MILES A. TINKER

Legibility of Print

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About the Author . . .

Miles A. Tinker is an internationally recognized authority on legibility of print, eye movements in reading, and illumination for reading. Now a consulting psychologist residing in Santa Barbara, Calif., he was a member of the University of Minnesota Psychology Department from 1927 to 1959. A native of Massachusetts, Dr. Tinker earned the B.A. and M.A. degrees from Clark University and the Ph.D. degree from Stanford University. From the first, his research interests have been centered around the applied experimental psychology of vision. Results of his studies have provided material for nearly 200 publications, including seven books. Dr. Tinker has served as consultant for a number of groups in both government and industry, in addition to his research and teaching programs. He is a Fellow of the American Psychological Association, a Fellow in Distinguished Service Foundation of Optometry, and a member of many professional and honorary organizations. He holds a citation of merit from the International Reading Association.

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Preface

THIS BOOK is one of a series dealing with research in human communication. Others in the series include:

Adoption of New Ideas and Practices
by Herbert F. Lionberger
Measurement of Readability
by George R. Klare

The development of these books was sponsored by the National Project in Agricultural Communications, and published for the use of students, practitioners, and researchers in the several fields concerned with various aspects of communications.

NPAC operated under the auspices of the American Association of State Universities and Land-Grant Colleges and was supported financially by the W. K. Kellogg Foundation and the institutions and organizations that participated in its activities. Its program was one of research, training, and service activities designed to contribute to the improvement of communications in agriculture and home economics. Housed at Michigan State University throughout its life, it became a formal part of that institution's structure in March, 1960, and was closed officially in March, 1962. Continuation of the projects in this series was effected by the Iowa State University Press through publication and distribution of the valuable information thus derived.

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Dr. Donald G. Paterson, coauthor with me, for permission to adapt materials from our book *How To Make Type Readable,* published by Harpers in 1940 and taken over by the authors a few years after publication. Also much material was adapted from many scientific reports by Dr. Paterson and myself that had appeared in the *Journal of Applied Psychology, Journal of Educational Psychology, American Journal of Psychology, Journal of Experimental Psychology, Journalism Quarterly,* and the *American Journal of Optometry* and *Archives of American Academy of Optometry.* The paraphrasing of materials from all authors has been given full credit in the bibliographical citations.

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1. Introduction

EDITORS, PRINTERS, ophthalmologists, and educators have been concerned with the legibility of print for more than a century. In the earlier years, there were many opinions and recommendations expressed on this subject; however, these were based on casual observation rather than upon research findings. Prior to 1900, there were very few experimental studies reported, but since 1925, research in the field has expanded markedly.

Before the nineteenth century, the main concern was with esthetic appearance of print. With improved technology of printing, two additional factors entered the picture: Economy of printing and traditional practices. For many years, these three factors dominated the arrangement of the printed page. These emphases are still operating, although to a somewhat lesser degree. Because of these practices and views, a truly scientific typography has been slow in developing.

Print for Adults and Children

This discussion of legibility of print is concerned primarily with printed material to be read by adults. At what level do children read enough like adults so that it is not necessary to differentiate between the two in a discussion of the legibility of print? The results of two investigations provide an answer to this question. In a study of eye movements of children during reading, Buswell[1] found a definite stabilization of the oculomotor patterns by the end of the 4th grade. In the second investigation, Ballantine[2] discovered rapid gains in eye-movement efficiency from the 2nd to the 4th grade and slower progress from the 4th to the 8th grade. Since oculomotor behavior represents efficiency in the mechanics of reading, one may conclude from these studies that the mechanics of reading becomes well stabilized, or like that of adults, somewhere between the 4th and the 8th grades, i.e., between the ages of 10 and 13 years. This suggests that children read enough like adults so typographical arrangements having optimal legibility for adults should also be optimal for children who are about 10 years of age or older. This is supported by some upublished data of the writer.

Legibility Versus Readability

In all earlier discussions of factors affecting ease and speed of reading, the term "legibility" was employed. But since 1940, certain writers have been using the word "readability" for this purpose. For a time, it appeared to be a broader term and perhaps more meaningful. However, with the advent of the "readability formulas," devised to measure the level of mental difficulty of reading material, we have had the same terminology employed with entirely different meanings. Obviously, this has led to confusion. To avoid this confusion, this report confines itself to the term "legibility of print."

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[1] G. T. Buswell, *Fundamental Reading Habits: A Study of Their Development*, Supplementary Educational Monographs, No. 45. University of Chicago Press, 1937, pp. 158ff.

[2] F. A. Ballantine, *Age Changes in Measures of Eye Movements in Silent Reading*. University of Michigan Monographs in Education, No. 4. University of Michigan Press, Ann Arbor, 1951, pp. 63–111.

Nature of Legibility

In summarizing the experimental studies on the legibility of print, it is necessary to state first of all just what is meant by the term. There have been many approaches to the study of legibility, ranging from investigation of the relative perceptibility of the letters to studies of speed and ease of reading continuous meaningful text. To a considerable degree, legibility has been defined in terms of a specific method of approach to the study of the problem. Although certain writers such as Pyke (92) state that legibility is not concerned with recognizability, perceptibility, etc., each of several research techniques contributes something of value to the study and understanding of legibility. Therefore, it should be helpful to examine each of the techniques or methods of approach and then formulate a generalized definition of legibility. Details of the methods will be given in the next chapter.

Legibility: Methods of Investgation

1. **Speed of Perception.** By employing a short-exposure technique, the quickness and accuracy with which letters, digits, words, and phrases can be perceived are measured. The "recognizability" of printed symbols is ascertained by this procedure. This method has been found useful for determining the relative legibility of the letters of the alphabet, digits, mathematical signs, particular letters in different type faces, and the role of word form in the perception of materials printed in lower case versus upper-case type. It has also been used advantageously in studying various factors which increase or decrease the legibility of a printed character, such as the use of serifs, hairlines, boldness in letters, and optimal width of stroke and optimal height-width ratio in digits.

2. **Perceptibility at a Distance.** This technique is used to

measure the distance from the eyes at which printed symbols can be perceived accurately. It has been employed to advantage in determining the relative legibility of printed symbols and the role of word form in perception. Research studies over a period of 50 years, using this and the preceding method, have contributed worthwhile information concerning the legibility of printed characters.

3. Perceptibility in Peripheral Vision. This involves the measurement of the horizontal distance from a fixation point at which a printed symbol can be perceived accurately. It has been useful in studying the relative legibility of letters and of white versus black print.

Use of the *Focal Variator* produces similar results. It measures the distance that a printed symbol may be thrown out of focus and still be recognized.

4. Visibility. Visibility is usually measured by the Luckiesh-Moss Visibility Meter. This is a technique for determining the threshold visibility of printed material. Its use has contributed some worthwhile data on the legibility of type faces, boldness of type faces, and print with various degrees of brightness contrast between type and background.

5. The Reflex Blink Technique. Although there is some question about the validity of this method, it must be considered because it has been employed extensively in legibility research. The method is based upon the assumption that reading print with less than optimal legibility will increase the reader's frequency of blinking.

6. Rate of Work. This technique, in one form or another, has been used widely since 1896. Examples of the variations of this method include speed of reading, amount of reading completed in a set time limit, time taken to find a telephone number, time taken to look up a power or root in mathematical tables, and work output in a variety of situations which involve visual discrimination. The method has come to be accepted as the most valid technique for studying the legibility of printed material.

7. Eye Movements. In general, the recording of eye movements during reading yields the same results as the measurement of speed of reading. However, there is an added advantage derived from the analysis of eye-movement records. Such analysis provides information as to why a nonoptimal typographical arrangement is read more slowly than an optimal arrangement; viz., due to (a) more fixation pauses along the line of print, (b) longer enduring fixation pauses, (c) an increase in regression frequency, or (d) any combination of these. For instance, a slower rate may be due to lack of characteristic word forms (more fixations), difficulty of visual discrimination (longer pauses), or to losing one's place in going from the end of one line to the beginning of the next (more regressions).

8. Fatigue in Reading. Although much research has been undertaken to find or devise a satisfactory method of measuring visual fatigue, all efforts to date have failed. For instance, visual fatigue is not necessarily indicated by a reduction in rate of work. But a typographical arrangement that significantly reduces speed of reading in comparison with another arrangement can be considered less legible. In other words, legibility of print is not concerned with visual fatigue as such, but with ease, accuracy, and efficiency of perceiving printed symbols while reading with understanding.

Definition of Legibility

Legibility, then, is concerned with perceiving letters and words, and with the reading of continuous textual material. The shapes of letters must be discriminated, the characteristic word forms perceived, and continuous text read accurately, rapidly, easily, and with understanding. In the final analysis, one wants to know what typographical factors foster ease and speed of reading.

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

2. Methodology and Definitions

LEGIBILITY of print has been defined to some degree in terms of the technique employed for measuring it. Most of these techniques do measure one or another aspect of those factors which contribute something to the understanding of legibility. Such a contribution may be concerned with the reading of continuous meaningful text, or it may only have application to some specific reading task, or both. It should be helpful, therefore, to describe briefly the different methods and to point out the usefulness and limitations of each. Furthermore, in succeeding parts of the discussion, it will be possible to refer to this chapter on methodology without repeating, in detail, descriptions, evaluations, and limitations.

Visibility Measurement

The measurement of the visibility of print is associated primarily with the contributions of Luckiesh and Moss (46) and the Luckiesh-Moss Visibility Meter. This meter essentially consists of two photographic filters with precise circular gradients of varying density which may be rotated simultaneously in front of the eyes while looking at print, or while performing a visual task. The subject holds the instrument in about the same position that eyeglasses are worn. With a finger he slowly turns the disk which rotates the circular gradients until the threshold of the visual task is reached, that is, until a printed word can be recognized. The circular filters, which vary from almost clear to very dark, reduce the apparent brightness of the field as they are rotated, and thus lower the contrast between the visual object and the background. The maximum range of measurement of the instrument corresponds to scale values of 1 to 20. The latter is 20 times the threshold size. The meter is calibrated in terms of threshold size. Thus a visibility-scale value equal to "1" indicates the standard test object (parallel bars) whose critical detail subtends a visual angle of one minute; a scale value of "2," two minutes, etc. The Visibility Meter has been used to measure, among other things, the relative visibility of type faces (Luckiesh and Moss: 48, 51, 52, 59), type forms, size of type, and effects of variation in brightness contrast between print and paper.

Evaluation. Essentially, the scale values of 1 to 20 on the Visibility Meter measure threshold visibility. These measurements, therefore, have approximately the same drawback as measurement of visual acuity in legibility studies. For instance, one does not know what scale value corresponds to optimal legibility when investigating size of type. Also, for studying the effects of variation in type face, in leading, or in line width, visibility measures are of little value.

Situations where visibility scores are useful include studies of the effects of brightness contrast between print and paper, and relative legibility of letters of the alphabet, digits, and other isolated symbols. Visibility scores are related to those obtained with the two methods described below.

Distance Method

This method has found considerable use in studying legibility (actually, visibility or perceptibility at a distance) of isolated symbols and symbols in groups and in words. The apparatus and method are described in Tinker's study of modern and old style numbers (112) and Sanford's study of the relative legibility of small letters (94). The apparatus consists of a wooden rail about 3 meters long placed before the subject, slanted downward at about a 15-degree angle. There is a headrest at the upper end of the rail. A centimeter scale is fastened to the edge of the rail. The stimulus material (letters, digits, words, etc.) is placed in a small, well-illuminated car which can be moved any desired distance along the rail.

The experiment is begun by starting with the stimulus material near the far end of the rail and moving the car toward the subject by steps of about 10 centimeters at a time. At each step the subject reads as much of the material as possible. Records of correct readings and errors are made at each position. This is continued until all symbols are read correctly. The score for each symbol is the farthest distance from the eyes at which it can be read correctly.

A modification of this method is used at times to study the legibility of large print to be used in advertisements or highway signs. Here, the stimulus material is placed in a fixed position and the subject walks slowly toward it until he can just read it correctly. Again, the score is in terms of distance at which the correct reading is made.

Evaluation. The distance method of studying legibility of print yields measures somewhat comparable to visibility scores. It has little or no validity for investigating such typographical factors as leading, line width, determination of optimal type size for reading continuous text, or optimal type faces. However, the method has been found useful in studies of relative legibility of letters of the alphabet and digits, of specific letters in different type faces, and the effects of brightness contrast between print and paper. With the exception of brightness contrast data, and the results from studying legibility of print for road signs, billboards, and poster advertisements, the application of results obtained by this method to the legibility of print is somewhat dubious.

The Short-Exposure Method

The short-exposure method measures legibility by determining the speed of accurately perceiving printed symbols. The essential characteristics of this method are a pre-exposure field, an exposure field containing the printed material, and a post-exposure field. The pre-exposure field is *briefly* supplanted with the exposure field which is followed by the post-exposure field. In some apparatus the post-exposure field is the same as the pre-exposure field.

Ordinarily the exposure field with the printed material remains in view so briefly (1/10 second or less) that the eyes of the subject do not have time to move from one fixation to another. This means that the exposure of print is shorter than the reaction time of the eye. An exposure of about 1/10 second provides enough time for a clear view of the exposed print. This arrangement yields a *single act of vision,* since the timing prevents movement of the eyes to a second fixation point. In certain experiments in which *speed of vision* is to be measured, the exposure of the printed symbols may be reduced to a time interval which just permits accurate identification of the symbol. This interval may at times be as short as 3 to 5 thousandths of a second.

The short-exposure apparatus is termed a tachistoscope. Many varieties of tachistoscopes have been employed in research. The most commonly used is the Dodge mirror tachistoscope as described by Dockeray (23). The essential parts consist of a box with two apertures and mirrors so arranged that light admitted through one aperture is reflected by a mirror to the fixation point, and is then reflected to a "transparent mirror" set at a 45-degree angle. The fixation point is reflected from the near surface of this mirror to the eyes of the subject. Light is reflected similarly to the exposure field through the second aperture and then to the eye, the rays passing this time through the transparent mirror. This arrangement results in a pre-exposure fixation point which is the same distance from the eyes as the card containing the printed material on the exposure field. Either a falling shield, or a rotating disk with appropriate openings and speeds, is placed between a light source and the apertures, and provides successive illumination with appropriate timing of the pre-exposure, the exposure, and the post-exposure (which is the same as the pre-exposure) fields.

Ordinarily, the procedure is as follows: A card with the print is inserted in the exposure field. At a "ready" signal, the subject fixates the mark on the pre-exposure field. About two seconds after the signal, the exposure is made. The subject writes down or reports verbally what he perceived. Errors as well as correct responses are recorded. A few practice trials are given prior to the experimental series.

Evaluation. Like the two preceding techniques, the short-exposure method is useful for measuring the relative legibility of letters and digits, specific letters in different type faces, and the effect of variation in brightness contrast between print and paper. The relation between tachistoscopic reading and ordinary reading of continuous textual material is so small that conclusions concerning legibility of continuous printed text from tachistoscopic results must be made with caution. About the only exceptions to this rule are results for (a) brightness contrast between print and paper and (b) small print versus an optimal size. Such typographical factors as line width, leading, and determining optimal size of type cannot be investigated by this method.

The Focal Variator Method

Essentially, the focal variator, devised by Weiss (170), consists of a system of lenses so related to each other that a visual stimulus (print) may be projected upon a ground glass screen in any degree of clearness from an unrecognizable blur to clear definition of focus, and thus the degree of clearness can be accurately measured. The lenses are interconnected in such a way that they travel in opposite directions. As one lens increases the size of the image, the other lens reduces its size. The result is a blurred image on the ground glass which is the same size as the clear image would be.

The apparatus is operated as follows. At the beginning there is no image on the ground glass. The subject turns a wheel so that the image appears and gradually comes into focus. The subject reports as soon as he perceives a meaningful form, a letter or word. The report is recorded, together with the scale value on the apparatus. This process is continued until the subject reports accurately all the printed material presented. A variation is for the experimenter to employ equal steps in going from blurred to a clear focus, and record what the subject thinks he sees at each step. The scale values on the apparatus indicate degrees of clearness. A zero scale value indicates maximum clearness. The focal variator has been used to advantage by Burtt and Basch (18) in comparing the legibility of specific alphabet letters of three different type faces.

Evaluation. This method is somewhat limited to the investigation of the relative legibility of letters of the alphabet, of digits, and of specific letters in different type faces. However, the apparatus yields precise measurements which should have high validity.

Rate of Involuntary Blinking Method

Luckiesh (44) and Luckiesh and Moss (53, 57) have promoted blink rate as a measure of readability (legibility). The technique has been employed by Luckiesh and his colleagues in numerous investigations which presumably dealt with the ease of seeing. Several of the studies were concerned with effects of varying typographical factors. It is assumed that any factor which reduces ease of seeing will increase frequency of involuntary blinking. Conversely, a typographical setup which is read with greater ease should produce fewer blinks. All the data reported by Luckiesh and his colleagues would seem to support the contention that blink frequency is a satisfactory criterion of ease of seeing, and therefore may be employed to measure legibility of print.

