatting	
Typeface	Rrf	Jt
Sdmp	Group A	Group B
Ddmp	Group C	Group D
Pcdmp	Group E	Group F
Sst	Group G	Group H

The analysis of covariance (ANCOVA) allowed for a comparison of group means on the dependent variable, comprehension, after the group means had been adjusted for differences between the groups on the covariate pretest. ANCOVA allowed for stronger statistical precision (Lindquist, 1940) in the conclusions drawn from the experiment. This analysis should have adjusted for any group differences so that any significant differences in adjusted mean scores of the treatment groups could have

been attributed to the treatments. The posttest means [Y1; Y2; Y3] were adjusted on the basis of the covariate [pretest] means and these adjusted means of each group were examined for possible differences.

As with ANOVA, there were assumptions which should not be violated (Huck, et. al, 1978). Since there was an unequal number of subjects in the groups, a test of the homogeneity of variance was employed.

Application and interpretation of the two way ANCOVA was similar to the two way ANOVA, except that the analysis was made on the adjusted means. F-Ratios pertained to adjusted means and there was one less degree of freedom because of the inclusion of covariate data (Huck, et. al, 1978). The Two Way ANCOVA allowed for a comparison of the overall adjusted means, the main effects, for the levels making up each of the independent variables. Additionally, interactions were analyzed to look at every possible combination of typeface by type formatting. The F-values of the adjusted means were checked for any statistical significance at the .05 level.

The factorial design shown in Table 5 was also used for the reading speed test. Reading speed was analyzed by performing a two way analysis of variance [ANOVA] on the scores of the reading rate test. Statistical significance of the f-test at .05 level of significance determined if there was any significant difference between the overall

row and column means, the main effects, as well as an interaction of the means of each of the cells.

Summary

The research methodology employed in this study differed from the original research plan in two respects. First, the originally planned data collection period of approximately two weeks was somewhat unrealistic. Inclement weather and the realities of data collection resulted in a longer time frame required to collect enough usable data. The extended data collection period did, however, provide a greater number of subjects for this study.

Secondly, the original plan assumed that equal cell sizes would be obtained for the statistical analysis. Again the human factor intervened and some data was omitted from the study because of erroneous responses. Neither of these differences should have affected the outcome of the study, since every effort was made to insure that the identical procedures and methodologies were employed during the extended data collection period and adequate statistical procedures were employed to compensate for the unequal cell sizes.

CHAPTER IV

Analysis Of Data

The purpose of this data analysis was to:

1. Determine if the groups tested were homogeneous.

2. Identify any significant differences in the mean reading rate scores when tested on two levels of type formatting and four levels of typeface design.

3. Identify any significant differences in the mean reading comprehension scores when tested on two levels of type formatting and four levels of typeface design.

4. Determine whether or not there was a significant interaction of type formatting and typeface on reading rate.

5. Determine whether or not there was a significant interaction of type formatting and typeface on reading comprehension.

Analysis Strategy

The data collection produced a total of 231 usable instruments that could be analyzed for reading rates and 208 instruments that could be used to analyze reading comprehension. A non-orthogonal approach was used to conduct the data analysis because of the resulting unequal cell sizes.

Group Homogeneity

Since cell sizes were unequal, the basic homogeneity

of groups could not be assumed (Hinkle, et al., 1981; Huck et. al., 1974; Kerlinger, 1973). Pretest scores of students who took the reading rate test and the reading comprehension scores were used to assess homogeneity of variance. Although there were a number of popular tests for homogeneity of groups, Hartley's F-Max test of homogeneity of variance was performed because of the test's simplicity. The results of the F-Max test indicated the groups were not significantly different.

Table 6

Results of F-Max Test
for Homogeneity of Variance

	Reading Rate		Reading Comprehension	
	n	Variance	n	Variance
Treatment				
A	30	80.13333	30	80.133330
B	30	63.82069	25	47.826670
C	29	79.73399	29	79.733399
D	30	99.05747	26	100.258500
E	26	55.65538	23	57.407110
F	29	124.8768	24	117.036200
G	29	71.30542	26	72.966150
H	28	81.92063	25	84.560000
F Max =		2.243751		2.4447092
Fcv [8,30] [from Hartley F Max Table] p < .05 = 3.12				

F values were calculated for each of the groups tested for reading rates and reading comprehension. The largest variance was divided by the smallest variance to determine F [see Table 6]. The largest sample size [n=30] as recommended by Hartley was used to obtain the degrees of

freedom [8,30] used in the analysis. The results in Table 6 have substantiated that the F value for both reading rates [2.243] and reading comprehension [2.244] did not exceed the critical value [3.12] at the .05 significance level when tested against Hartley's F-max table.