In studying typographical factors, the eye blinks are counted by direct observation for a period of five minutes while the subject is reading continuous text printed in each setup (i.e., 6-point type, 12-point type, etc.). Ordinarily the tests are repeated in a different sequence to prevent errors due to order. Illumination is held constant for all tests. Data for several subjects are averaged. The experimenter sits to the side and slightly behind the subject while counting and recording the blinks. To study the effects of illumination level on reading, the blinks are recorded during the first and last five minutes of approximately an hour of continuous reading under each light intensity level. If the illumination is less adequate for ease of seeing under one intensity of light than under another, there should be a significantly greater increase in blink frequency during the period (60 minutes) of reading under the less adequate intensity. The data published by Luckiesh and his co-workers appear to confirm the expected trend.

An evaluation of this method first requires a general consideration of reliability and validity of legibility measurements.

Reliability and Validity of Measurement

To be satisfactory, every method of measurement should have adequate reliability and validity. *Reliability* is concerned with consistency of measurement. This consistency may be obtained by correlating scores, (a) on two different but equivalent forms of the same test, (b) on two parts (odd versus even items, or one half versus a second half of the test items) of a test, or (c) on two responses to the same test given one or more days apart. The split-half method (odd-even or first versus second half) tends to yield the higher reliability coefficients. For group comparisons, such as ordinarily employed in legibility studies, a reliability should not be less than .50; preferably, it should be .60 or above. If one is dealing with individual diagnosis, the reliability coefficient should be at least .80, and preferably .90 or above.

Validity of a test indicates whether the measuring device is measuring what it purports to, i.e., legibility of print. One method of determining validity is to correlate test scores obtained on the "legibility" measure with a criterion. A criterion is an accepted or "true" measure of the item in question, such as legibility of print, intelligence, etc. The size of the correlation is to be interpreted in terms of correlations ordinarily obtained in such a situation. For instance, a correlation of .60 between a new college ability (intelligence) test and grades achieved in college is considered high, for most such correlations range from .30 to .50. However, a correlation between a new intelligence test and the Revised Stanford-Binet Test (criterion) of about .70 is considered low, for such coefficients should be at least .90 if the new test to be accepted as satisfactory. In other situations, the validity of a test is deemed to be self-evident because of the nature of the measuring device. This is called *face validity;* for instance, the scores on a speed-of-reading test with comprehension constant, such as on the *Tinker Speed of Reading Test* or the *Chapman-Cook Speed of Reading Test,* have face validity (see references 139 and 153). In these tests, speed of reading is measured as a single variable. Comprehension is constant. Therefore the tests are considered valid measures of reading speed. Similarly, scores obtained from the Luckiesh-Moss Visibility Meter are supposed to yield valid legibility scores in terms of threshold visibility. Also, tachistoscopic reading is supposed to yield valid legibility scores in terms of accuracy of perceiving the exposed material.

Reliability of the Blink Technique. In a study which duplicated the conditions specified by Luckiesh (44), Tinker (123) checked the reliability of the blink technique during reading, employing 74 and 64 subjects respectively in two experiments. For adjacent 5-minute periods (one 5 minutes following immediately after the other), the reliability coefficients were fairly high, ranging from .74 to .92. A similar trend was found for 10 and 15-minute periods. But when an interval of as much as 20 minutes of reading intervened between 5-minute periods, the reliability dropped to .49 or .56, which is marginal and indicates inconsistency of the blink rates. Furthermore, when individual records of 11 subjects were examined, marked variability was found from one 5 minutes of reading to another. To minimize the effects of such individual differences, fairly sizable groups of readers should be employed when using blink frequency as a measure of legibility or ease of seeing. If only 10 to 20 subjects are used, the reliability may well be too low even for group comparisons.

Validity of Blink Technique. Irrespective of how high the reliability of a measuring device, it must be valid to become a satisfactory measure of legibility. Prior to the work of Tinker, no researcher had questioned the validity of the blink technique as a measure of ease of seeing or of legibility. In an initial experiment, using 60 readers, Tinker (125) compared blink rate and also speed of reading while the subjects read material printed in lower case and material in all capitals. Each kind of print was read for 10 minutes at each of two sessions. Scores were recorded for every 5-minute period. Eye-blink results showed no significant advantage for the lower-case text during 5, 10, or 20 minutes of reading. Speed of reading, however, was significantly faster for the lower case in every instance (9.53 to 19.01 per cent). Since Luckiesh (44) criticized the procedure in the above experiment, Tinker (127) duplicated exactly the method described by the former. The reading of 12-point book type was compared with reading 7-point newsprint at each of two experimental sessions. Eye blinks were recorded for 5 minutes for each kind of material at each session with a reversal of order at the second session.

TABLE 2.1—Frequency of Blinking of 60 Readers While Reading Book Type and Newsprint

	Book Type Scores			Newsprint Scores		
	First 5 min.	Second 5 min.	Total 10 min.	First 5 min.	Second 5 min.	Total 10 min.
Mean	34.28	35.08	69.37	31.77	29.50	61.27
S.D.	26.27	29.94	53.65	26.26	25.66	49.78

In this experiment, in which all procedures specified by Luckiesh were fulfilled, the results appear convincing. The data seem to indicate that newsprint is easier to read than book print. It is well established that the reverse is true (80, 85). Every other investigator (except Luckiesh) who has attempted to validate the blink technique as a measure of ease of seeing or legibility of print has obtained only negative results: Bitterman (13) and Bitterman and Soloway, (14, 15); Carmichael and Dearborn (20); McFarland, Holway, and Hurvich (63).

In another study, Tinker (130) compared increase in rate of blinking from beginning to end of 55 minutes of reading under 2 and 100 foot-candles of light. Again the experimental conditions of Luckiesh (44) were duplicated. Under 2 foot-candles, rate of blinking increased 31.6 per cent from first to last 5 minutes, while under 100 foot-candles the rate increased 32.0 per cent; i.e., there was no difference in the increase, although adequate measurements would show that reading under 100 foot-candles is significantly faster and presumably easier.

It appears that frequency of reflex blinking cannot be accepted as a valid measure of ease of seeing or legibility. At least, the technique is questionable if no experimenters other than Luckiesh and his colleagues are able to duplicate his results. It has been suggested that the results of Luckiesh may be due to use of small numbers of subjects who were test-wise, that is, subjects who were used over and over again on successive experiments, and unconsciously gave the results desired by the experimenter. Furthermore, none of the results from Luckiesh's laboratory was evaluated statistically. In any case, rate of blinking as a criterion of ease of seeing is in question.

Speed-of-Reading Method

Common sense would seem to indicate that one should be able to find rather readily a satisfactory measure of visual fatigue due to reading. Such is not the case. As pointed out by Carmichael and Dearborn (20), attempts by able researchers to devise a satisfactory measure of visual fatigue have been rather fruitless. One reason for this is the amazing flexibility and adaptability of the human visual mechanism in its capacity to adjust to a bewildering variety of situations requiring visual discrimination. For example, we habitually read rather small newsprint in short line widths and shift to the reading of books or magazines in larger type and longer lines without noticeable discomfort. To ascertain legibility of print in terms of "visual fatigue," therefore, most research workers have turned to some measure of ouput in a performance test.

A much favored functional criterion of legibility is speed of reading, or speed and accuracy of reading or of other visual performance. For instance, Pyke (92) considers that a type "can most properly be tested for legibility by actually being read." He also favors reading at maximum speed, for it is easier to maintain one speed for a short time by reading as fast as possible. Ovink (69) employed speed of reading in part of his experiments. A number of other experimenters, such as Griffing and Franz (30) and Baird (3), have made use of speed of reading or speed of visual discrimination in their studies.

Tinker, and Paterson and Tinker, in numerous studies have employed a well-controlled reading performance technique to measure legibility (readability). They hit upon a measuring device admirably suited to their purpose, the *Chapman-Cook Speed of Reading Test*[1] (153). Later, a new and longer test, similar in form, was devised by Tinker (143) for use in certain studies in which longer reading periods seemed desirable. Use of the Chapman-Cook test permitted measurement of speed of reading as a single variable. The test consisted of two equivalent forms, A and B. Each form included 30 items of 30 words each. The vocabulary em-

[1] Educational Test Bureau, Minneapolis 14, Minn.

ployed was relatively simple. Each item contained one word that spoiled the meaning. This word was to be crossed out by the reader as a check on comprehension. The following is a sample item:

> When I am enjoying anything very much, time seems to go very quickly. I noticed this the other day, when I spent the whole afternoon reading a very uninteresting book.

In the above item, the word *uninteresting* is to be crossed out by drawing a horizontal line through it. For adults (college students or high school seniors), the average percentage accuracy is 99.7. Therefore, the researcher virtually has a pure test of speed-of-reading perfomance uncomplicated by a comprehension factor. A variety of checks carried out by Tinker and Paterson (153) revealed the usefulness of this device for legibility investigations. The median reliability (correlation of equivalent forms) was about .85. The "face validity" is in terms of measuring speed of reading as a single variable.

In general, the scores on Form B are equivalent to those on Form A when Form B follows Form A and the typography and testing conditions are alike. Since there occurs some slight variation in scores on Forms A and B from time to time, it was found advisable to introduce a control group. This was done in all studies except a few early ones. This permitted correction in the experimental groups for variation from equivalence of the two forms.

The *Tinker Speed of Reading Test*[2] consists of 450 items of 30 words each in Form I and also in Form II. It is possible to employ up to 30 minutes of testing time on each form. Only 1¾ minutes were used with the Chapman-Cook test described above. The median reliability (equivalent forms)

[2] University of Minnesota Press, Minneapolis 14, Minn.

of the Tinker test is approximately .90. Like the Chapman-Cook test, the comprehension accuracy is nearly 100 per cent.

Evaluation. Speed-of-reading performance in continuous text or in special reading situations has been adopted by most researchers as a criterion of legibility. In general, we want to know the typographical factors influencing speed and ease of reading. Other things being equal, a typography that is read faster than another should be easier to read. However it may be unsafe to claim that there are no legibility differences when no significant difference is found between two typographical setups. But when one arrangement is read significantly faster, legibility must be a factor of importance.

Certain pitfalls must be avoided when the reading performance method is employed to measure legibility. (a) The reading material must be uncomplicated by comprehension difficulties. (b) Sets of reading materials employed in comparisons must be of equal difficulty. (c) Enough reading material and a sufficient number of readers must be used to establish beyond question the accuracy of the findings (see "Length of Work Period" below). A brief paragraph or two and 10 to 15 subjects will not do. (d) There must be an adequate check on comprehension. Except in the studies by Tinker and Paterson, few investigators have checked comprehension. "Reading" without understanding *is not reading.* (e) Actual printing practice must be duplicated. Photographic enlargements or reductions as used by some investigators are not satisfactory in studying variations in size of type, line width, etc. (f) Approved statistical methods of analyzing results are essential. Differences obtained in comparisons are unimportant unless they are *statistically significant.* (g) To be adequate, any experimental design for studying legibility of print must incorporate the above points. In an *attempt to demonstrate* that speed-of-reading performance is worthless as a technique for studying legibility, Luckiesh and Moss

(57) ignored all of the above conditions for controlled experimentation except (e).

It would seem, after reviewing all the literature in the field, that speed-of-reading performance is one of the more satisfactory methods for investigating legibility of print. Obviously the technique is not perfect, although it is the best available at present. At times, supplementary data from use of other techniques are helpful, such as eye movements or visibility scores.

Measurement of Eye Movements

Many different techniques have been employed to record eye movements in reading. During recent years, either a corneal reflection or an electrical method has been used in most studies. The essentials of the corneal reflection method are described by Tinker (113). The image of a small beam of light directed into the eye and reflected into an enlarging camera is photographed. A cutting disc interrupts the beam of light 50 (or 25, or 30) times per second so that the record on the film is a series of sharply focused dots. Each movement of the eyes produces a change in the beam of reflected light so that horizontal and vertical movements are recorded on the film. This 35-mm. film moves at a constant rate past the far end of the camera. Eye movements are readily distinguished from head movements on the film record.

In reading, the eyes move in quick jerks, called saccadic moves, from one fixation to another along a line of print. The fixation pauses are the periods of clear vision. Perception of reading material only occurs during these pauses since saccadic interfixation moves are so rapid that no clear vision is possible. On the average, pauses take 92 to 94 per cent of the reading time, and movements take 6 to 8 per cent (Tinker, 126). Regressions are backward moves within a line to re-examine material not clearly perceived or understood.

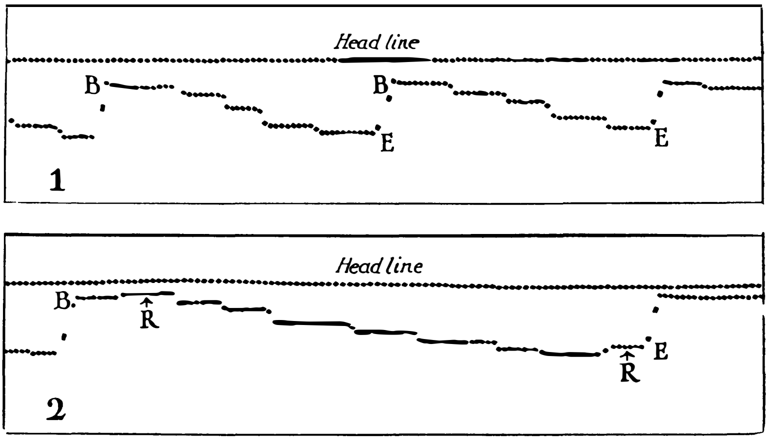

FIG. 2.1—A sample eye-movement record. The upper figure (1) shows the eye movements of a "good" reader reading two lines of print, whereas the lower figure (2) shows the eye movements of a "poor" reader reading one line of the same text.

Figure 2.1 shows samples of eye-movement records of a good and a poor reader. B indicates beginning and E the end of the line. E to B is where the return sweep from the end of one line to the beginning of the next line occurs. R shows a regression.

Electrical recording of eye movements, as ordinarily made, depends upon an electric potential difference which exists between the cornea and the retina of living eyes. Changes in these corneo-retinal potentials are closely proportional to the sine of the angle of rotation of the eye which occurs in eye movements. These movements in reading are recorded by placing electrodes on the skin near the eye and attaching the electrodes to an amplifying system and an ink-writing oscillograph or a photographic device. The obtained record closely resembles the record of the corneal reflection method and is readily interpreted. Hoffman, Wellman, and Carmichael (33) have shown that the results obtained approximate closely those from the corneal reflection method. Recently there has been a tendency to employ some method of electrical recording of eye movements because the technique is much more flexible than the corneal reflection method. For instance, the head of the reader in electrical recording is not held rigidly in one position, and records for longer periods of reading can be obtained.

The reliability (two forms) of eye-movement measures are entirely satisfactory for group comparison even when only 5 lines of material are read. For short paragraphs, Tinker (117) found reliabilities from .66 to .89; for reading 20 to 25 lines, the mean reliability was .81. These measures, therefore, have satisfactory reliability for studying legibility of print.

The validity of certain eye-movement measures is high. According to Tinker's findings (117), the apparently artificial situation of reading before the camera has no deleterious effects on reading. Perception time has face validity, for it consists of the sum of the pauses which are the periods of perceiving. In other words, it is merely another satisfactory measure of reading speed. Perception time (117) correlates highly with performance test scores on comparable materials; the coefficient is —.90 (negative because short time equals fast reading) . Tinker and Frandsen (146) have shown that fixation frequency correlates highly with perception time with a median coefficient of .85. This means that fixation frequency is a valid measure of speed of reading. In continuous reading material, regression frequency and pause duration are less adequate as measures of speed; median coefficients with speed are .59 and .52, respectively.

Evaluation. Perception time and fixation frequency are highly reliable and valid eye-movement measures of speed of reading. Pause duration and regression are less satisfactory for this purpose. However, all eye-movement measures provide valuable supplementary information in investigating legibility. Analysis of eye-movement patterns reveals the reason for variation in reading speed from one typographical arrangement to another. For instance, retardation in reading speed performance in one setup may be due to increased pause duration, in another, to increased fixation frequency, and in still another, to changes in more than one eye-movement measure. In studying legibility of print it would seem that eye-movement measures provide an excellent supplement to reading performance.

Length of Work Period

Investigators of legibility of print tend to employ tasks of relatively short duration. Although there has been some variation, most of the studies in visual research, including legibility studies, have employed 1 to 5-minute work periods. Several individuals have questioned the use of such short periods without experimental evidence to support their criticisms. Tinker and Paterson (153) in 1936 were the first to investigate the adequacy of short time limits in measuring legibility. They had assumed that any measurable effect obtained during a brief reading period of 1¾ minutes would also be present during a longer period of reading. To test this assumption, the reading of Cloister Black (Old English) type was compared with reading text in Scotch Roman under three different time limits, namely 1¾ minutes, 5¾ minutes, and 10 minutes. The retarding effects in speed of reading the Cloister Black in comparison with Scotch Roman were:

For 80 readers, 1¾ minutes: 11.6 per cent
For 91 readers, 5¾ minutes: 12.4 per cent
For 94 readers, 10 minutes: 14.1 per cent.

It is clear that the initial retarding effect persists, and even increases a little, as the reading periods are lengthened.

Tinker (139, 143) has completed two visual research studies on length of work periods. In one part of the first study, a comparison of speed of reading all capitals versus lower-case Roman print was made with 127 college readers. In four successive 4-minute periods, the retarding effects of the all-capital print were, respectively, 11.6, 14.2, 13.6, and 10.2 per cent. For the entire 16-minute period, it was 12.4 per cent. In a second part of the study, the reading speed of italic print was compared with speed for Roman lower case. Ninety-six college students read each type form for three successive 10-minute periods. The retarding effects of the italics were, respectively, 4.2, 5.2, and 6.3 per cent. For the 30-minute period, it was 4.9 per cent.

In the second report (143), Tinker found similar trends for the effects of illumination intensity upon speed of reading, with time limits of 1½, 5, and 10 minutes. For 25 versus 5 foot-candles, there were no significant differences with change in time limits.

Evaluation. Any effects of typographical factors upon speed of reading found for brief work periods of 1½ or 1¾ minutes hold for longer periods up to 30 minutes. Periods of 1¾, 5¾, and 10, or 4 to 16 or 10 to 30 minutes, all show the same trend. Any differences found for the short period hold or increase slightly for longer periods of work. One may safely conclude from these studies that reading for relatively short periods yields a valid measure of legibility. Such workers as Pyke (92) and Weston (171, 172) advocate and use work periods as short as 1 minute.

Measurement Cautions

There are certain additional questions concerning methods of measurement in studying legibilty of print. Three of these will now be considered.

Time-Limit Versus Work-Limit Method of Administering Speed Tests. Pyke (92) claims that the two methods yield different results experimentally but supports his contention only by logical argument. The question was raised and tested experimentally by Paterson and Tinker (71). Forms A and B of the *Chapman-Cook Speed of Reading Test* were employed with the following results:

Intercorrelations

Form A, Time-limit Form B, Work-limit	r = .87, N = 185
Form A, Work-limit Form B, Time-limit	r = .84, N = 183

Reliabilities

Form A, Work-limit Form B, Work-limit	r = .86, N = 162
Form A, Time-limit Form B, Time-limit	r = .84, N = 560

The similar sizes of the intercorrelations and reliability coefficients indicate that the two methods of test administration agree with each other as closely as each agrees with itself. Application of the correction for attenuation results in a correlation of +1.00. Thus the time-limit method and the work-limit method produce speed-of-reading scores which are perfectly correlated within the reliability of each. These results can be applied only to data from the *Chapman-Cook Test* and other strictly comparable tests such as the *Tinker Speed of Reading Test*.

Practice Effects. In studying methodology, Tinker and Paterson (153) found that equivalence of test forms in the speed-of-reading tests held only when the readers had not had the tests earlier and only when Form B followed Form A. Because of these conditions and also because of various incidental factors (distractions, motivation, etc.), it was decided to check for equivalence and make corrections where necessary in every subsequent study by means of a control group. This important procedure has been followed by few other investigators.

Mental Set. Some critics have suggested that the change in mental set in going from Form A (standard) to Form B with a changed typography may be responsible in part for the lower scores frequently obtained on Form B of the speed-of-reading tests employed. This has been checked by Tinker and Paterson (152) by using Cloister Black as the standard for comparison with Scotch Roman type face. In a previous study (75) the Scotch Roman was used as the standard to compare with Cloister Black. When Cloister Black was the standard, it retarded speed of reading 15.98 per cent; when Scotch Roman was the standard, the retardation due to Cloister Black was 16.5 per cent. The two contrasting methods, therefore, yield approximately the same result. Apparently changes in mental set are not causing the differences obtained when typographical variations are introduced. In other words, the obtained differences can safely be assigned to the typographical variation.

Summary

No single method of measurement is adequate for determining the legibility of print in all kinds of typographical set-ups. Some techniques supplement others to give a more complete picture of the legibility, while other techniques are limited to specific situations such as legibility of isolated characters. The limitations of each may be briefly recapitulated:

1. Visibility measurements essentially yield threshold scores comparable to visual acuity data. They may be employed to advantage in measuring the effects of variation in brightness contrast between print and paper, and in studying the relative legibility of isolated symbols such as letters. The method is unsatisfactory for determining *optimal* size of type, type face, line width, and leading.

2. The distance method measures the distance from the eyes at which print can be perceived accurately. The data obtained are somewhat comparable to those obtained in visibility measurements. The technique has about the same advantages and limitations as the visibility method.

3. The short-exposure method measures the quickness of accurately perceiving printed symbols. In general, it is useful in the same situations as the two previous techniques. Results obtained have little bearing on legibility of continuous text.

4. The Focal Variator may be used to determine legibility by measuring how far a letter or word may be thrown out of focus and still be recognized. This technique is largely limited to determining the relative legibility of single characters such as letters.

5. The rate of involuntary blinking during reading is assumed to be inversely related to ease of seeing, i.e., the easier the visual task, the fewer the blinks for a set period of reading. There are serious doubts concerning the validity of this method of measuring legibility. In the following chapters, data obtained by this technique will be cited, with the reservation that the reader must be cautious in accepting them.

6. The large majority of investigators have come to depend upon some aspect of rate of work or speed (and sometimes accuracy) of performance for studying legibility of print. In addition to measuring speed of reading continuous

text, the method can be employed to determine legibility of tabular materials, print in dictionaries and telephone directories, and backbone titles on books. At times it is helpful to supplement speed-of-reading measurements with analysis of eye movements in reading. While speed of performance is not a perfect technique, it appears to be the most nearly satisfactory method we presently have. It has high reliability and apparently good validity. However, the method can be valid only when the experimental design specified in this chapter is followed.

7. Certain measures of eye movements during reading (perception time and fixation frequency) are virtually measures of speed of reading and can be used as such. In addition, an analysis of eye-movement patterns will yield information on why one typographical arrangement is more or less legible (read faster or slower) than another. Eye-movement records tend to be reliable and valid measures of legibility of print.

8. Experimental evidence shows that brief reading periods are as satisfactory as longer periods in visual research, including legibility studies.

9. One may employ either a time-limit or work-limit method for speed tests such as the *Chapman-Cook Speed of Reading Test* or the *Tinker Speed of Reading Test*.

10. In addition to following the specifications given in the Tinker and Paterson studies, it is always best to use a control group to check the equivalence of the test forms employed.

11. In an adequate experimental design, mental set does not affect the measurable results in going from one to another typographical setup during reading.

12. Finally, it should be emphasized that measurement of legibility of print is a delicate and painstaking job. Inadequate tools of measurement and controls may well lead to false conclusions.

3. Legibility of Letters and Digits

INTEREST in the legibility of letters began with personal observations and subjective judgments as early as 1825. Opinions concerning the best type of serifs to use, the effects of ascenders and descenders, brightness contrast between paper and ink, and various other factors in legibility of letters were freely expressed throughout the nineteenth century and even up to the present. In 1949, a publication on typography (177) emphasized *legibility of the specific letters* in defining legibility of print. This point of view was derived from opinions expressed by type designers and typographers rather than from research data.

The first *controlled* research on the subject was done by Cattell (187) in 1885. Numerous investigations were reported between 1885 and 1938. Most of the studies have been concerned with the relative legibility of the letters of the alphabet, with an analysis of the factors which appear to produce good as contrasted with poor legibility of individual letters. Suggestions for improving the legibility of letters which are difficult to identify or are confused with other letters are frequently given.

Upper-Case Letters

Until rather recently, the consensus was that the maximum legibility of letters was represented by the old Roman capitals which are made up almost entirely of straight lines and sharp angles. This view reveals a strong emphasis upon the ease of discriminating or perceiving single letters correctly. Beginning with Cattell (187) in 1885, there have been at least 10 reports of the relative legibility of capital letters. For the most part, a short exposure or distance method of experimentation was employed. The orders of legibility in each of these studies are reported by Tinker (111). There was little or only moderate agreement of results from one study to another. The results of Roethlein (93), obtained by a distance method, are fairly typical. From most to least legible, the capital letters were:

W M L J I A T C V Q P D O Y U F H X G N Z K E R B S

The correlations of this series with the other series reported ranged from —.09 to +.87, with a median coefficient of +.24. Lack of agreement between results must be due partly to differences in the methods of investigation and in the kind of type used. Considering all reports, capital letters of consistently high legibility in most studies were A and L, while B, G, and Q were consistently low. Many of the capital letters were fairly low or very low in relative legibility because of confusion with other letters, such as B with R; G with C and O; Q with O; M with W.

Ovink (69) studied by a distance method the effect of variations of thickness of the constituent parts on legibility of capital letters. Capitals from the following display types were used: Block, Futura, Reform Grotesk B, Fanfare, Goudy Heavy, Poster Bodoni, Lo, Futura Black, Shadow Nobel, and Bifur. The subjects were required to give a detailed and complete description of what they saw, in addition to naming the letter. From these data an evaluation of each letter was given with suggestions to help maintain maximum legibility in printing display cards and other advertisements.

An analysis of these suggestions reveals certain areas of emphasis: (a) The most frequently occurring principle is that characteristic differentiating parts should be simply and clearly defined. Examples: A long horizontal cross at top of T; a pronounced cross stroke at bottom of Q; a curve at the bottom of J that is easily noted; adequate opening in C; a rather heavy horizontal stroke in the G with enough white opening above it. (b) Avoid narrowness in such capitals as A, V, X, and Z. (c) The middle horizontal in E and F should be shorter than the top one and should not be too thin. (d) Extreme contrasting hairlines in obliques, horizontals, and verticals should be avoided. Examples: In Y, N, F. (e) Avoid heavy or too long terminals (serifs) on horizontals and verticals. Examples: In F, top of U, etc. (f) Avoid too close verticals in such letters as U. (g) Keep bifurcation near the middle (vertically) in such letters as Y and M.

Actually, studies of the comparative legibility of capital letters contribute little that is useful in ordinary printing. The one exception, perhaps, would be studies to determine letters of nearly equal legibility for use in tests of visual acuity (see references in Tinker, 111). Investment in cast type, economy of printing space, esthetic taste, and the attempt to create atmosphere have been opposed consistently to legibility. However, a modification of some of the undesirable practices, as suggested above, might well be effected.

Lower-Case Letters

Most of the printing material for ordinary reading, as in newspapers, magazines, and books, is in lower-case letters except for (the capitalization of) a few words such as proper names and the initial word in the sentence. This is fortunate, for lower-case printing is much more legible than all-capital printing (see next chapter). Lower-case letters have more "character" in terms of variation in shape and the contrasting of ascenders and descenders with short letters. This leads to characteristic word forms that are much easier to recognize than words in all capitals. This is true, even though the sheer visibility of capital letters is much greater than that of lower-case letters.

Relative Legibility of Lower-Case Letters. From 1885 to 1928, seven research reports on the relative legibility of lower-case letters appeared. These have been summarized by Tinker (111). The methods of investigation employed were distance, short exposure, and peripheral vision (the farthest distance from fixation that a letter can be accurately perceived). Intercorrelations between the rankings for legibility found in the seven studies ranged from .48 to .88, with a median coefficient of .62. This represents rather close correspondence, considering that three methods of experimentation were used. The order from most to least legible found by Tinker (111) is a typical example (letters connected by an underscore were equally legible):

k d q b_p m w f h j y r_t x v z c o a_u g e_i_n s l

Consideration of data from all seven studies reveals the following fairly consistent trends:

Letters of high legibility: d m p q w
Letters of low legibility: c e i n l
Letters of medium legibility: j r v x y

Other letters revealed a greater amount of variation in legibility position in the series.

An analysis of the reports by Roethlein (93), Ovink (69), Sanford (94), and Tinker (111) revealed a marked tendency for the letters of poor relative legibility to be confused with other letters: c with e; i with j; n with a; l with j.

This analysis also provided information concerning factors which improve and which lessen legibility of single letters:

1. Size influences legibility. This is particularly clear in comparing m and w with e or i.

2. Simplicity of outline undoubtedly makes for good legibility. The most legible end of the series contrasts forcibly in this respect with various characters lower in the series, as w with a or q with g.

3. The manner in which serifs are employed may affect legibility of letters. For instance, too heavy and too long serifs should be avoided at the top and bottom ends of double strokes, as in h, u, and n. With such letters as a, s, and z, short, triangular serifs would simplify the letter outlines.

4. Shading appears to affect legibility. Although certain letters, such as x and z, are differentiated largely by shading, this does not mean that a character composed of *thick* and *thin* lines is the most legible possible. In a mechanical font, there is no meaning or advantage in having one part of a stroke thicker than another. The tendency to use hairlines to form a part of certain letters should be strongly condemned, as with the horizontal stroke of the e which differentiates it from c. On the other hand, an unduly thick horizontal stroke infringes on the enclosed space and therefore reduces legibility.

5. Area of white space or spaces included within the black outline of a letter influences legibility. Other things being equal, the greater the enclosed white space of a letter, the greater the legibility. This is obvious from comparing the more legible with the less legible letters in the above series.

6. Some single part which serves as a distinguishing characteristic for that letter aids legibility. This is well illustrated in the letters b d p q k. Lack of an adequate differentiating part favors illegibility, as in n and u.

Analysis suggests that, of all the factors listed above, the emphasis upon differentiating parts is the most influential in determining relative legibility of the lower-case letters. White area within a letter and size appear to be next most important.

Apparently little can be done to improve legibility of lower-case letters because of custom, economy of printing space, investment in cast type, and esthetic taste. However, it might well be possible to improve some of the poorly legible characters by increasing simplicity of outline, modifying serifs, omitting use of hairlines, and emphasizing distinguishing characteristic parts.

The results of Roethlein (93) showed that the legibility of all letters is decreased when the letters are presented in groups. In her work, the letters in each group formed nonsense combinations.

In a carefully designed experiment, Vernon (167) determined the amount of confusion between similar appearing letters, such as o and e, f and t, a and s, in words and in continuous meaningful material. The results indicated that confusion of similar appearing letters occurred mainly in material with little contextual meaning. In ordinary reading of meaningful materials comprehended by the reader, the confusion of individual letters was a *very minor factor*.

To what degree does the illegibility of certain lower-case letters interfere with the reading process? There are two aspects to this question. For poor readers and especially for *children who are learning to read,* illegible letters can become a real problem. For instance, children must distinguish between similar word forms by discriminating between certain letters. Examples are "house" and "horse," "these" and "there," "put" and "pat," "draw" and "drew," etc.

It may be concluded, therefore, that in children's books the individual letters should be as legible as possible, particularly those letters that tend to be confused with each other. This can be accomplished by choosing a type face which incorporates in individual letters the specifications listed above. In addition, the type size should be somewhat larger than that used for adults. To some degree, the same advice holds for material to be read by poor or immature readers. In ordinary reading by mature readers, individual letters are not confused with each other enough to cause concern or to advocate radical changes in letter forms.

Legibility of Digits

The only study of the relative legibility of digits as used in ordinary printing was reported by Tinker (112) in 1930. Using the distance method, he determined the perceptibility of 10-point digits printed in Modern and in Old Style, i.e., digits varying in height and alignment. The digits were presented in isolation and in groups of five. The orders from most to least legible follow:

Modern (isolation): 7 4 1 6 9 0 3 2 8 5
Old Style (isolation): 7 4 6 0 1 9 3 5 2 8
Modern (groups): 7 1 4 0 2 9 8 5 6 3
Old Style (groups): 8 7 6 1 9 4 0 5 3 2

The rankings for legibility were nearly the same when the digits appeared in isolation. There was little correspondence between the legibility ranking for the two styles of print when the digits appeared in groups. Apparently, as with letters of the alphabet, the perceptibility of a character within a group depends partly on the nature of the symbols on either side of it. This effect was more prominent with the Old Style digits.

An over-all comparison showed that the Old Style digits were slightly more perceptible than Modern in isolation, but markedly more easily identified when in groups. The variation in height and horizontal alignment in the Old Style digits probably contributes to this difference. In both styles of type the digits were much more easily perceived correctly when in isolation. As has been noted for letters (93), the digits in the initial and final positions of a group are more easily perceived than those within the group.

In Part 2 of the experiment, 20 subjects read 25 groups of five digits each as fast as possible, silently and orally. The order of presentation was counterbalanced to equate practice effects. Time and errors were recorded. The average results follow:

Silent reading (Modern)	Time	= 55.5	seconds
Silent reading (Old Style)	Time	= 55.7	seconds
Oral reading (Modern)	Time	= 71.8	seconds
Oral reading (Old Style)	Time	= 70.7	seconds
Oral reading (Modern)	Errors	= 3.1	
Oral reading (Old Style)	Errors	= 2.8	

These results show clearly that, on the average, grouped Modern digits are read just as rapidly and just as accurately as grouped Old Style.