Therefore, the hypotheses stating there were no significant differences in the variances of the subgroups who took either the reading rate tests or the reading comprehension tests were not rejected.

Testing The Null Hypotheses

Testing the null hypotheses involved a more complex approach than anticipated because of the unequal cell sizes. Three options, the classical, hierarchical, and regression approaches, which were designed to compensate for unequal and/or disproportionate cell frequencies were used in the analysis. Each of the approaches yielded little difference in the computational results. Therefore, the default option, the classical experimental approach, was used in the analysis. According to SPSS (1975), the classical experimental approach has generally partitioned the total sum of squares into three types and all three components have been made orthogonal to one another by having a certain hierarchy imposed:

SSa,b = sum of squares due to additive effects of A and B

SSab = sum of Squares due to the interaction effect =

SSa,b,ab - SSa,b

SSerror = sum of squares due to error = SSy - SSa,b,ab.

With the classical experimental approach, the main effects for A were assessed with B held constant, and the main effects for B were assessed with A held constant. Interaction was assessed with the main effects held constant.

Strategies for significance testing were followed as recommended by SPSS:

1. Testing for significance of interaction.

2. Testing the significance of the additive model if the interaction proved insignificant.

3. Testing the significance of each main effect.

The results have been summarized in Tables 7 [reading rates] and 8 [reading comprehension].

Reading Rates

Typographic variations of the Nelson-Denny Reading Rate Test were administered to eight groups to determine differences in reading rates. A two way analysis of variance was used to analyze the reading rate data. The results of the two way analysis of variance indicated there was no significant interaction of typeface and typeface format on reading rate ($F = 1.400$, $df = 3,223$). There was also no significant effect attributed to typeface or type format due to the non-significant differences between the

typeface groups (F = .535, df = 3,223); or type formatting groups (F = .489, df = 1,223). An ANOVA summary table for reading rates is found in Table 7.

Table 7

Analysis of Variance: Reading Rates

Source	SS	df	MS	F
Typeface [A]	7950.395	3	2650.131	.535
Formatting [B]	2420.867	1	2420.867	.489
A x B	20801.820	3	6933.938	1.400
Error	1104131.000	223	4951.258	
Total	1135345.000	230	4936.281	

Reading Comprehension

The mean post-test comprehension scores were used with the covariate pre-test scores in the analysis of covariance. The covariate was used in the design to adjust post-test means for differences in pre-test performance of the groups.

Table 8

Analysis of Covariance: Reading Comprehension

Source	Adjusted df	Adjusted MS	F
Typeface [A]	3	87.177	1.078
Formatting [B]	1	8.614	.107
A x B	3	98.833	1.223
Error	199	80.877	
Total	207	105.002	

The analysis of covariance indicated there were no

significant interactions among the groups (F = 1.223, df = 3,199). There was also no significant effect attributed to typeface or type format due to the non-significant differences between the typeface groups (F = 1.078, df = 3,199); or type formatting groups (F = .107 df = 1,199).

Findings

Hypothesis 1

Hypothesis 1 stated that there would be no significant difference between the mean scores of the reading rate tests when tested on two levels, justified and ragged right, of type formatting.

After analyzing the Nelson-Denny reading rate data collected from each of the formatting groups, using two-way analysis of variance procedures, it was found that there was no significant difference, at the .05 level, between the mean reading rate scores of the groups tested on justified and ragged right type formats. The mean reading rate score of subjects who were tested on ragged right format was 239.64 while the mean score of those who read justified type was 233.11.

Slight, though insignificant differences were found in the reading rates of the formatting groups. However, using the .05 level of significance, the null hypothesis 1 could not be rejected.

Hypothesis 2

Hypothesis 2 stated that there would be no significant

difference between the mean scores of the reading rate tests when tested on four variations [levels] of typefaces [single density dot matrix print; dual density dot matrix print; photo-copied single density dot matrix print; and typewriter print].

The analysis of the Nelson-Denny reading rate data collected from each of the typeface groups, using the two-way analysis of variance procedures, found that there was no significant difference, at the .05 level, between the single density, dual density, and photo-copied dot matrix print and typewriter type.

Table 9 depicts the mean Nelson-Denny scores of all groups who read each specific typeface.

Table 9

Mean Nelson-Denny Typeface Scores

	SD	M
Sdmp	55.27	231.20
Ddmp	81.04	245.54
Pcdmp	67.98	231.33
Sst	76.37	237.04

The slightly different scores show that groups reading dual density type scored higher than the other typeface groups, but the difference was not statistically significant.

Hypothesis 3

Hypothesis 3 stated that there would be no significant interaction of typeface and typeformatting. The analysis

of variance procedures indicated there was no significant interaction at the .05 level.