In terms of perceptibility at a distance, the results suggest that Old Style digits are more easily read or identified than Modern ones. However, in the natural reading situation, this difference seems unimportant. One style of printing is read just as fast and just as accurately as the other. This finding was confirmed in a study of the legibility of mathematical tables, as will be seen in Chapter 13.

Apparently it is not valid to apply legibility results for specific digits to ordinary reading situations where digits are grouped in text or in mathematical tables. Only where a single digit appears in the text, as in some arithmetical problems, are the perceptibility data applicable.

The Form of Digits. A few studies have been concerned with the effects of form on legibility of digits.[1] Soar (98), employing a short-exposure method, investigated the effect of different combinations of height and width, with area held constant, on the legibility of digits printed in 10-point type. The results indicated that the most readily perceived combination of height, width, and stroke width for all digits was a height-width ratio of 10:7.5 and a stroke width-to-height ratio of 1:10.

In one experiment, Berger (8) measured perceptibility at a distance and visibility with the Luckiesh-Moss Visibility Meter for the digits 0 and 5 to check the influence of width of area on legibility. The digits were 6 mm. high. There was a general increase in legibility as the width of the symbols was increased. Obviously, digits of small width tend to be illegible.

The investigations by Lansdell (41) and by Berger (7) were concerned with large numbers such as those used on billboards and road signs. They are mentioned in passing but details are not considered, since this report is concerned mainly with regular printing used in books, bulletins, magazines, and newspapers.

Roman Versus Arabic Numerals. It seems obvious to most people that Roman numerals are more difficult to read rapidly and accurately than Arabic. The difficulty is not one of visibility, since the Roman numerals are like capital letters and the Arabic are more like lower-case letters. Apparently the difficulty is one of interpretation due to two things: (a)

[1] Various research studies by the Armed Services have investigated the effects of size, shape and arrangement of numerals for use on instrument dials, panels, etc. These will not be considered in this report.

The Roman numerals are relatively cumbersome and complex, viz., XXXVIII versus 38, and (b) the ordinary reader has had little experience with Roman numerals, particularly the larger ones.

Perry (88) has reported how much speed and accuracy are lost by the use of Roman numerals. Using a counterbalanced design, he obtained responses from 30 university students while they read aloud as fast and as accurately as possible numerals from 1 to 9, 10 to 49, and 50 to 99. Errors and the total number of items read in one minute were recorded. The results follow:

*Average Number Read per Minute**

Digits	Arabic	Roman
1–9	183.9	122.5
10–49	115.7	40.3
50–99	119.4	24.4
	Average Number Errors per Minute	
Digits	Arabic	Roman
1–9	0.1	0.4
10–49	0.3	8.4
50–99	0.3	10.2

* All differences between Arabic and Roman numerals were statistically significant.

The percentage difference between the reading of the two kinds of numerals was large: 50.1, 137.5, and 349.4 for speed, and 75, 96.4, and 97.1 for errors, all in favor of the Arabic. It would seem that Arabic rather than Roman numerals should be employed for most purposes because of their greater "legibility." This requirement should apply to chapter numbers in books and in the indices, volume and table numbers in magazines and journals, dates of historical events in certain books and on monuments, and on title pages of certain books.

Summary

1. There is considerable variation in the legibility of capital letters of the alphabet and also of lower-case letters.

2. Individual capital letters are more legible than lower-case letters in terms of visibility or perceptibility at a distance.

3. Lower-case letters differentiate and therefore have more "character" than capitals. This permits more recognizable word forms in words printed in lower case.

4. The legibility of certain letters, capital and lower case, can be improved by more judicious use of the following: (a) Serifs, (b) heaviness of stroke, (c) delineation of distinguishing characteristics, (d) simplification of outline, (e) white space within a letter, and (f) width of the letter.

5. For the mature reader, variation in legibility of letters due to mutual confusion of individual letters is a *very minor factor* and should cause little concern. But for children who are learning to read and for poor or immature readers, confusion of letters of similar form, as c and e, or r and t, can and usually does cause difficulty. Suggestions for improving the legibility of such letters, as described above, could be helpful.

6. Digits do vary in legibility whether in isolation or in groups. The form of some of these can be improved, such as 6, 9, 3, and 5, by accentuating the open parts or by employing optimal height-width proportions.

7. It is easier to perceive Old Style digits, which vary in height and alignment, at a distance than Modern digits which are all the same height. But in the practical reading situation, such as grouped numerals in context or in mathematical tables, the two kinds of digits are read equally fast and with equal accuracy.

8. Arabic numbers are read significantly faster and much more accurately than Roman numerals. Since the percentage differences are so large, the use of Roman numerals should be discontinued in most printing.

9. Due to custom, economy of space, esthetic taste, and investment in cast type, changes to improve the legibility of letters and digits are difficult. Nevertheless, specific letters in some type faces are more legible than in others. Such type faces should be employed in children's books and in printed material for immature readers.

To a considerable degree tradition and esthetic taste have obstructed the designing of more legible type. The accumulated research provides information which could be useful to the typographer for achieving more legible letters without any marked departure from standard or acceptable forms. Esthetic taste need not be eliminated. A satisfactory compromise is possible. The artistic aspects of type could be limited to that which is truly functional. This might well lead to the development, when necessary, of more functional art forms in the design of type.

4. Kinds of Type

TRADITION, rules of printing, and artistic appearance often dictate a typographical arrangement in specific situations. For example, most book and magazine material is printed in Roman capitals (initial letters of proper names, the initial letter of each sentence) and lower case. At times, however, a phrase, a sentence, a paragraph or even a page or more may be printed in italics, all capitals, or boldface.

There is a considerable area of discretion in which decisions on kinds of type or form will affect ease and speed of reading and at the same time maintain a typography preferred by the reader. Printing for effective communication will of necessity aim to employ type forms which enhance legibility of the print. This might be termed *averaging the possible strengths of a typographical arrangement.* To choose proper *type forms,* one must know the *forms* or characteristics of type which promote effective communication through print by maintaining an approved level of legibility. This chapter will (a) present research evidence on the type forms and styles which may be employed to advantage to maintain the most legible print; (b) provide answers to the *what, how,* and *why* of type forms in printing, and (c) be confined to printing practice in books, magazines, and pamphlets. Newspaper typography will be dealt with in Chapter 12.

Printing Practice

To what extent are present and past publications following recommendations on type form derived from research? Following the specifications outlined by Paterson and Tinker in *How To Make Type Readable* (79), Soar (97) surveyed the printing practices in 18 different psychological journals. Issues 30 years apart (1920 and 1950) were examined. All these journals were following optimal practices in the use of italics and boldface in both 1920 and 1950. There was, however, a widespread and in some cases an increasing use of all-capital type, which is a nonoptimal form of print. There was frequent use of all capitals for journal titles, journal cover information, article titles, page headings, section headings, and table titles.

Employing the same criteria of optimal printing practice (79), Nelson (65) appraised the typography in 36 employee handbooks. She found that the use of all-capital printing in headings, on covers, or combinations of both all capitals and lower case were dominant in 26 or 27 of the 36 handbooks. Thirty-two of the 36 employed all capitals on covers or for headings. Only four used all lower case for both. There was also a prominent tendency to employ typographical variations within paragraphs by the random introduction of a medley arrangement of lower case, italics, all capitals, and boldface phrases and sentences. Such an arrangement is difficult to read, even though it may attract attention. It was concluded that, in general, editors of employee handbooks have attempted to prepare attractive manuals without an awareness of optimal type forms.

Tinker (120) completed a somewhat unsystematic survey of print in comic books. In a very large proportion of these books, all-capital printing was used. Thus the utilization of word-form clues to perception was inhibited. The development of skill in reading by word units, which is so important to the mature reader, is obstructed by the all-capital printing.

Another nonoptimal form of printing is italics. Even so, it is noted that there have been several pages of italic print in books which have been listed among those with the most artistic typography for a particular year. It is apparent that much printing practice fails to conform to the specifications for use of optimal type forms.

Styles of Type Face

Books on typography devote far more space to descriptions of type faces and their uses than to all other typographical factors combined. Editors, advertisers, and publishers, therefore, seem to believe that styles of type faces are far more important than other typographical factors. In these discussions, the emphasis is largely upon appropriateness of particular type faces for conveying specific kinds of messages. In the rare instances when legibility is considered, the inadequate data derived from use of the distance method (Roethlein, 93) or visibility measurements (Luckiesh and Moss, 48) are referred to. As will be demonstrated below, these methods of investigation yield data with little or no bearing on the question at issue. What we want to know is which type faces can be read most rapidly in the normal reading situation. Only then can one identify the more legible type faces.

Paterson and Tinker (75), on the basis of suggestions from 37 publishers, selected the seven most frequently mentioned type faces for study: Scotch Roman, Garamond, Antique, Bodoni, Old Style, Caslon Old Style, and Cheltenham. Three radically different faces were added: Kabel Light, American Typewriter, and Cloister Black (Old English). Samples of each are given in Figure 4.1. The speed-of-read-

Scotch Roman

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Garamond

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as I

Antique

3. This morning my mother asked me to find out what time it was. I therefore ran just as

Bodoni

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Old Style

3. This morning my mother asked me to find out what time it was. I therefore ran just as

Caslon

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

Kabel Light

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as I could to

Cheltenham

3. This morning my mother asked me to find out what time it was. I therefore ran just as rap-

American Typewriter

3. This morning my mother asked me to find out what time it was. I therefore

Cloister Black

3. This morning my mother asked me to find out what time it was. I therefore ran just as rapidly as

FIG. 4.1—Styles of type face.

ing technique described in Chapter 2 was employed. The reading material was printed in 10 point, set solid on a uniform paper stock in a 19-pica line width. Nine hundred college students were the subjects. The speed of reading each type face was compared with Scotch Roman as a standard. The results appear in Table 4.1.

Inspection of the data in Table 4.1 reveals that type faces in common use do not differ significantly. With 80 or more readers in the Paterson-Tinker studies, (a) a difference of 2.6 to 3.5 per cent is ordinarily statistically significant between the 2 and 5 per cent level, i.e., barely significant; (b) a difference of about 3.6 per cent or greater tends to be significant at the 1 per cent level, i.e., highly significant. Only the American Typewriter and Cloister Black were read significantly more slowly than Scotch Roman.

In a supplementary investigation, Tinker and Paterson (155) recorded eye movements of subjects reading material printed in Scotch Roman and in Cloister Black. This was done to determine the specific differences in eye-movement patterns that underlie the 13 per cent retardation in speed of reading Cloister Black print in comparison with reading Scotch Roman. There were significant increases in fixation frequency, and in perception time (sum of pause durations)

TABLE 4.1—Variation in Speed of Reading Eleven Type Faces

Type Face	Differences in Per Cent
Scotch Roman (standard)	0.0
Garamond	+0.4
Antique	—0.2
Bodoni	—1.0
Old Style	—1.1
Caslon Old Style	—1.3
Kabel Light	—2.2
Cheltenham	—2.4
American Typewriter	—4.7
Cloister Black	—13.6

of 5 and 6.4 per cent respectively. Average pause duration and regression frequency did not change significantly, although they increased slightly. These changes indicate greater difficulty in discriminating Cloister Black print and in reading by word units. Thus, a more complete understanding of why retardation occurs is obtained when analysis of eye movements supplement speed-of-reading scores.

The results of Roethlein (93), Burtt and Basch (18), and Luckiesh and Moss (48) do not agree with the above. Both Roethlein and Burtt and Basch dealt with the perceptibility of isolated letters and meaningless groups of letters, and therefore failed to duplicate ordinary reading conditions. Luckiesh and Moss employed visibility measurements of lower-case letters which are also not valid for determining legibility in ordinary reading (see below).

Reader Opinions. Reader opinions and preferences with regard to print are important from the viewpoint of consumer satisfaction. According to the combined judgments of 210 college students, important differences in legibility exist between the type faces used in the Paterson and Tinker study. The results are given in Table 4.2.

Examination of the average rank column in Table 4.2 reveals that Cheltenham and Antique are grouped together

TABLE 4.2—Ten Type Faces Ranked According to Reader Opinions of Relative Legibility

Type Face	Average Rank	Rank Order
Cheltenham	2.3	1
Antique	2.4	2
Bodoni	4.2	3
Old Style	4.6	4
Garamond	5.4	5
American Typewriter	5.5	6
Scotch Roman	6.2	7
Caslon Old Style	6.4	8
Kabel Light	8.2	9
Cloister Black	9.8	10

as distinctly more legible than the remainder. A glance at Figure 4.1 discloses that these tend toward a heavy or darker face. Successive groupings are (a) Bodoni and Old Style; (b) Garamond and American Typewriter; (c) Scotch Roman and Caslon Old Style; (d) Kabel Light; and (e) Cloister Black. The only point of agreement with the speed of reading is that Cloister Black is at the bottom of the ranking.

Two inferences may be drawn from these findings: (a) Mere opinions are not always safe guides to legibility of print. For many other typographical factors, however, reader judgments do coincide with speed-of-reading results (see below). (b) There is a practical value to opinions that should not be overlooked by editors who desire to cater to the preferences of their readers. Where legibility differences are slight or practically nonexistent, the editor can follow reader preferences without decreasing legibility. In this instance, material set in Cheltenham or Antique will give the impression of being easily and rapidly read. The same would be true of other well-designed type faces which are now used more frequently and which approach in appearance a boldface type. Types used in the 1932 study are not employed so often now, but analysis showed that the same conclusions hold. Some attention to reader opinions, therefore, makes it possible to capitalize on the psychology of the readers.

Those who stress esthetic values in typography would like to know to what degree "judged pleasingness" of type agrees with opinions on legibility and with speed of reading. Tinker and Paterson (156) completed an extensive series of studies on this subject. In all cases, judged pleasingness of print was closely related to judgments of legibility. In other words, readers place high esthetic values on those printing arrangements that appear to be most legible. Therefore, judged legibility may be accepted as equivalent to pleasingness. Furthermore, in many cases, judged legibility agrees closely with speed-of-reading scores.

Pyke (92) investigated the relative legibility of eight type faces. He employed several methods, none of which was very satisfactory to him. The faces were Old Style No. 2, Modern Extended No. 7, Imprint Old Face No. 101, Modern Condensed No. 39, Caslon, Modern Series No. 23, Old Style Antique No. 161, Cushing Series No. 17, and Lining Grotesque Series No. 10. Although Old Style No. 2 seemed the most legible and Modern Condensed No. 39 the least legible, Pyke considered that legibility differences between the faces were small. He then advanced the viewpoint that differences in type faces would have to be very radical indeed in order to produce appreciable differences in legibility in everyday reading situations.

The Paterson and Tinker findings cited above are in complete agreement with Pyke's viewpoint. There is one finding of Roethlein (93) which tends to agree somewhat with Pyke. She found that the degrees of legibility of the eight type faces tended to be reduced to a common level when the letters were in groups.

A further check on the legibility of type faces was made by Webster and Tinker (168). Using the same faces employed in the Paterson and Tinker (75) experiment, they compared each type face with Scotch Roman as a standard by measuring perceptibility at a distance. The differences and orders of perceptibility are given in Table 4.3.

The first seven type faces in the table were perceived at a statistically significant and greater distance than Scotch Roman standard. For Kabel Light and Cloister Black the differences were unimportant. With the exception of Cloister Black, the order of legibility was strikingly different from that found by the speed-of-reading method. Apparently cer-

TABLE 4.3—Differences Between Scotch Roman and Ten Type Faces in Perceptibility

Type Face Compared With Scotch Roman	Perceptibility or Legibility Rank	Differences in Per Cent
American Typewriter	1	+26.40
Cheltenham	2	+14.91
Antique	3	+14.83
Old Style	4	+11.43
Caslon Old Style	5	+ 7.88
Garamond	6	+ 6.80
Bodoni	7	+ 4.57
Scotch Roman	8	0.00
Kabel Light	9	− 0.05
Cloister Black	10	− 1.57

tain factors which increase perceptibility at a distance retard speed of reading in the ordinary reading situation.

A final experiment in this area by Tinker (122) presented data and an analysis of criteria for determining the legibility of type faces. The ten type faces employed by Paterson and Tinker, and by Webster and Tinker, as described above, were used. Visibility measurements, as described in Chapter 2,

TABLE 4.4—Comparison of Visibility, Perceptibility at a Distance, Speed of Reading, and Reader Opinions of Legibility for Ten Type Faces

Type Face	Visibility Rank	Perceptibility Rank	Speed of Reading Rank	Reader Opinion Rank
Antique	1	3	3	2
Cheltenham	2	2	8	1
American Typewriter	3	1	9	6
Cloister Black	4	10	10	10
Bodoni	5	7	4.5	3
Garamond	6	6	1	5
Old Style	7	4	4.5	4
Caslon Old Style	8	5	6	8
Kabel Light	9	9	7	9
Scotch Roman	10	8	2	7

were obtained. These data were compared with perceptibility data, speed-of-reading data, and readers' judgments as shown in Table 4.4.