Table 10 presents the mean Nelson-Denny reading rates of the eight groups. The group of students who read ragged right, dual density dot matrix print scored highest on the Nelson Denny Test, but not enough to be significantly different from the other groups.

Table 10

Mean Reading Rate Scores

	Ragged Right		Justified Type	
	SD	M	SD	M
Sdmp	63.74	229.73	46.34	232.67
Ddmp	99.0	265.03	53.89	226.70
Pcdmp	67.98	225.96	86.50	236.14
Sst	63.59	236.76	68.41	237.32

Hypothesis_4

Hypothesis 4 stated that there would be no significant difference between mean reading comprehension scores of two levels of type formatting when adjusted for the covariate scores.

The analysis of Cloze test reading comprehension data concluded that there was no significant difference, at the .05 level, in the mean reading comprehension scores, when adjusted for the covariate, of students tested on justified and ragged right type formats. The mean Cloze test scores of subjects tested with ragged right format was 56.25 while the mean scores of those tested with justified type was

55.38.

Slight, though nonsignificant differences were found in the reading rates of students who read justified and unjustified type. Therefore the null hypothesis 4 was not rejected.

Hypothesis 5

Hypothesis 5 stated that there would be no significant difference between the mean comprehension scores of four levels of typeface variations when the scores were adjusted for the covariate scores.

The analysis of Cloze test reading comprehension data concluded that there was no significant difference, at the .05 level, in the covariate scores of subjects who were tested on single density, dual density and photo-copied dot matrix print and typewriter type.

Table 11 reflects the mean Cloze test scores of all groups who were tested on a specific typeface. Interestingly, the groups who scored lowest on comprehension were those who read solid stroke type.

Table 11

Cloze Test Means of Typeface Groups

	SD	M
Sdmp	11.95	55.19
Ddmp	9.00	57.12
Pcdmp	10.60	57.11
Sst	11.20	53.96

From the preceeding findings, the null hypothesis 5

could not be rejected.

Hypothesis 6

Hypothesis 6 stated that there would be no significant interaction of typeface and typeformatting on the adjusted postest means. The analysis of covariance procedures indicated there was no significant interaction at the .05 level.

Table 12 depicts the individual cell means of the Cloze tests. The group who scored highest on the Cloze reading comprehension test was those who read ragged right, dual density dot matrix print, but not enough to be statistically significant from the other groups.

Table 12

Individual Groups Means of Cloze Tests

	Ragged Right		Justified Type	
	SD	M	SD	M
Sdmp	6.36	53.53	6.75	57.17
Ddmp	9.2	59.06	13.0	54.95
Pcdmp	6.49	58.00	9.71	56.25
Sst	12.0	54.69	54.18	53.20

From the preceeding findings, the null hypothesis 6 was not rejected.

CHAPTER V

Summary, Discussion, and Recommendations

Summary

Background

The methods used to create instructional aids have undergone many changes because of computerized word processing. Two design characteristics which have attracted renewed attention are the dot-matrix typestyles and formatting variables associated with word processing. The combination of these variables has raised questions as to whether the most common word processing typestyles and formatting options affect the reading rates and reading comprehension of certain groups of students. The problems may be compounded when the computer output was photo-copied for use in classes.

Researchers have concluded that reading rate and reading comprehension can be affected by a combination of reader and typographic variables. Readers' ages, abilities, attitudes and backgrounds can affect reading while a number of typograhical variables, including spatial and type factors, influence readability and legibilty.

The literature review indicates that a void exists between the legibility research on the traditional solid stroke type and computer generated type. Although a substantial amount of research has been done in both solid

stroke and computer screen imagery, little has been done on dot-matrix print.

Purpose

The purpose of this study was to examine the effects of two major typographical variables of computer type, type formatting and typeface, on reading rates and reading comprehension of college students. Three computer typefaces, [single density, dual density, photo-copied dot-matrix print] as well as typewriter type were compared. Two formatting variables, justified and ragged right type, were tested.

This study focused on administering reading rate and reading comprehension tests to eight groups of college students to determine which groups scored higher. These groups consisted of students who read:

1. single density, ragged right dot-matrix print.
2. dual density, ragged right dot-matrix print.
3. photo-copied, ragged right dot-matrix print.
4. solid stroke, ragged right type.
5. single density, justified dot-matrix print.
6. dual density, justified dot-matrix print.
7. photo-copied, justified dot-matrix print.
8. solid stroke, justified type.

Procedure

Thirty subjects were randomly assigned to each of the treatment groups. Nelson Denny reading rate tests and

Cloze reading comprehension tests were administered to the subjects in an eleven week period. Each group received the same treatment throughout the testing session.

Reading rate data were collected from one test. A two way analysis of variance was used to test for any significant interactions among groups and any differences between typeface groups or type formatting groups.

Four tests, a pretest and three post-tests, were used to measure reading comprehension. The postest means of each group were adjusted against the pretest means, or the covariate. The adjusted means were used to perform an analysis of covariance to determine any significant interactions and any differences between typeface groups and type formatting groups. The .05 significance level of the F test was used in each analysis.

Findings

No significant interactions were found among the mean reading rate or the mean reading comprehension scores. Additionally, no significant differences were found between typeface or type formatting groups of the subjects measured on either reading comprehension or reading rate.

Conclusion

The conclusion of this study is that typeface and type format did not influence reading rates or reading comprehension of the subjects studied.

Discussion

The literature review identifies that one of the weakensses of typographic research has been that variables, methodologies, and even statistical procedures have been largely inconsistent, and have yielded varying results and limited generalizations. The review of literature indicated that the two large categories of typographic research, behavorially-related and ergonomically-related, have yielded different results primarily because of the methods in which the variables were treated. Behaviorially-related research, such as that of Wendt (1979), Shibelski (1981), and Lewis and Sykes (1984) incorporated reader variables into the studies, and for the most part, have simulated realistic reading situations. Ergonomic related research, such as that of Snydor and Maddox (1978), and Riley and Barbato (1978) focused on individual letter character recognition.

Since one of the objectives was to determine the effects of typographic variables on classroom instructional materials, this study focused on collecting data in a realistic [i.e. classroom] environment. In the absence of concrete models for performing typograpical research, the design of this study was based on a synthesis of and recomendations from the literature review.

Past studies of Tinker (1963) and others provide evidence that either spatial or typographic variables can affect legibility or readability. Of all of the spatial

factors, justified and ragged right type seemed most pertinent to word processing. The four typestyles were selected and tested because they were most common to the computer and/or classroom environment.

None of the methodologies seemed appropriate for measuring the dependent variables of this study, especially reading comprehension. Of all the methods used for testing typographical variables against reading compehension, [timed, nonsense sentences, question and answer tests, oral scanning/retrieval], the Cloze procedure seemed most appropriate and perhaps the least intimidating of the methods used. Comprehension is best measured in an untimed atmosphere, and the informal administration of the Cloze procedure was determined by Hartley (1975) to be the most effective for typographical research. The informal administration of the Cloze test in this study perhaps reduced anxiety among subjects and/or other common flaws of experimental testing.

Failure to simulate an actual classroom situation could yield inaccurate generalizations. Foster and Bruce (1982) cautioned that, in the interpretation of research outcomes, one should distinguish between the experiments which involved subjects reading text and those in which the subjects were involved in identifying single characteristics or individual words, such as visibility studies.

Ergonomic related research would perhaps have yielded somewhat different results. From the behaviorial perspective, ergonomic research has several shortcomings. Many of the visibility studies have examined only single character, half-font [either uppercase or lowercase letters] presentations, and utilized the tachistoscope or timed exposures.

The results of such studies would yield different results for several reasons. Significant differences in type fonts or individual characters were found by Snydor and Maddox (1978), Shurtleff and Owen (1966), and Riley and Barbato (1981). A disadvantage of the tachistoscope is that the testing process does not measure the interaction of reader and text variables. Specifically, it does not allow for measuring the psychological [perception of learning or kind of material] nor the physiological factors [eye movement, eye fixation, and letter and word recognition] that Massaero, et. al. (1981) identified as essential for measuring reading. Therefore, these studies do not offer the contextual advantage or disadvantage of normal reading material, and fail to measure the readability of textual and environmental interactions. Thus, the use of the tachistoscope has limited generalization to actual reading situations, or comparison to other types of studies.

An intermediate research methodology utilizing

artificial reading situations is not purely experimental but provides for more control than a classroom environment. Artificial reading situations are those experiments in which the investigator does not rely on normal reading conditions, such as passages, for data collection. Two such tests are the Nelson-Denny comprehension test and the nonsense passages used by Hartley (1975).

Outcomes using either of these methods might have yielded different results. Although comprehension, prior knowledege, and passage difficulty would have been controlled, the timed test characteristic of the Nelson-Denny test may have affected the outcome of the study.

The Hartley procedure would not have controlled for the variables test anxiety, attitude, and frustration. The nonsense sentences used in Hartley's experiment were intended to control for comprehension and the students' prior knowledge. Although passage difficulty was not an intervening factor, student attitude toward the sentences may have affected the outcome of the study. Additionally, data concerning the validity and reliability of the test procedures were not available. The literature suggests there are a varitey of extraneous variables that are difficult to control in the research design.