All differences between Scotch Roman and other faces for the visibility data in Table 4.4 were statistically significant. All but those in ranks 8, 9, and 10 were significant for perceptibility, while only those in ranks 9 and 10 were significant for speed of reading. Rank 1 means best. In some instances, however, the difference between successive ranks was small. The correlations between rank orders follow:

Visibility vs. perceptibility,	correlation = + .58
Visibility vs. speed of reading,	correlation = − .30
Perceptibility vs. speed of reading,	correlation = − .33
Visibility vs. judged legibility,	correlation = + .58
Perceptibility vs. judged legibility,	correlation = + .67
Speed of reading vs. judged legibility,	correlation = + .33

These correlations indicate that visibility and perceptibility measurements of type face legibility have much in common. But neither visibility nor perceptibility shows any agreement with speed of reading. The fourth and fifth correlations suggest that judged legibility of type faces is based largely upon visibility or perceptibility of the type. As noted earlier, judged legibility of type faces has only slight correspondence to speed-of-reading scores. And in general, type faces judged most legible are also most pleasing. There are exceptions to this rule, i.e., American Typewriter and Cloister Black.

The trends of these data suggest that of the type faces read equally fast, readers prefer those that are more perceptible and of high visibility. But readers do not prefer type faces which significantly retard speed, even though these type faces have high visibility.

With these data at hand, how is one to decide which ones are more valid as measures of legibility? First of all, both visibility and perceptibility at a distance represent abnormal and artificial reading situations. It would seem that legibility should be measured during normal reading if the measure is to be valid. Furthermore, visibility and perceptibility scores as criteria of legibility can lead to absurd conclusions. For instance, large type sizes such as 14, 18, 24, and 36 point yield high visibility and perceptibility scores, but they produce print which retards reading speed due to lack of effective word-form clues to perception. Word-form clues are highly important for smooth and rapid reading in which words are perceived as units. Furthermore, the fact that the larger type sizes produce fewer words per unit horizontal distance prevents maximal use of peripheral vision in reading. In optimal typography, use of peripheral vision provides premonitions of coming word forms and thus speeds up reading. As noted in Chapter 2, however, visibility and perceptibility scores provide useful measures of legibility in certain situations.

Of the techniques employed in this investigation, speed of reading appears to provide the most valid determination of legibility of type faces. It yields measurement in a normal, ordinary reading situation. As specified in Chapter 2, there must be satisfactory controls such as equivalent forms of reading material and checks on comprehension. In addition, a speed-of-reading technique detects those type faces which are equally legible, although there may be marked differences in visibility and perceptibility. Later, we shall find that speed of reading finds wide application in determining the influence of various typographical factors on legibility.

Italic Print Versus Roman Lower Case

Printing experts rather uniformly consider italic type far less legible than Roman lower case. In fact, a page of print set in italics does look formidable and difficult to read. As early as 1914, Starch (216) reported that italic print was read more slowly than ordinary lower case. Forty subjects read the same material printed both ways. No data were given. In the first controlled experiment, Tinker and Paterson (147) found that italic print was read 2.7 per cent more slowly than Roman lower case. This difference was significant between the 2 and 5 per cent level. In a more extensive experiment, Tinker (139) compared speed of reading italics and lower case. The 96 subjects read each kind of print for three successive 10-minute periods, 30 minutes in all. The data are given in Table 4.5.

TABLE 4.5—Difference Between Lower Case and Italics in Speed of Reading

	Difference Between Means*	
Reading Time	Paragraphs of 30 Words Each	Per Cent
First 10 min.	— 4.5	—4.2
Second 10 min.	— 5.5	—5.2
Third 10 min.	— 6.7	—6.3
Total: 30 min.	—15.4	—4.9

* All differences are significant at the 1 per cent level.

The data reveal that italic print retards reading by a small but statistically significant amount—about 15.5 words per minute. This amount of retardation does not seem large, but other considerations must be taken into account. First, readers do not like italics. Of 224 adult readers, 96 per cent judged that lower case could be read more easily and faster than italics (79). Second, when italic print is combined with other marginal conditions, the combined effect is markedly deleterious.

Tinker (129) organized two sets of conditions: (a) Material set in 10-point Roman lower-case type with a 20-pica line width and 2-point leading on eggshell paper stock was to be read under 25 foot-candles of well-diffused illumination. This was considered an optimal reading situation. (b) Material set in 8-point italic type with 1-point leading in a 12-pica line width on eggshell paper stock was to be read under 3 foot-candles of light intensity. These latter conditions were considered marginal. By marginal we mean that any further change that is deleterious will result in a distinctly nonoptimal reading situation, i.e., a smaller size of type and a lower illumination intensity. For example, italic print, as stated above, is read 2.7 to 4.9 per cent more slowly than lower case. The time limit was 10 minutes for each kind of material.

Performance under these marginal conditions retarded rate of reading by about 37 words per minute. Apparently, when these three marginal conditions are all present at the same time, they produce a decidedly nonoptimal visual situation which is not produced by any one of the three alone. In combination, they produced a retardation of about 10.5 per cent. This amount of retardation is only achieved by marked degrees of nonoptimal typography or by reducing illumination to less than 0.1 foot-candle.

The implications of these findings for the hygiene of vision, printing arrangements, or otherwise are as follows: It is not safe to use marginal typography (type form, type size, leading, line width) which tends to reduce legibility somewhat but perhaps not significantly. A combination of two or more such conditions, which might well occur, operate together to produce markedly nonoptimal visual performance.

Two factors indicate that italics should seldom be used: It is read slightly more slowly than ordinary lower-case characters, and readers do not like it. Therefore, the use of italics should be restricted to those rare occasions when added emphasis is needed.

Capitals Versus Lower Case

The use of all-capital printing occurs less frequently than formerly in certain newspapers, books, magazines, and pamphlets. All too frequently, however, all capitals are still employed in journals and books for table titles, chapter headings, section headings, titles of articles, and in some instances for newspaper headlines. As early as 1914, Starch (216) reported that text set in Roman lower case was read 10 per cent faster than similar material set in all capitals. The first carefully controlled study was reported by Tinker and Paterson (147) in 1928. The speed-of-reading technique was used with 320 readers. Later (79), reader preferences for all capitals and lower case were obtained from 224 college students. The results in brief are given in Table 4.6.

From Table 4.6, it is clear that speed of reading and reader opinions agree that lower-case type is much more legible than all-capital type. Pleasingness ratings revealed the same trend.

Later, Tinker (139) reported an investigation in which 60 college students read material in all capitals and then in

TABLE 4.6—Legibility of All Capitals Versus Lower Case

Speed of Reading		
Type Form	Average No. Paragraphs Read	Difference in Per Cent
Lower case	18.83	—11.8
All capitals	16.61	
Reader Opinions of Relative Legibility		
Type Form	Average Rank	Percentage Choice
Lower case	1.1	90
All capitals	1.9	10

lower case for four successive 5-minute periods. The speed-of-reading technique was employed. Scores were obtained for 5, 10, and 20-minute periods. The differences were all statistically significant and in favor of the lower case. For the 5 and 10-minute periods, the percentage differences ranged from 9.53 to 19.01. For the 20 minutes, the retarding effect of the all capitals was 13.89 per cent. It is apparent from the above data that all-capital printing retards speed of reading to a striking degree, and that most readers consider lower-case print faster and easier to read than all capitals.

Slow, meticulous reading apparently fails to show differences between capitals and lower case in rate of work. Stern (101) compared output of beginning linotype operators in composing from upper-case wire copy and from typewritten lower-case copy. A counterbalanced design was employed. Records were kept for number of lines set daily while the operator worked one week with each kind of copy. No significant difference in speed or errors was found in setting from all capitals in comparison with lower-case copy. Lack of difference seems to be due partly to the emphasis on accuracy in linotype operation. The operators must work slowly. They read carefully every letter and symbol they set in type. However, this study has little bearing upon legibility in ordinary reading.

Explanation of Difference. Tinker (115) investigated the influence of form of type on the perception of words printed in lower case and in capitals as one of the factors involved in the greater legibility of lower-case printing. He studied, by the distance method, the perceptibility of words and the perceptibility of letters in meaningless groups in both kinds of type to investigate the influence of word form in perception. The stimulus material consisted of 105 five-letter words and 105 groups of five letters in unrelated arrangement. The same material was printed in capitals and in lower case. In

TABLE 4.7—Perceptibility at a Distance of Material in Capitals and Lower Case

	Mean Scores in cm. for Perception		
Type Form	Nonsense	40 Words	105 Words
Lower case	164.6	173.4	173.2
Capitals	233.3	238.8	239.9

Differences

Comparison	Mean Difference: Cm.	Critical Ratio
105 L. C. words vs. words in cap.	66.7	26.89*
105 L. C. words vs. nonsense in cap.	68.5	29.02*
L. C. nonsense vs. 40 words	8.8	2.84*
L. C. nonsense vs. 105 words	8.6	4.22*
Capitals: nonsense vs. 40 words	5.5	1.57
Capitals: nonsense vs. 105 words	6.6	2.71

* Significant at the 1 per cent level.

40 of these words, the nonsense arrangement was obtained by spelling the words backwards, i.e., "evoba" from "above." Practice and fatigue effects were controlled. Illumination was constant at 35 foot-candles. Scores were distance in centimeters at which correct perception occurred. The comparisons are given in Table 4.7.

Examination of the data in Table 4.7 leads to the following conclusions:

1. Both letters and words in capitals are perceived at a much greater distance from the reader than letters and words in lower case.

2. There is only a small (5.5 cm. to 6.6 cm.) and statistically insignificant difference between distances at which capital letters and words in capitals were perceived correctly.

3. With lower-case print, the differences for perceiving words and unrelated letters are greater and are statistically significant.

4. These comparisons suggest that total word form is

more important in perceiving words in lower case than in all capitals where perception occurs largely by letters. This conclusion is supported by the fact that words in lower case yielded more misreadings than words in capitals. In the lower-case print, the incorrect word frequently had a total configuration or form similar to that of the stimulus word.

5. Reading by word units is characteristic of mature readers. Presence of distinctive total word form facilitates reading by word units and is one ot the factors contributing to faster reading of lower-case type.

The fact that word form is more distinctive when words are printed in lower case than when printed in all capitals is well illustrated in Figure 4.2. The configuration of "stopped" is more characteristic in ordinary lower case, italics, and boldface lower case than in capitals where letters are all the same height and in straight horizontal alignment.

There are other reasons why material in capitals has poor legibility. For the same type face and size, the printing surface required for all-capital text is about 35 per cent greater than for the same material set in lower case. This alone would greatly increase the number of fixation pauses required to read the material. In the eye-movement study by Tinker and Paterson (154), although pause duration was less, fixation frequency and perception time were significantly greater for reading the all-capital print. There was no difference in regression frequency. Casual examination of print

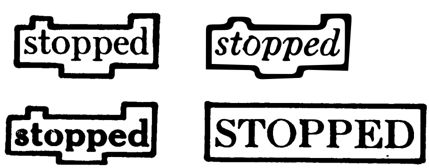

FIG. 4.2—Block outlines of the printed word "stopped" illustrate that lower case, italics, and boldface exhibit a characteristic "word form," whereas "word form" .is absent when printed in all capitals.

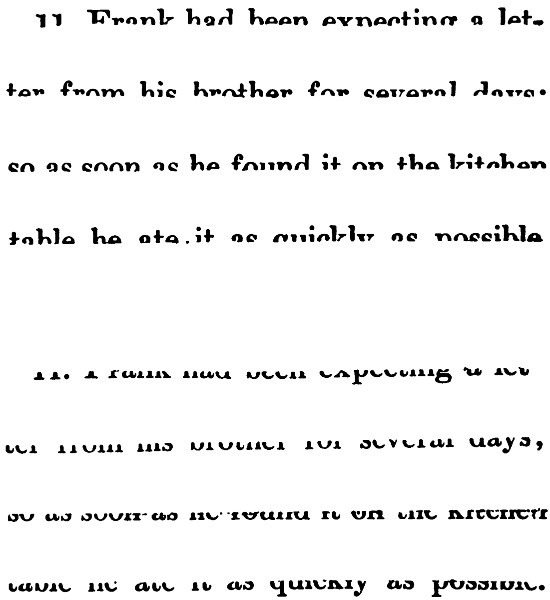

FIG. 4.3—This illustrates how the upper half of a printed line furnishes more clues to "word form" than the lower half.

reveals that the upper half of a printed line in lower case furnishes more clues to word form than the lower half. This is illustrated in Figure 4.3. Finally, reading habits favor lower case since practically all our reading is concerned with lower-case rather than all-capital printing.

In view of the evidence which demonstrates that capitals greatly retard speed of reading in comparison with lower case and are not liked by readers, it would seem that all-capital printing should be eliminated whenever rapid reading and consumer views are a consideration. This would hold for continuous reading material, posters, car cards, billboards, magazine advertising copy, headings in books, business forms and records, table titles, titles on books, and many other kinds of printing.

Boldface Type

Printing in boldface type is frequently employed to emphasize phrases or sentences in continuous reading material, for titles of books, and for chapter headings and section headings in books. Roethlein (93) showed that letters in boldface were perceived at a greater distance than ordinary lower-case print. Luckiesh and Moss (56) obtained visibility measurements for Memphis Light, Memphis Medium, Memphis Bold, and Memphis Extra Bold. They found that the greater the heaviness of face, the greater the visibility. Employing the blink technique, they found that Memphis Medium produced fewest blinks during five minutes of reading. They also found that there was no appreciable difference in speed of reading for the four degrees of boldness.

In a carefully controlled experiment, Paterson and Tinker (79) discovered no difference in speed of reading boldface and ordinary lower-case type. They also found that 70 per cent of 224 readers preferred the ordinary lower case and 30 per cent the boldface. As noted above, readers preferred Cheltenham and Antique type faces which were no more legible than several other faces. However, these two faces approached in appearance medium boldface type.

These results indicate that boldface type can be safely used for emphasis in such situations as book titles, section headings, and advertising matter without loss of legibility.

Mixed Type Forms

In some printing, especially newspapers, a variety of type forms are mixed together in the same paragraph or article to achieve perhaps a "change of pace" or emphasis. Although confined mostly to newspaper printing, the topic is considered in the present discussion of type forms.

Tinker and Paterson (162) investigated the relative legibility of two medley typographical arrangements (mixed type forms) and ordinary lower-case Roman type. Their speed-of-reading and reader preference techniques were used. Three groups of 94 college students each participated in the speed of reading part of the experiment and 181 gave opinions of legibility.

The medley arrangements included variations in type size, form, boldness, line length, etc. The second medley arrangement was considerably more extreme than the first. The ordinary lower case was set in 7-point Excelsior type with 1-point leading in a 12-pica line width. The results are given in Table 4.8.

Both medley arrangements were read more slowly than ordinary lower case by significant and practical amounts. Medley No. 2 (extreme) was less legible than No. 1. The judged legibility was in line with speed-of-reading scores.

TABLE 4.8—Effect of Mixed Type Form on Legibility

Speed of Reading		
Comparison	Mean Difference in 30-Word Paragraphs	Per Cent Difference
Regular vs. Medley No. 1	—1.48	— 8.35*
Regular vs. Medley No. 2	—2.00	—11.39*
Reader Opinions of Legibility		
Type Variation	Mean Rank	Rank Order
Ordinary lower case	1.83	1
Medley No. 1	1.98	2
Medley No. 2	2.19	3
Reader Opinions on Pleasingness		
Ordinary lower case	1.86	2
Medley No. 1	1.70	1
Medley No. 2	2.44	3

* Significant at the 1 per cent level.

The uniform arrangement came first, Medley No. 1 next, and Medley No. 2 last. Somewhat in contrast, Medley No. 1 was considered most pleasing, the uniform arrangement next, and Medley No. 2 last. Apparently, readers feel that a moderate degree of variation in type form is pleasing, even though they judge such variation to be less legible than the customary uniform arrangement. They neither like nor consider legible the more extreme medley arrangements.

Summary

Surveys of printing practice suggest that printers, editors, and typographers go their own way with little attention to the influence of variations in type form upon legibility. They seem to depend upon opinion and tradition, either because they are not familiar with research findings or because they are not convinced of their value. There are now considerable experimental data on the subject. The findings are summarized below.

1. Type faces in common use are equally legible. Apparently there must be a marked difference in type faces such as Cloister Black versus Scotch Roman, before there is a significant difference in legibility.

2. Readers prefer a type face that appears to border on boldface, such as Antique and Cheltenham. Printers and editors might well cater to reader preferences when the preferred type face is just as legible as the others. Furthermore, preferences tend to coincide with judgments of pleasingness.