Although the research procedures in this study were carefully designed to eliminate the effect of the

extraneous variables, there were several factors which may have influenced the outcome. Most importantly, students generally seemed more motivated and receptive in the beginning of the experiment than in the end. The researcher observed a general decline of student interest as the study proceeded. The observed change in attitude may have been caused by the length of the data collection period or by the repeated use of the Cloze tests in the data collection.

There was no way to determine if the extended data collection period had any affect on student attitudes and therefore the outcome of the study. The study did not control for the effect that each successive passage may have had on the outcome, or whether one passage significantly affected the outcome of the study. With the Cloze tests, the students had the option to read and reread the material until they were comfortable with the response, or until reader frustration set in.

The review of literature did not identify a test that controls for reader attitude and related problems. The primary difference between the Cloze test and other passage-related tests was that the reading of Cloze test passages more closely simulated a typical classroom situation.

The results of this study suggest that university level educators may freely use any of the common computer

typestyles or type formats without affecting reading rates or comprehension. The means of both the reading rate and reading comprehension tests were higher when the students read dual density, ragged right computer print. While these differences were not significant, the sample data did show a trend which may indicate a preference for reading computer print which most closely resembles traditional solid stroke type and formatting.

Recommendations

Recommendations for additional research could be justified on the basis of the scarcity of research in computer generated print. Reader variables such as age and ability level may affect the research outcomes, perhaps justifying research using other populations. As a result of this study the researcher recommends:

1. Extended research on the effects of computer generated type on elementary and secondary school students. The literature review suggested that the outcome of reading tests can depend on the subject's age, reading ability, and attitude. Since each of these variables are characteristic of certain public school populations, it would seem probable that different results may be obtained from other groups.

2. The development of a model reading rate and reading comprehension test for typographical research. The literature review has suggested that research methodologies

have been largely inconsistent and have limited generalizations to other populations. A valid and reliable model would provide for consistency in research procedures and findings and therefore allow for more generalization.

3. The development of a model attitudinal scale for typographical research. A valid attitudinal scale for typographical research is virtually non-existent at this time. A valid and reliable model would provide more insight into the effect that attitude has on typographical variables, since attitude can significantly affect the outcome of a study.

4. The development of a more co-operative research effort between industry and education in ergonomic and human factor related research. Requests for pertinent literature and/or support of the research from computer printer manufacturers yielded little usable information. The scant amount of information received from industry as well as the literature review indicate a need for bridging the research gap between ergonomic and behavior science research.

5. The use of the tachistoscope approach to test character legibility. Since the tachistoscope forces a brief timed exposure to visual objects for determining the conditions under which they are perceived, the methods employed would likely yield somewhat different results. Using this approach would maximize control for reader

variables and emphasize individual character and/or word recognition.

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APPENDIX A

SESSION ONE TEST SPECIMEN

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

GENERAL INSTRUCTIONS

Thank you for participating in this experiment. You will be involved in four test sessions and today will be the first session. In this session you will be involved in two separate tests: a test on reading rate and a test on reading comprehension. Please read the following instructions as the moderator reads aloud.

A. This is a reading rate test. When you begin the test remember that there are three pages to this test and you are to continue from page to page until the monitor or instructor signals you to stop.
B. When the monitor gives the signal to stop reading, mark (by underlining) immediately the last word you read.
C. You may put your pencil down and wait for further instructions from the monitor.
D. Thank you for your participation.

About three centuries after Homer's time, Greek poets began to discover new kinds of verse, and the way in which poems were made. No one has ever done so much for the poetry we write and read to-day as the singers who sang in the islands of the AEgean Sea and in the cities on the mainland of Greece, like Thebes and Athens, during a few hundred years of supreme poetic activity.

Who were these poets?

Many names have come down to us, and very little poetry. Of some of the singers the Greeks thought greatest, only a few complete poems remain, and some fragments, usually quoted in the essays or romances or histories of other writers. For poetry had to be written down by hand or cut on stone, and war and fire, frost and earthquakes have destroyed most of the marble tablets and manuscript books that were made. Those remaining are like the fragments of a beautiful broken vase. Much is dust, much is marred or lost. The pieces will never be put together. We can only guess what the whole was like, we shall never know.

But from what the Greeks wrote of their poets in manuscripts that have survived, and from such poetry as we have, we can get some idea of certain great singers.

The first is hesoid, a poet living not long after Homer, or perhaps in Homer's own time, among shepherds of Boeotia. It is possible that at the time Hesoid wrote, certain changes that were to take place in the Greek world had already begun. We know that it was not long after Homer's day that the cities and islands began to shake off the rule of the kings. They made oligarchies, or governments-of-the-few, and democracies, or governments-by-the-people. They began to pay less attention to war and more to commerce, art, games, oratory, singing, dancing, and talking.