3. A serifless type, Kabel Light, is read as rapidly as ordinary type, but readers do not prefer it. It was placed ninth among 10 type faces in judged legibility.

4. Neither visibility nor perceptibility at a distance shows any agreement with speed of reading as measures of legibility of type faces. But readers' judgment of legibility tends to

be in terms of visibility and perceptibility scores, except that readers do not prefer type faces which significantly retard speed of reading, i.e., Cloister Black.

5. Italic print is read somewhat more slowly than ordinary lower case. Ninety-six per cent of readers prefer lower case. Furthermore, when italics are combined with marginal conditions of illumination and type size, speed of reading is retarded more than 10 per cent. In general, the use of italics should be restricted to those rare occasions when added emphasis is needed.

6. All-capital print greatly retards speed of reading in comparison with lower-case type. Also, most readers judge all capitals to be less legible. Faster reading of the lower-case print is due to the characteristic word forms furnished by this type. This permits reading by word units, while all capitals tend to be read letter by letter. Furthermore, since all-capital printing takes at least one-third more space than lower case, more fixation pauses are required for reading the same amount of material. The use of all capitals should be dispensed with in every printing situation.

7. Boldface type is read at the same rate as ordinary lower case. Seventy per cent of readers prefer the ordinary lower case. Boldface printing may be used for emphasis whenever desired, without loss of legibility. It should not be employed for large amounts of text because reader preferences are definitely against it.

8. Material printed in mixed type forms markedly retards speed of reading and is less preferred in comparison with ordinary lower-case type.

9. Research dealing with individual letters or letters grouped in nonsense arrangement offers little that is important concerning the legibility of type faces. Satisfactory results are obtained by measuring speed of reading continuous,

meaningful material. There must be control of the equivalence of test forms, checks on comprehension, and statistical evaluation of results.

10. Speed of reading seems to be the most satisfactory measure of legibility of type faces. A legible type is one that can be read rapidly and easily.

5. Size of Type

THERE CONTINUES to be a lively interest in size of type in relation to legibility of print. Publishers are quite willing to state their opinions about what size is optimal (79). The tendency is to suggest that nothing smaller than 10 or 11-point type should be used for books. Investigators do not agree with each other on this subject. Some claim that size of type is the most important typographical factor in legibility, while others minimize its importance in relation to other factors such as leading. Starch (100) points out that, from 1880 to 1910, advertisers moved during each decade from use of 5, 6 or 8-point type to larger sizes.

Printing Practice

In view of the lack of agreement regarding optimal type size among experts and investigators, it would be surprising to find much uniformity in printing practice. Paterson and Tinker (79) reported in 1940 a survey completed a few years earlier. A total of 1,500 books and magazines was studied, distributed as shown in Table 5.1.

The American nonscientific magazines showed a heavy concentration at 9 and 10-point sizes in Table 5.1. Over two-thirds of American scientific journals were printed in 10 point and 19 per cent were in 11 point. The foreign scientific journals employed the same type sizes with a tendency toward

TABLE 5.1—Survey of Printing Practice: Size of Type

Kind of Journals or Books	Range in Points	Median Type Size in Points	Per Cent in Median Size
100 American nonscientific journals...	7–11	10	45.0
200 American scientific journals	8–12	10	68.5
200 foreign scientific journals	8–12	11	48.0
200 history texts	10–14	11	33.5
200 education texts	8–12	11	44.0
200 psychology texts	9–14	11	34.0
200 economics texts	9–12	11	42.0
200 literature texts	8–14	11	40.5

11 point. The large majority of textbooks employed 10, 11, or 12 point with a preference for 11 point.

The diversity revealed in this survey of practices raises a number of questions. What justification is there for the wide variation in usage? Do scientists and students require larger sizes of type than the reader of nonscientific materials? Are all the type sizes used equally legible? These questions indicate how important it is to have definite knowledge concerning the legibility of type sizes.

Subsidiary Research on Type Size

It seems best to consider first some of the early studies on type size and also those investigations which are inadequate. As early as 1886, Griffing and Franz (30) compared 5-point type with 12-point type. The 12 point was read 10 per cent faster than the 5 point. A short-exposure technique was also employed. In general, legibility appeared to increase with type size up to 12 point. The authors concluded that type size was the all-important condition of "visual fatigue." They suggested that the lowest limit to size in common use should be about 10 point.

Gilliland (25) employed photographic reductions and enlargements of 12-point type to obtain sizes "equivalent" to 3 to 90 point. Legibility was measured in terms of speed of reading and eye-movement recording. Gilliland, on the basis of his results, concluded that size of type was a relatively unimportant factor in legibility. His findings and conclusions may be dismissed as not valid because photographic reductions and enlargements do not reproduce actual printing conditions. Furthermore, practice effects were not controlled since the same material was read in the different type sizes.

In the Luckiesh and Moss (52) study, visibility measurements were made of Bodoni Book type in sizes 3, 4, 5, 6, 8, 10, 12, 14, 18, and 24 point. The visibility measurements improved consistently from 3 to the 24-point type. Although visibilty is shown to increase with increase in type size, there is no way of determining from these data which type size has optimal legibility in the ordinary reading situation. It will be shown later that some of the larger point sizes significantly retard the speed of reading.

Speed-of-Reading Studies

Paterson and Tinker (70, 79) completed two studies of the influence of type size on legibility of print. They employed their speed-of-reading method. In the first investigation, using 320 college students as readers, they determined the relative legibility of 6, 8, 10, 12, and 14-point type. The appearance of variations in type size is shown in Figure 5.1. Results in Study 1 are given in Table 5.2. Material was set solid in Scotch Roman type with a line width of 19 picas. The standard with which the other type sizes were compared was 10 point.

6 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

8 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

9 point

16. This band of men and women set sail for the new world where they could live in peace. There was great rejoicing when

10 point

16. This band of men and women set sail for the new world where they could live in peace. There was

11 point

16. This band of men and women set sail for the new world where they could live in peace. There was

12 point

16. This band of men and women set sail for the new world where they could live in peace.

14 point

16. This band of men and women set sail for the new world where they

FIG. 5.1—Seven sizes of type set solid, 19-pica line width. Six through 12 point are Granjon, 14 point is Scotch Roman.

The data in Table 5.2 show that for this line width and for material set solid, all the type sizes were read significantly more slowly than 10 point.

The experiment was repeated with some modifications. Granjon type was used in 8, 9, 10, 11, and 12-point sizes. All were set solid in a 19-pica line width on eggshell paper stock. Also, a control group was included. The results for 475

TABLE 5.2—Comparative Legibility of Five Sizes of Type: Study 1

Type Size Compared With Standard 10 Point	Differences in Per Cent*
6 point	—5.8
8 point	—4.9
12 point	—5.5
14 point	—6.4

* All differences are significant at the 1 per cent level. Minus signifies less legible than standard 10 point.

readers are given in Table 5.3. The standard was the 10-point type.

The 8-point was read significantly more slowly than 10-point type and 11 point was read significantly faster than 10 point, (Table 5.3). Other differences are not significant. Note, however, that 12 point was read slightly more slowly than 10 point. Probably the results, especially for 12-point type, should be minimized in the first study. Later results (Chapter 7) will confirm this view.

An analysis of eye-movement patterns reveals that very small and very large type sizes were read more slowly than 10 point. Employing the technique described in Chapter 2,

TABLE 5.3—Size of Type: Study 2

Type Size Compared With Standard 10 Point	Differences in Per Cent*
8 point	—3.8
9 point	+2.3
10 point (control)	0.0
11 point	+5.1
12 point	—2.1

* Minus signifies less legible than the 10-point standard.

TABLE 5.4—Eye Movements in Reading 6 and 14-Point Type in Comparison With 10 Point*

	Fixation Frequency	Pause Duration	Perception Time	Regression Frequency
	10-Point Vs. 6-Point Type			
Difference	+12.4	+0.01	+ 5.6	+ 1.8
% difference.......	+ 7.4	+7.20	+14.7	+11.0
	10-Point Vs. 14-Point Type			
Difference	+32.1	—0.02	+ 4.7	+ 2.2
% difference.......	+21.1	—6.00	+13.6	+12.6

* Pause duration and perception time are reported in seconds. All differences are statistically significant at the 1 per cent level.

Paterson and Tinker (80) reported a study of this kind. The results are listed in Table 5.4

Examination of the data in Table 5.4 reveals that the 10-point type was read with oculomotor patterns which indicate greater efficiency than either the 6 point or the 14 point. The results suggest that the reduction in efficiency for the 6 point was due largely to reduced visibility of the small type. For the 14 point, however, the reduced efficiency appears to be due to the increased amount of printing area to be covered in reading a given amount of material.

Reader Judgments of Legibility. The opinions of 224 readers were secured by asking them to rank the materials in the five type sizes for legibility in terms of ease and speed of reading. The results are listed in Table 5.5.

Eleven point is considered the most legible of all. Close below come 10 and 12 point. But 8 and 9 point are relegated to the bottom of the list. As will be shown later, this ranking of opinions corresponds to the measured legibility when optimal line widths and leading are used.

Cordination of Size With Other Typographical Factors. The incautious researcher or reader might be tempted at this

TABLE 5.5—Legibility of Type Sizes According to Reader Opinions

Size of Type	Average Rank	Rank Order
8 point	4.7	5
9 point	3.7	4
10 point	2.4	2.5
11 point	1.9	1
12 point	2.4	2.5

point to draw a final conclusion with regard to legibility of size of type. One must realize, however, that in addition to size of type, other typographical factors such as line width and leading are involved and must be taken into consideration. In other words, line width, leading, and type size must be coordinated in any final judgment concerning the legibility of type size. All three factors should be studied under conditions where simultaneous and systematic variations of all three are made. Only under these conditions will final results be significant. Therefore, the reader should suspend judgment with regard to legibility of type size pending a detailed presentation in Chapter 7 of the effects of all three factors varied simultaneously. First, it is desirable to consider some of the effects of line width on legibility.

6. Width of Line

There has long been a lively interest in the effect of line width (sometimes called line length) upon legibility of print. Ophthalmologists, educators, psychologists, advertisers, editors, and typographers from 1881 to 1923 made casual observations and carried out a few uncontrolled measurements. These led to definite recommendations based upon opinion and inadequate data. Pyke (92) has reviewed this material in detail. A few citations will reveal the diversity of opinions concerning line widths for 10 to 12-point type:

Publication Year	Recommended Line Width in Picas
1881	24–36
1883	7–26
1906	18–20
1910	14 is optimum
1912	22 is maximum
1922	18 preferred
1927	13–16

Most opinions list the optimum line width at about 22 picas. On the whole, the suggestions favor use of relatively short lines. But the recommendations tend to be somewhat contradictory. Obviously, carefully controlled experimentation is needed to determine the range of line widths that may be used safely with each size of type.

An illustration of variations in line width is given in Figure 6.1. The lines ranging from 9 to 37 picas in 8-point

9 picas

6. Mr. Smith gave a news-
boy a quarter for a paper

13 picas

6. Mr. Smith gave a newsboy a quar-
ter for a paper and left without his

17 picas

6. Mr. Smith gave a newsboy a quarter for a paper
and left without his change. When the boy ran and

21 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left
without his change. When the boy ran and told him he said he

25 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without
his change. When the boy ran and told him he said he had never

29 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When
the boy ran and told him he said he had never seen such dishonesty. 7. It was a cold day

33 picas

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy
ran and told him he said he had never seen such dishonesty. 7. It was a cold day in winter and the

37 picas

6. Mr. Smith gave a newsboy a quarter for a paper anl left without his change. When the boy ran and
told him he said he had never seen such dishonesty. 7. It was a cold day in winter and the ground was cov-

FIG. 6.1—Line widths for 8-point type, Scotch Roman, set solid.

TABLE 6.1—Printing Practice With Reference to Line Width

No. of Journals or Books	Range in Picas	Median Interval	Per Cent in Interval
Double-Column Printing			
93 American nonscientific journals	11 to 24	17–18	12.9
54 American scientific journals	11 to 20	17–18	35.2
Single-Column Printing			
7 American nonscientific journals ...	23 to 28	27–28	57.1
146 American scientific journals	21 to 30	25–26	49.9
200 foreign scientific journals	16 to 30	25–26	40.5
200 history texts	17 to 28	21–22	36.5
200 education texts	17 to 28	21–22	38.0
200 psychology texts	17 to 28	21–22	42.5
200 economics texts	16 to 30	21–22	40.5
200 literature texts	16 to 28	21–22	51.0

type will help the reader to visualize what line widths in picas look like. One pica is about one-sixth inch.

Printing Practice

A wide diversity of practice is employed for line widths in all kinds of printing. A total of 1,500 journals and books were surveyed by Paterson and Tinker (79). The results are presented in Table 6.1.

Both single and double-column printing were used in American magazines and scientific journals. With double-column printing, the line widths used in nonscientific journals were spread rather evenly from 14 to 22 picas. But in the double-column scientific journals, most were printed in 13 to 18-pica line widths.

In single-column printing, there was greater uniformity. The journals employed mostly 23 to 28-pica line widths. Most of the textbooks concentrated on 19 to 24-pica lines. There was a strong tendency to limit line widths to a narrow range. For journals, the typical line width is in the neighborhood of 24 picas, or about 100 mm. or 4 inches. Contrasting somewhat with this, the typical line width for books is approximately 21 picas, or about 90 mm. or 3½ inches. In that there is a tendency to employ rather short lines, usage is closely in line with most of the recommendations prevailing since 1881.

Experimental Results

In an early study, Starch (100) had 40 subjects read the same material printed in line widths of 1½ inches (9 picas), 2¾ inches (16.5 picas), and 5 inches (30 picas). The material in 16.5 picas was read 16 per cent faster than that in the 9-pica width, and 7 per cent more rapidly than the 30-pica text. Starch considered that an optimum line width would be somewhere in the neighborhood of 18 picas.

Line Widths for 10-Point Type

In an initial investigation, Tinker and Paterson (148) compared speed of reading material set in a 19-pica line with material in 14, 23, 27, 32, 36, 40, and 44 picas. All material was in 10 point set solid. The results for 560 readers are shown in Table 6.2.

TABLE 6.2—Effect of Line Width on Legibility of 10-Point Type Set Solid

Line Width Compared With Standard 19 Pica	Differences in Per Cent*
14 pica	—4.1
23 pica	0.0
27 pica	—2.5
32 pica	—2.3
36 pica	—3.4
40 pica	—5.1
44 pica	—7.5

* Minus signifies less legible than the standard.

The data in Table 6.2 suggest that materials set in 14, 36, 40, and 44 picas are read significantly more slowly than that in a 19-pica line. But line widths of 19, 23, 27, and 32 picas in 10-point type set solid are about equally legible. This holds only for set solid material. When leading is added (see Chapter 7), the picture changes.

In a second study of 10-point type set solid, Paterson and Tinker (79) varied line width by one-pica steps from 17 to 27 picas. The readers were 935 college students. The results indicated that 10-point type set solid can be varied from 17 to 27-pica line widths without any measurable effect on legibility.

In a third study of 10-point type set solid (79), line widths were varied by large steps from 9 to 43 picas. The results for 500 readers are given in Table 6.3.

The data reveal that for 10-point type set solid, short line widths of 9 and 14 picas and long line widths of 31 and 43 picas significantly retard speed of reading.

The introduction of leading modifies the legibility. In a fourth study of 10-point type, Paterson and Tinker (79) employed the same line widths as in Study 3 but used 2-point leading throughout. The data from 435 readers are given in Table 6.4.

TABLE 6.3—Effect of Line Width on Legibility of 10-Point Type Set Solid: Study 3

Line Width Compared With Standard 19 Pica	Differences in Per Cent*
9 pica	—6.7
14 pica	—4.2
19 pica (control)	0.0
31 pica	—6.8
43 pica	—6.0

* Minus signifies less legible than the standard.

TABLE 6.4—Effect of Line Width on Legibility of 10-Point Type With 2-Point Leading: Study 4

Line Width Compared With Standard 19 Pica	Differences in Per Cent*
9 pica	—5.3
14 pica	+0.3
19 pica (control)	0.0
31 pica	—2.4
43 pica	—5.9

* Minus signifies less legible than the standard.

The data in Table 6.4 seem particularly significant since 10-point type is frequently set on a 12-point body, i.e., with 2-point leading. With the 2-point leading, 10-point type appears equally legible in line widths varying from 14 to 31 picas. The very short 9 pica and the very long 43-pica lines are read significantly more slowly.

Preferences from 224 readers were obtained for relative legibility of the 10-point type set solid in varying line widths. Readers judged 19 picas to be best of all, with 14, 31, 43, and 9 picas following in that order. The 43 and 9-pica lines were practically in tied ranks at the bottom of the list.

Luckiesh and Moss (58) investigated the readability (legibility) of 10-point type with 2-point leading in line widths of 13, 17, 21, 25, and 29 picas. Use of the blink technique showed that the 13-pica line widths was 10 to 22 per cent more legible than the longer lines. Their use of the eye-movement technique and speed of reading, however, revealed an advantage for the longer lines.