At any rate, Hesoid wrote much poetry suited to this quieter, friendlier life. He made a kind of encyclopedia of the gods, their ancestry, birth, adventures and habits; and for hundreds of years, the Greeks conulted and quoted his Theogony. He wrote also and Works and Days, a long poem about the times to plough and sow and the way to choose a wife and educate children and go about farming and trading. Such poems drew later poets more easily into poetry about their new life. They did not forget their heroes--Odysseus and Agamemnon and Theseus and Jason, but began to sing also of politics, trade, athletic contests, love.

As they turned to new subjects, they made a

tremendously important change in poetry. One of their poets, Archilochus, began to make poems in a metre different from Homer's. He used word groups of two instead of three syllables--iambics they were called. He also used fewer feet in each line, often writing in trimeter and tetrameter (three and four measure) instead of hexameter. He began also to write poems ridiculing the faults of men and women -- the beginning of what we call satiric poetry. He and other poets discovered that, not only was it possible to make one or two kinds of poetry different from the Epic verse, but that every thought or feeling could be sung in a poetry suited in metre to its own character. Epic poetry had been poetry of the race. The new poetry was personal.

One of their earliest of the new poets was Sappho. The Greeks used to say that Homer was the greatest of men who made poetry, and Sappho was the greatest of women.

She lived in the island of Lesbos in the Seventh and Sixth centuries before Christ, and had there a school in which she trained young women to dance and write and chant poetry.

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DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

The second part of the testing session today will be a comprehension test. When you are told to do so, you will begin reading a passage which has some words deleted. The first and last sentence of the passage are complete sentences. As you read the passage, fill in the blanks with the word which you think is the correct word. The following is an example of the procedure. Read the passage and fill in the blanks with the word you think is correct.

EXAMPLE:

My mother said it is impossible to teach an old dog new tricks. However, _____ should see the dog _____ have. She is ten _____ old, and has just _____ to to do several _____ including rolling over, fetching _____ newspaper, and playing dead. _____ all these new tricks, _____ might be able to _____ her in some kind _____ contest; that is, if _____ will allow old dogs _____ such competition. I believe I could have a good argument with my mother that old dogs can learn new tricks if the trainer has enough patience.

Now look at the complete passage below. Were you very accurate with your answers? The number of correct answers [those that match the passage] will be used to measure reading comprehension.

COMPLETE PASSAGE

My mother said it is impossible to teach an old dog new tricks. However, you should see the dog I have. She is ten years old, and has just learned to to do several tricks including rolling over, fetching the newspaper, and playing dead. With all these new tricks, I might be able to enter her in some kind of contest; that is, if they will allow old dogs in such competition. I believe I could have a good argument with my mother that old dogs can learn new tricks if the trainer has enough patience.

When the moderator gives the signal, you may begin this portion of the test. The actual test passage is not very long, but you may have as much time as you like. When you complete the passage, this first session is completed.

THANK YOU AGAIN FOR YOUR CO-OPERATION

Most of the fellows and girls in Milford High thought that Spider Johnson was a clown. "_____" wasn't his real name, _____ somehow fitted him perfectly. _____ was a long, lanky _____, all arms and legs. _____ wasn't sensitive about his _____ or his nickname though. _____ was always good-natured. _____ laughed a lot, he _____ affectionate, he was optomistic -- _____ ever seemed to get him _____. We all liked him.

_____ first turned out for _____ in his junior year. _____ year, at the district _____, he came in last _____ his event, the half-_____ race. But because he _____ so good-natured, we _____ not take his loss _____. He was laughable with _____ ungainly stride, and out _____ cheered him on right _____ the finish line.

I _____ him right after the _____. He was still shaking _____ the effort he had _____, but just smiled _____ me and shrugged his _____. "Well, somebody had to _____ in last," was his _____ comment. But the defeated _____ in his brown eyes _____ his sunny tone. It _____ then that I realized _____ Spider was dead serious _____ his running.

During the _____ school year, Spider and _____ became better acquainted, and _____

began to have a _____ understanding of him. He _____ no all a clown, _____ had a serious side, _____. He loved sports, but _____ was too thin for _____ and too awkward for _____. Those were my games. _____ was a senior, captain _____ halfback on our football _____ and guard on the _____ team.

Spider managed our basketball team.

PRETEST ANSWER SHEET

1. Spider
2.it
3.he
4.youth
5.He
6.appearance
7.Spider
8.He
9.was
10.nothing
11.down
12.Spider
13.track
14.That
15.meet
16.in
17.mile
18.was
19.did
20.seriously
21.his
22.fans
23.to
24.saw
25.race
26.with
27.made
28.at
29.shoulders
30.come
31.cheerful
32.look
33.belied
34.was
35.that
36.about
37.next
38.I
39.I
40.deeper
41.was
42.he
43.too
44.he
45.football
46.basketball
47.I
48.and
59.team

50.basketball

APPENDIX B

SESSION TWO TEST SPECIMEN

GENERAL INSTRUCTIONS

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

This is the second of four reading tests on comprehension you will be taking. The process is the same as the process which was done in the previous session. If you do not remember the procedure, please notify your monitor now for a demonstration.

When the moderator gives the signal you may begin, and you may have as much time as you like to complete the test.

When you are finished, return the test to your packet.

The young man and his sister were craning their necks at the steel framework of the office building rising so gracefully into the blue summer sky, they had just come from church, and there in the business section of the city, the streets were almost deserted.

"How proud she stands into the _____!" said Roger Benz. The _____ of the hoisting engines, _____ derricks and booms, and _____ pneumatic hammers was all _____ for Sunday.

"You said _____ as if you love _____ building," Helen said.

Roger _____ his gaze down from _____ topmost steel column and _____ at his sister. "Do _____ know what you would _____ like from up there _____ I work?" he asked.

_____ shook her head.

"An _____."

"What a thing to _____!" she pouted.

"I mean _____look as small as _____ ant," he laughed. "Come _____, let's walk around, and _____ try to explain some _____ the work to you."

"_____, he asked, "Any questions?"

"_____, one. Why do you _____ in

doing such work _____ summer, when you know _____ going to engineering school _____ the fall?"

He pretended _____ wince at her use _____ the word fall. "Please _____ autumn, Sis. Don't mention _____ word to me all _____. But to answer your _____----Well, you see, I _____ a taste of the _____ side of engineering before _____ got into the theory _____ . Anything wrong in that?"

"_____ suppose not," she answered, " _____ you don't get hurt."

" _____ danger of that," he _____ with a heartiness that _____ wished he could feel.

_____ was a rivet jack, _____ apprentice who climbed up _____ ladders and teetered across _____ wind swept beams to _____ the workmen buckets of _____ or anything else they _____ need. And, in common _____ the other "sky boys," his greatest enemy was the wind. Only those who have climbed the heights of steel, and even on the coldest day have wiped the sweat away, can know the trickiness of the wind.

ANSWER SHEET FOR SCORING SESSION TWO

1. sky
2. clangor
3. the
4. the
5. silvered
6. that
7. this
8. swung
9. the
10. looked
11. you
12. look
13. where
14. She
15. ant
16. say
17. You'd
18. an
19. on
20. I'll
21. of
22. Later
23. Yes
24. persist
25. this
26. you're
27. in
28. to
29. of
30. say
31. that
32. summer
33. question
34. wanted
35. practical
36. I
37. part
38. I
39. if
40. Little
41. he
42. he
43. He
44. An
45. steep
46. the
47. bring
48. rivets
49. might

50.with

APPENDIX C

SESSION THREE TEST SPECIMEN

GENERAL INSTRUCTIONS

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

This is the third of four reading tests on comprehension you will be taking. The process is the same as the process which was done in the previous session. If you do not remember the procedure, please notify your monitor now for a demonstration.

When the moderator gives the signal you may begin, and you may have as much time as you like to complete the test.

When you are finished, return the test to your packet.

I parked my motor scooter on Eaton Avenue and started up the street. It was cold and _____ in the mid morning, _____ I had a cold, _____ feeling in the pit _____ my stomach as I _____ through the back door _____ into our town's main _____ office. The big room _____ out ahead of me. _____ seemed about a mile _____.

The P.A. box above _____ head sputtered, and a _____ said, "All Christmas helpers _____ Auburn High are to _____ to the time clock _____ once. I repeat, all----"

_____ me, I thought, looking _____ for the time clock.

"_____ from the high-school?" a voice inquired at _____ elbow.

"Yes, sir," I _____. I'm Walter Halleck."

"Come _____ me."

The man took _____ arm, and we went _____ an aisle between tall _____ bins. There was a _____ of activity on every _____, and a huge canvas _____ on wheels zipped around _____ corner, forcing us back _____ the wall.

"Wow!" I _____. "Are you always this

_____?"

"No," grinned my guide. "_____ after light business all _____ week, half the people _____ town decided to mail _____ packages this morning. That's _____ we called your school. _____ sudden rush is more _____ we can handle."