Paterson and Tinker (78) analyzed the eye-movement pattern for reading 10-point type set solid in a 19-pica line width in comparison with 9 and with 43-pica lines. For the 9 pica versus 19-pica line, the fixation frequency, pause duration, and perception time were significantly increased.

Apparently, the readers were unable to make maximum use of peripheral vision in reading the 9-pica lines. For the 43 pica versus the 19-pica line, the fixation frequency, pause duration, perception time, and *regression frequency* were all significantly increased. It is worth noting that regression frequency was increased 56.7 per cent. With this excessively long line of 43 picas, the major difficulty appeared to be in accuracy in relocating the beginning of each new line when the back sweep was made. It is probable that this difficulty so upsets the usual reading process that re-establishment of the most efficient oculomotor patterns in reading each successive line becomes impossible.

Line Widths for 12-Point Type

Paterson and Tinker's next study (79) was concerned with the effect of line width on legibility of 12-point type set solid. Materials set in 17, 21, 23, 25, 27, 29, 33, and 40 picas were read by 760 subjects. No significant differences in speed of reading the different line widths were discovered. In a second study (same report) involving 640 readers, they also investigated line widths of 12-point type set solid. In comparison with the previous study, the reading material was organized into longer paragraphs. Five items of 30 words each were put into each paragraph arrangement. There were six such paragraphs. This is the six-unit printing arrangement described in Chapter 8. The line widths studied were 17, 21, 25, 29, 33, 37, 41, and 45 picas. Line widths from 17 through 37 picas were equally legible, while the very long lines of 41 and 45 picas significantly retarded speed of reading.

The two authors (79) also reported a third study of line width for 12-point type with 2-point leading. The data for 450 readers are presented in Table 6.5.

TABLE 6.5—Effect of Line Width on Legibility of 12-Point Type With 2-Point Leading

Line Width Compared With Standard 25 Pica	Differences in Per Cent*
9 pica	—5.8
17 pica	+0.8
25 pica (control)	0.0
33 pica	0.0
41 pica	—3.5*

* In the original report the authors insisted upon a critical ratio (D/P.E. diff.) of 4.00 for statistical significance. Actually, a difference of 2.6 to 3.5 per cent with 80 or more subjects yields significance between the 2 and 5 per cent levels. The writer of this report considers significance at this level of considerable importance.

Minus signifies less legible than standard.

When 2-point leading is used, 12-point type in line widths of 17 to 33 picas is equally legible. The short and long lines of 9 and 41 picas, respectively, significantly retard speed of reading.

Line Widths for 8-Point Type

A study of the effect of varying line width on the legibility of 8-point type set solid was reported (79) using 640 readers. The data are given in Table 6.6.

When 8-point type is set solid, line widths ranging from 13 to 25 picas are equally legible. But lines in 9, 29, 33, and 37 picas significantly retard speed of reading.

In a second study (79) of 8-point type, 2-point leading and line widths of 7, 14, 21, 28, and 36 picas were used. There were 500 readers. The 7-pica line significantly retarded reading but line widths ranging from 14 to 36 picas were equally legible. The introduction of leading apparently improves legibility greatly for this size of type.

TABLE 6.6—Effect of Line Width on Legibility of 8-Point Type Set Solid

Line Width Compared With Standard 17 Pica	Differences in Per Cent*
9 pica	—5.3
13 pica	—0.7
17 pica (control)	0.0
21 pica	+1.2
25 pica	—0.9
29 pica	—5.6
33 pica	—6.0
37 pica	—5.8

* Minus signifies less legible than the standard.

Line Widths for 6-Point Type

Paterson and Tinker (79) completed two studies of the effect of line width on the legibility of 6-point type. The first investigation was concerned with 6-point type set solid and used 560 readers. The results appear in Table 6.7.

Examination of the table reveals equal legibility for material in 6-point set solid with line widths ranging from 9 to 25 picas. But a line width as short as 5 picas or as long as 29 picas retards speed of reading significantly.

TABLE 6.7—Effect of Line Width on Legibility of 6-Point Type Set Solid: Study 1

Line Width Compared With Standard 13 Pica	Differences in Per Cent*
5 pica	—12.3
9 pica	— 1.7
13 pica (control)	0.0
17 pica	+ 0.3
21 pica	+ 1.8
25 pica	— 2.1
29 pica	— 4.0

* Minus signifies less legible than the standard.

TABLE 6.8—Effect of Line Width on Legibility of 6-Point Type With 2-Point Leading: Study 2

Line Width Compared With Standard 21 Pica	Differences in Per Cent*
7 pica	—4.1
14 pica	—0.1
21 pica (control)	0.0
28 pica	—1.8
36 pica	—3.2

* Minus signifies less legible than the standard.

In the second study 490 readers were used. The 6-point type was set with 2-point leading in the line widths listed in Table 6.8.

According to the data in Table 6.8, when 6-point type is set with 2-point leading, line widths ranging from 14 to 28 picas are equally legible. A 7-pica line significantly retards speed of reading (1 per cent level), while a 36-pica line retards reading somewhat (barely significant between the 2 and 5 per cent levels).

Paterson and Tinker (81) analyzed the eye movements made while reading material in 6-point type set solid and printed in different line widths. In contrast with a 13-pica line, material in a 5-pica line was read with more fixation pauses, a longer pause duration, a longer perception time, and fewer regressions. All differences were significant. Apparently, inability to make effective use of peripheral visual clues reduces legibility, even though there are fewer regressions. In reading material in a 13-pica line width versus 36 picas, there was a significant increase in pause duration and perception time, but the principal change was tremendous increase in regressions, i.e., 67.7 per cent. The latter seems to be due primarily to the inability of the eyes to locate accurately the beginning of successive lines of print.

Simultaneous Variation of Type Size and Line Width

There is a common belief that line width should vary somewhat with type size. That is, small sizes of type should be printed in shorter lines and larger type in longer lines. A survey of printing practice reveals no consistency along this line. The diversity of practice which exists indicates that 9, 10, 11, and 12-point types are printed in all line widths from 14 to 29 picas. There is some concentration of practice in that 18 to 28-pica line widths are employed more frequently than the shorter lines. At any rate, it is apparent that there is no consistent tendency to increase line width for the larger type sizes. If there is an optimal line width for each size of type, it is not made use of in printing practice.

Obviously, the area covered by print increases when the type size becomes greater. Ten point covers nearly twice as much area as 6 point, and 14 point covers more than three times the area taken by 6 point (79).

TABLE 6.9—Simultaneous Variation of Type Size and Line Width

Type Size and Line Width Compared With Standard 10 Point, 19 Pica	Differences in Per Cent*
6 point, 16 pica	—6.0
8 point, 17 pica	—0.6
10 point, 19 pica (control)	0.0
12 point, 23 pica	—3.1
14 point, 27 pica	—3.3

* Minus signifies less legible than the standard.

Tinker and Paterson (79) studied the effect of simultaneous variation of type size and line width on legibility. The reading material was set in 6, 8, 10, 12, and 14-point type. The line width varied by following a *line for line* printing procedure. This is shown in Figure 6.2. There were 400 readers. All materials were set solid with the line widths given in Table 6.9.

6 point, 16 picas

28. On Sunday Mr. Jones never reads anything but good books for he is a very religious man. Each

8 point, 17 picas

28. On Sunday Mr. Jones never reads anything but good books for he is a very religious man. Each

10 point, 19 picas

28. On Sunday Mr. Jones never reads anything but good books for he is a very religious man. Each

12 point, 23 picas

28. On Sunday Mr. Jones never reads anything but good books for he is a very religious man. Each

14 point, 27 picas

28. On Sunday Mr. Jones never reads anything but good books for he is a very religious man. Each

FIG. 6.2—Simultaneous variation of type size and line width, Scotch Roman, set solid (line for line printing).

Examination of Table 6.9 suggests that there is no direct relation between variation in size of type and width of line on the one hand and speed of reading on the other. Actually, 8-point type in a 17-pica line and 10-point type in a 19-pica line are read equally fast, and both are read more rapidly than the smaller and larger sizes. Six-point type, even when printed in a shorter line, is markedly illegible. It slows down reading speed at least 6 per cent. The larger sizes, 12 and 14 point, in the longer lines appear to slightly retard reading, i.e., significant between the 2 and 5 per cent levels.

Summary

1. In printing practice, line widths are confined to rather narrow limits. With double-column printing in magazines, the median line width was 17 to 18 picas. For single-column printing, the median line width was 25 to 26 picas for scientific journals and 21 to 22 picas for textbooks.

2. For 10-point type set solid, results from three studies show that materials in line widths between 17 and 27 picas are equally legible.

3. When 10-point type is printed with 2-point leading, line widths ranging from 14 to 31 picas were equally legible. Eye-movement records demonstrated that more fixation pauses of greater duration were employed in reading the very short lines. For very long lines, all eye-movement measures revealed less efficient reading, particularly regressions following the backsweep to the beginning of a new line.

4. Line width seemed to be a less important factor with 12-point type. From the results of two studies it appeared that 12-point print set solid was equally legible in line widths ranging from 17 to 37 picas.

5. For 12-point print with 2-point leading, line widths ranging from 17 to 33 picas were read equally fast.

6. For 8-point type set solid, line widths ranging from 13 to 25 picas were equally legible. When 8-point type is leaded 2 points, line widths of 14 to 28 picas showed no difference in legibility.

7. Six-point type set solid was equally legible in line widths of 9 to 25 picas, and with 2-point leading in line widths of 14 to 28 picas. Eye-movement patterns of illegible line widths differed markedly from those of a more legible line width.

8. All the studies of 8 and 10-point type reveal the importance of leading. They indicated that line widths can be extended without loss of legibility for material leaded 2 points.

9. Reader preferences quite definitely favor moderate line widths. Relatively long and very short line widths are disliked. In general, printing practice seems to be adjusted to the desires of the average reader with regard to line width.

10. When type size and line width are varied simultaneously by printing material line for line in the different sizes

of type, no consistent trend in legibility was found. Mere area covered by the printed material does not entirely determine legibility. The smallest (6 point) and the largest types (12 and 14 point) were read more slowly than the medium sizes.

11. Before recommendations concerning optimal type size and line width can be made, the influence of leading must be considered.

7. Leading and Relationship of Leading, Type Size, and Line Width

OPINIONS concerning the usefulness of leading to improve legibility of print are far from uniform. In his survey of the literature, Pyke (92) shows that at least 25 per cent of the writers believed that leading is unimportant while some were uncertain. But letters from publishers to Paterson and Tinker in the 1930's revealed a consensus in favor of leading. Some writers tend to give advice on the use of leading without any experimental foundation.

Prior to 1932 there was little experimental evidence concerning the effect of leading on legibility of type. Griffing and Franz (30) found a slight increase in legibility when leading was introduced in 5-point type. Bentley (6), employing a distance method combined with speed of reading, also found that leading increased legibility of 6, 9, and 12-point type. Seven-point leading appeared to be optimal. Failure to duplicate the ordinary reading situation, lack of equivalent test forms, absence of statistical evaluation of results, and use of oral reading make it difficult to interpret the results. Certainly, these early investigations constitute a meager and inadequate foundation of knowledge with respect to a typographical factor considered by many to be of prime importance.

Printing Practice

The survey of printing practice by Paterson and Tinker (79) included 1,500 journals and books. The data of this survey are given in Table 7.1.

Examination of these data reveals that, with the exception of American nonscientific journals, there is a marked tendency to employ 2-point leading, i.e., one-half to two-thirds of the scientific journals and textbooks used 2-point leading. The scientific journals and the textbooks tended to use the lesser or greater amounts of leading sparingly. Apparently, printers show greater uniformity in the use of a given amount of leading than in the use of a given type size. On the other hand, nonscientific magazines tended to utilize little or no leading.

TABLE 7.1—Printing Practice With Reference to Leading*

Type of Publication	Points of Leading					
	0	1	2	3	4	5
100 American nonscientific journals	33.0	44.0	23.0	0.0	0.0	0.0
200 American scientific journals ...	13.0	14.0	68.5	4.5	0.0	0.0
200 foreign scientific journals......	10.5	14.0	61.5	10.5	3.5	0.0
200 history texts	6.5	19.0	50.0	15.0	8.0	1.5
200 education texts	5.0	28.5	65.0	8.5	3.0	0.0
200 psychology texts	3.5	27.0	61.5	11.0	7.0	0.0
200 economics texts	5.0	20.0	63.0	6.0	6.0	0.0
200 literature texts	4.0	22.0	52.0	23.5	8.0	0.5

* Note that frequencies are given in per cent.

Is the diversity of practice in the use of leading revealed in Table 7.1 due to a coordination of leading with type size and line width? Examination of the original data by Paterson and Tinker (79) reveals that line width is not at all related to the amount of leading employed. Type size is only slightly related to the amount of leading. Most 10-point type was set with 2-point leading and, in a few instances, 12 point was set with larger amounts of leading. Evidently editors believe that leading improves legibility of type. But, in terms of printing practice, it would be difficult to predict the effect of leading on legibility.

Experimental Study of Leading

The survey of opinions and practice discussed above suggests the need for detailed experimentation to discover the effect of leading on legibility of type. This might seem a relatively simple job at first; but Paterson and Tinker found that one experiment led to another until 11 studies were completed in which over 11,000 readers served as subjects.

Leading With 10-Point Type

In a study of 10-point type in a 21-pica line, Luckiesh and Moss (50) investigated the effect of 0, 1, 2, 3, and 6-point leading on readability. The blink technique was used. Employing the material set solid as a base (100 per cent), the relative rate of blinking was obtained for 5-minute samples of reading. These relative rates were 100, 99.6, 90.3, 84.1, and 81.2 per cent, for 0, 1, 2, 3, and 6-point leading respectively. It

Set solid

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and

1 point leading

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and

2 point leading

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and

4 point leading

6. Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and

FIG. 7.1—Set solid to 4-point leading for Scotch Roman, 10 point.

was concluded that 3-point leading was optimum for 10-point type in a 21-pica line width.

In their first experiment on leading, Paterson and Tinker (74) investigated the effect of leading on legibility of 10-point Scotch Roman type in a 19-pica line width. Material was set in 0, 1, 2, and 4-point leading. The appearance of different amounts of leading is shown in Figure 7.1. The speed-of-reading method was used. The results for 400 readers are listed in Table 7.2.

The results indicate that 1-point leading contributes nothing to the legibility of 10-point type in a 19-pica line width. The use of 2-point leading yields a significantly different result; it improves legibility by over 5 per cent. Surprisingly enough, a further increase of 2 point to 4-point leading is not as satisfactory as 2 points alone. Although material in 4-point leading is read slightly faster than set solid, this is not a highly significant difference. For 10-point type in a 19-pica line width, 2-point leading is apparently optimal. This is confirmed in a later study (see page 96). The above finding does not necessarily hold for other line widths and certainly not for other sizes of type.

Reader Opinions Regarding Leading for 10-Point Type. Ratings from 224 readers were obtained for samples of the 10-point type set solid and in 1, 2, and 4-point leading. They were asked to rank the samples in order of relative legibility,

TABLE 7.2—Leading for 10-Point Type

Leading Compared With Standard Set Solid	Differences in Per Cent*
Set solid (control)	0.0
1 point	−1.0
2 point	+5.2
4 point	+2.8

* Minus signifies less legible than standard.

i.e., the ease and speed with which they could be read. The material in 2-point leading was ranked as best, 1 point next, 4 point next, and set solid last. These data suggest that readers believe that leading is advantageous for easy and speedy reading. They like neither set solid nor large amounts of leading.

Leading With 12-Point Type. The use of leading with 12-point type does not necessarily have the same effect upon legibility as with other sizes of type. Paterson and Tinker (79) determined the influence of leading upon the speed of reading 12-point type. Material was set in Scotch Roman type in a line width of 25 picas with the amounts of leading listed in Table 7.3. Readers were 570 college students.

The results failed to reveal any significant effect of leading on legibility of 12-point type in a 25-pica line width. The notion that larger sizes of type need additional amounts of leading to maintain optimal legibility finds no support in these results. Of course it is dangerous to generalize from one printing arrangement to another. What was found to hold for leading with 10-point type turns out to be wholly misleading in dealing with 12-point type. All this points to the important and laborious task of checking the various typographical factors in a variety of printing arrangements.

TABLE 7.3—Leading for 12-Point Type

Leading Compared With Standard Set Solid	Differences in Per Cent*
Set solid (control)	0.0
1 point	—2.3
2 point	+1.8
4 point	+0.4
6 point	+0.7
8 point	+0.3

* Minus signifies less legible than standard.

This must be done carefully and systematically if editors are to have reasonably accurate information to guide their practice.

Leading With 8-Point Type

The fact that leading is not important for 12-point type, but is for 10-point type, quite naturally raises the question concerning its effect on the legibility of material printed in sizes smaller than 10 point.