Looking _____ me, I could believe _____. We worked our way _____ the corner and edged _____ a quieter back-water. _____ I saw the time _____ on the wall and _____ a dozen of my _____ standing around it. It _____ nice to see some _____ faces, particularly that face _____ Jean Holly, who is _____ senior class vice-president and my special favorite.

"You're late, Walter," she said in a friendly voice.

ANSWER SHEET FOR SCORING SESSION THREE

1. Gray
2. and
3. gray
4. of
5. walked
6. and
7. post
8. spread
9. It
10. long
11. my
12. voice
13. from
14. report
15. at
16. That's
17. around
18. You
19. my
20. said
21. with
22. my
23. down
24. metal
25. frenzy
26. side
27. basket
28. the
29. against
30. said
31. busy
32. But
33. last
34. in
35. their
36. why
37. This
38. than
39. around
40. that
41. around
42. into
43. There
44. clock
45. about
46. classmates
47. was
48. familiar

49.of
50.the

APPENDIX D

SESSION FOUR TEST SPECIMEN

GENERAL INSTRUCTIONS

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO

This is the last of four reading tests on comprehension you will be taking. The process is the same as the process which was done in the previous session. If you do not remember the procedure, please notify your monitor now for a demonstration.

When the moderator gives the signal you may begin, and you may have as much time as you like to complete the test.

When you are finished, return the test to your packet.

You never saw anybody more excited than I was that night at the railroad station in beaumont, Texas, back in February, 1930. _____ I was, just a _____ girl wanting to be _____ big athlete--and now _____ was getting a chance _____ go to Dallas and _____ with an insurance company _____ play on their basketball _____.

In those days it _____ an overnight sleeper trip _____ Dallas. To me that _____ like going to Europe. _____ never been more than _____ few miles away from _____ in all my life. _____ hardly ever been so _____ up either. I was _____ a silk dress that _____ made in school and _____ a prize with at _____ Texas State Fair. I _____ on my patent-leather _____ and the hat I'd _____ for graduating from junior _____ school. I was carrying _____ purse with my entire _____ in it--three dollars and _____ cents.

My dad was _____ with me. I took _____ upper berth, and Poppa _____ the lower. He propped _____ up, took his newspaper, _____ started puffing away on _____ big

black pipe the _____ he did at home.

_____ a while folks in _____ Pullman thought the car was on fire.

I'll bet _____ traveled a couple of _____ miles since then, competing _____ many parts of the _____, but that first trip _____ the start of everything. _____ then I had other _____ besides playing basketball. I _____ to take part in _____ Olympic Games and be _____ far and wide as _____ athletic star.

How did _____ this begin? Let's go _____ to my childhood days.

_____ had a wonderful childhood. That must prove that it doesn't take money to be happy, because the Didriksons surely weren't rich.

TEST ANSWER SHEET FOR TEST SESSION FOUR

1. Here
2. high-school
3. a
4. I
5. to
6. work
7. and
8. team
9. was
10. to
11. was
12. I'd
13. a
14. home
15. I'd
16. dressed
17. wearing
18. I'd
19. won
20. the
21. had
22. shoes
23. got
24. high
25. a
26. fortune
27. forty-nine
28. traveling
29. the
30. took
31. himself
32. and
33. his
34. the
35. For
36. the
37. I've
38. million
39. in
40. world
41. was
42. Ever
43. ideas
44. wanted
45. the
46. known
47. an
48. all

49.back
50.I

VITA

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Ed. D. (Vocational-Technical Education), 1986 Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

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B.S Industrial Arts Education, 1970, Appalachian State University, Boone, North Carolina

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August, 1980 - Ausust 1982: Graduate Assistant, Division of Vocational-Technical Education, Virginia Tech, Blacksburg, Virginia.

January, 1980 - August 1980: Lecturer, Division of Vocational-Technical Education, (Graphic Arts, Industrial Arts Program Area), Virginia Tech,

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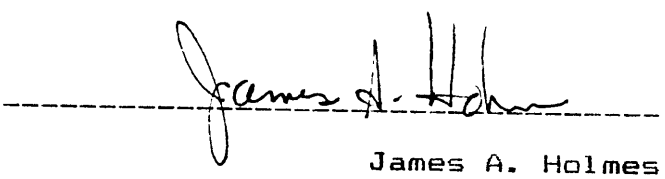
August, 1978 - December, 1979: Industrial Arts Instructor (Graphic Arts, School of Education), Virginia State University, Petersburg, Virignia.

July, 1975 - August, 1978: Graphic Arts Teacher, Petersburg High School, Petersburg, Virginia.

August, 1969 - June, 1975: Industrial Arts/Prevocataional Teacher, Peabody Junior High School, Petersburg, Virginia.



James A. Holmes