The next study (79) dealt with the effects of leading on the legibility of 8-point type printed in Scotch Roman in a line width of 17 picas. The number of readers was 504. Speed-of-reading scores were obtained for materials leaded as shown in Table 7.4.

The results show clearly that even a small amount of leading improves significantly the legibility of 8-point type in a 17-pica line width. In addition, no definite advantage is gained from increased amounts of leading beyond 2 point. The 2-point leading appears only slightly better than 1 point. Thus, in printing practice, legibility is definitely increased when 1 or 2-point leading is used with material printed in 8-point type and in a moderate line width.

TABLE 7.4—Leading for 8-Point Type

Leading Compared With Standard Set Solid	Differences in Per Cent*
Set solid (control)	0.0
1 point	+5.0
2 point	+5.8
4 point	+1.9
6 point	+3.0
8 point	+4.9

* Plus signifies more legible than standard.

Type Size Versus Leading

In a letter to Paterson and Tinker, it was stated that a smaller type size with double or triple leads is often more legible than a larger type set solid. And another writer claimed that a page of 10 point set solid is far more difficult to read than a page of 8-point type with 2-point leading between each line. At first sight this claim seems plausible. Therefore, it should be checked experimentally. Paterson and Tinker (79) compared speed of reading 10-point type set solid with speed of reading 8-point type with 2-point leading. Both were printed in a 19-pica line width. The results from 200 readers indicate that these two printing arrangements are *equally legible.* In other words, any claim that leading will make a smaller type size more legible than a larger type size set solid is false. However, there is a point to emphasize in relation to this finding. Other things being equal, 10-point type is more legible than 8-point type. Thus the present experiment may be accepted as additional proof of the value of 2-point leading for 8-point type. Obviously, both size of type and leading are important factors affecting legibility of typographical setups. It would seem that the best conditions for legible print are achieved when optimal leading is combined with optimal type size and line width.

Leading and Line Width in Relation to Type Size

Most of the previous discussion has been leading up to the material to be reported in this section. In order to obtain data of maximum usefulness to editors, advertisers, and publishers, experiments which vary line width and leading for each of the commonly used type sizes must be completed. Such systematic variation of typographical factors calls for a large number of readers. To study four degrees of leading and five line widths for one size of type requires 20 different printing arrangements and about 2,000 readers. Six sizes of type were studied: 10, 11, 12, 9, 8, and 6 in that order by Paterson and Tinker (79, 163).

The general procedure was the same in the six studies. Speed of reading material set in each of the variations in line width and leading was compared with the standard for that size of type. The number of subjects was as follows: 1,760 for the 10-point type study; 1,900 for the 11 point; 1,800 for the 12 point; 2,000 for the 9 point; 2,000 for the 8 point; and 1,960 for the 6 point. All material was printed on eggshell paper stock. The scores in the tables represent the percentage differences between the standard and each of the typographical arrangements. The arrangement which is the same as the standard is the control group and the per cent difference is 0.0. A minus (–) indicates poorer legibility than the standard. Differences of about 2.5 to 3.5 per cent are significant between the 2 and 5 per cent levels; those of 3.6 to 4.0 per cent or greater are significant at the 1 per cent level. All significant minus differences are printed in boldface type to indicate unsatisfactory typographical arrangements. They should be avoided by editors.

10-Point Type. Each of the variations of leading and line width used for the 10-point type (79) is shown in Table 7.5. The standard test material was set in a 19-pica line width with 2-point leading.

The table is read as follows: Ten-point type in a 9-pica

TABLE 7.5—Line Width and Leading for 10-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
9	**—9.3**	**—6.0**	**—5.3**	**—7.1**
14	**—4.5**	—0.6	—0.3	—1.7
19	**—5.0**	**—5.1**	0.0	—2.0
31	**—3.7**	**—3.8**	—2.4	**—3.6**
43	**—9.1**	**—9.0**	**—5.9**	**—8.8**

line width set solid is read 9.3 per cent slower than the standard; the 43-pica line width set solid, 9.1 per cent slower than the standard; the 19-pica line width with 4-point leading, 2.0 per cent (not significant) slower than the standard, etc. (Materials in the following five tables are read in a similar manner.) In this study, the agreement with previous data cited in the study of leading for 10-point type in a 19-pica line width is striking and gratifying (see Table 7.2).

There are certain cautions to be exercised in interpreting the data in Table 7.5. For instance, one cannot read horizontally across the table for a given line width, or vertically down the table for a given amount of leading and directly compare the size of the percentages. Although the difference between any two percentages does indicate the relative speeds with which any two arrangements were read, the interpretation is a matter of inference. For example, the materials in the 9-pica line width set solid and in the 9-pica line width with 1-point leading were read 9.3 and 6 per cent more slowly than the standard. It seems clear that the material set solid was read *more slowly* than that with 1-point leading, but the difference in the two percentages does not mean that the material set solid was read *exactly* 3.3 per cent more slowly than the material with the 1-point leading. A different group of 88 readers was involved in each of the 20 comparisons in the table. What each percentage does show is whether there is a significant difference between the reading of a specific typographical setup and the standard. In this study, it so happens that the standard is just as legible as certain other arrangements where no significant differences occur, or better than others where there are significant differences. From such data, one can infer which arrangements are nonoptimal and should be avoided in printing.

Examination of the results in Table 7.5 indicates that the region of optimal legibility for 10-point type includes a 14-pica line width with 1 or more points of leading and a line width of 19 picas with 2-point (and perhaps slightly more) leading.

Note that no line widths between 19 and 31 picas were used and that the 31-pica line width tends to be significantly poorer than the standard. Presumably, one can infer that the printer may use, for 10-point type, line widths from 14 picas to somewhat under 31 picas with 2 to 4-point leading without undue loss of legibility. Evidently, shorter or longer line widths, leaded or set solid, fall in the region of poor legibility.

One may assume that about 2.5 per cent decrease in legibility is sufficiently pronounced to warrant avoidance in printing practice. With this in mind, differences of 2.5 per cent and larger are indicated in Table 7.5 by the use of boldface type. This procedure permits the ready identification of the zone of safety and the zone of danger. Reference to this and the following five tables should be helpful to editors, printers, and others interested in discovering optimal typographical arrangements.

11-Point Type. Line width and leading for 11-point type (79) was investigated in a manner similar to the study of 10-point type just described. The line widths and leading employed are given in Table 7.6. The standard was a 25-pica line with 2-point leading.

TABLE 7.6—Line Width and Leading for 11-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
7	**−11.2**	**−9.0**	**−12.2**	**−10.2**
16	**− 4.7**	−0.6	− 0.8	**− 3.3**
25	− 0.7	+0.7	0.0	− 1.4
34	**− 2.5**	−0.1	− 1.6	**− 2.6**
43	**− 6.4**	**−4.7**	**− 3.5**	**− 2.8**

As in the preceding study, percentages representing significant retardation in speed of reading are printed in boldface type. The zone of safety includes a 16-pica line width with 1 or 2-point leading, a 25-pica line with or without leading, and a 34-pica line with 1 or 2-point leading. Presumably, the line widths between 16 and 34 picas with 1 or 2-point leading represent satisfactory legibility. It would appear that the shift from 10-point to 11-point type permits the use of a larger variety of line widths without loss of legibility. Certainly, line widths from about 20 picas to about 30 picas can be employed in printing practice without loss of legibility with 11-point type.

The trend toward the use of 11-point type seems to be amply justified. It seems to be somewhat more legible than 10-point type, it is most preferred by readers, and it permits greater flexibility in line width and leading specifications. In fact, the editor who specifies 11-point type needs to avoid only excessively short and excessively long lines to maintain optimal legibility.

12-Point Type. The next investigation dealt with line width and leading for 12-point type (79). The variations in line width and leading employed are listed along with the results in Table 7.7. The standard was set in a 25-pica line with 2-point leading.

The data for the 12-point type show that all very short

TABLE 7.7—Line Width and Leading for 12-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
9	**—7.4**	**—6.0**	**—5.8**	**—5.0**
17	**—2.6**	—0.9	+0.8	—0.9
25	—0.8	—2.5	0.0	+2.4
33	**—2.7**	—0.7	0.0	+2.1
41	**—8.1**	**—3.7**	**—3.5**	**—3.5**

lines (9 picas) and all very long lines (41 picas) are read significantly slower in comparison with the standard. Line widths ranging from 17 to 33 picas with 1 to 4-point leading are equally legible. (The apparent reversal of this trend for the 25-pica line width and 1-point leading is difficult to interpret.) In addition, a line width of 25 picas and presumably those a little shorter and a little longer would show no loss of legibility when set solid. Evidently, the detrimental effect of relatively short (17 picas) and of relatively long (33 picas) lines is counteracted by the use of some leading.

It seems clear that stepping up the size of type from 10 to 12 point, as was found in going from 10 to 11 point, brings about an increase in the zone of safety. This trend suggests that, as size of type increases above 10 point, the factors of line width and leading become somewhat less important. In some ways this is fortunate because it gives the printer greater leeway in the use of line width and leading when he adopts a type size as large as 11 or 12 point. For instance, when 11 or 12-point type is used, some saving in space can be effected by setting the material solid in a moderate line width of around 25 picas without loss of legibility. It should be remembered, however, that readers tend to prefer print with some leading.

9-Point Type. Variation of line width and leading should be considered also for the smaller sizes of type in common use. Tinker and Paterson (163) investigated line width and leading for 9-point type. The standard was printed in 9-point type in an 18-pica line width with 2-point leading. The line widths and leading used are given in Table 7.8.

In Table 7.8 the demarcation of the safety zone is clear cut. The typographical arrangements for 9-point type, which should not be used because of loss in legibility, include all line widths set solid plus all very short (8 pica) and very long (40 pica) lines. The safety zone includes line

TABLE 7.8—Line Width and Leading for 9-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
8	**—9.5**	**—4.8**	**—5.8**	**—6.8**
14	**—4.3**	+0.7	+0.5	+1.3
18	**—2.7**	+0.2	0.0	+3.2
30	**—5.2**	—0.5	+2.4	+0.4
40	**—5.8**	**—4.0**	**—5.8**	**—2.6**

widths of 14 to 30 picas with 1 or more point leading. As a matter of fact, the 18-pica line is read significantly *faster* in 4-point leading than in 1 or 2 point. Conservative practice would probably specify 1 or 2-point leading for 9-point type in line widths varying from 16 to 24 picas.

8-Point Type. In the next study, line width and leading for 8-point type was investigated (79). The standard was set in 8 point in a 21-pica line width with 2-point leading. The various line widths and leading used are listed in Table 7.9.

Examination of the results reveals a surprisingly large area of safety. Taking each line width separately, the table shows that: (a) A 7-pica line is illegible when set solid or with any degree of leading; (b) a 14-pica line has satisfactory legibility when set with 2 to 4-point leading; (c) a line width of 21 picas has maximum legibility when set with 2 to 4-point leading; (d) a 28-pica line reveals optimum legibility when leaded 1 to 4 points and (e) a 36-pica line width be-

TABLE 7.9—Line Width and Leading for 8-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
7	**—9.6**	**—6.8**	**—6.3**	**—8.6**
14	—1.0	**—2.9**	+1.1	—1.9
21	**—2.5**	**—2.5**	0.0	+1.0
28	**—6.3**	—1.0	—0.5	—1.7
36	**—5.2**	**—4.9**	—0.4	—0.3

comes legible only when 2 to 4-point leading is employed. Therefore, 8-point type needs 1 or more points of leading for optimal legibility. As with type sizes larger than 10 point, those smaller than 10 point also reveal a relatively large safety zone, i.e., there is a greater variety of typographical arrangements of optimum legibility available to the printer. In conservative practice, the printer would probably use line widths of 14 to 22 picas with 2-point leading, because readers dislike very short and very long lines and prefer some leading.

6-Point Type. The smallest type size investigated was 6 point (79). Type sizes smaller than this are seldom employed in printing. The standard was 6-point type set with 2-point leading in a 21-pica line width. The line widths and amounts of leading used, together with the results, are given in Table 7.10.

The results for 6-point type also reveal a relatively large safety zone. None of the typographical arrangements for the 7-pica line or for the 36-pica line have satisfactory legibility. Optimum legibility is demonstrated for the following: (a) A 14-pica line with 2 to 4-point leading; (b) a 21-pica line with 1 to 4-point leading, and (c) a 28-pica line with 2 to 4-point leading. In view of reader preferences and conservative printing practice, the printer would likely employ a relatively short line such as 14 to 22 picas with some leading.

TABLE 7.10—Line Width and Leading for 6-Point Type

Line Width	Set Solid	1-Point Leading	2-point Leading	4-Point Leading
7	**—6.4**	**—4.5**	**—4.1**	**—6.5**
14	—1.9	**—3.4**	—0.1	—0.1
21	**—3.3**	—0.9	0.0	—0.4
28	**—5.5**	**—3.9**	—1.8	—1.3
36	**—9.9**	**—7.0**	**—3.2**	**—3.7**

Considering all the data on line width and leading in relation to type size, it appears that leading plays an important role in the legibility of print. In a number of instances, the leading minimizes the poor legibility effects which long and short lines tend to produce. Without the beneficial effects of leading, the printer would be confined to a much smaller range of line widths in his attempt to produce legible print.

Cautions on Interpretation. The reader should not compare directly the findings presented in the preceding six tables for the various type sizes. These results hold only for a given type size. They contain no information with regard to the relative legibility of the various type sizes.

Relative Legibility of Six Sizes of Type

The necessary information is now available to design a crucial experiment on the relative legibility of the six sizes of type in common use. It is possible, by inspection of the preceding six studies, to set each type size in an optimal line width and leading. A typographical arrangement which falls within the safety zone was chosen for each of the six type sizes. In addition, reader preferences and, to some degree, printing practice were taken into consideration.

Paterson and Tinker (79) completed this final experiment to determine the relative legibility of 6, 8, 9, 10, 11 and 12-point type each set in an optimal line width and leading. All material was set in Granjon type face with 2-point leading. The standard was 11-point type set in a 22-pica line width with 2-point leading. The typographical setups used and the results for 504 readers are given in Table 7.11.

Inspection of the data reveals that 9, 10, 11 and 12-point type are equally legible when each is printed in an appropriate line width with 2-point leading. Speed of reading

TABLE 7.11—Relative Legibility of Six Type Sizes

Type Size and Line Width Compared With Standard 11 Point, 22 Picas	Differences in Per Cent
6 point, 14 picas	—5.0*
8 point, 16 picas	—3.4**
9 point, 18 picas	—0.3
10 point, 20 picas	—1.7
11 point, 22 picas (control)	0.0
12 point, 24 picas	+1.0

* Significant at the 1 per cent level.
** Significant between the 2 and 5 per cent level.
Minus signifies less legible than standard.

material in 8-point type is moderately but significantly retarded (3.4 per cent); and speed of reading is seriously retarded (5 per cent) when 6-point type is employed. There is a suggestion in the data that 11-point type is slightly more legible than 10 point (see also Table 5.3). These data, plus the fact that readers prefer 11-point type over all others, appear to justify the trend toward employing 11-point type more and more in printing practice.

In order to provide an analytical picture of the oculomotor patterns accompanying retardation in reading for each of the two smaller type sizes (6 and 8 point) in comparison with a larger one (all in an optimal typography), a new investigation was undertaken (82). Samples of the three typographical arrangements are given in Figure 7.2.

In the first comparison, 20 subjects read 10 paragraphs set in 11-point Granjon type in a 22-pica line width with 2-point leading, and 10 different paragraphs set in 8-point Granjon type in a 16-pica line width with 2-point leading. The second comparison was similar. The same 11-point type was compared with 6-point Granjon set in a 14-pica line width with 2-point leading. An additional 20 subjects were

Standard: 11 point, 22 picas, 2 point leading

11. When my mother saw the marks of muddy shoes on the floor, and all over the nice clean beds, she was surprised to see how careful the children had been. 12. When the little boy next door had both of his legs broken by being run over by an automobile, we were afraid he might never be able to see again. 13.

Comparison I: 8 point, 16 picas, 2 point leading

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living in a city near here always has a very serious expression on his face. This is perhaps because in his work he meets only

Comparison II: 6 point, 14 picas, 2 point leading

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living in a city near here always has a very serious expression on his face. This is perhaps because in his work he meets only well people. 13.

FIG. 7.2—Showing samples of three type sizes set in optimum line widths and leading.

readers for this comparison. To control practice effects, a counterbalanced design was used. The results are given in Table 7.12.

In examining the results, the reader should keep in mind that perception time represents a combination of fixation frequency and pause duration. The reduced efficiency in reading 8-point in comparison with 11-point type is due to more fixations, a longer pause duration, and a longer perception time for the 8-point type. Although there were more

TABLE 7.12—Eye Movement Measures for Reading 11 Versus 8 and 6-Point Type

Type Size Compared With Standard 11 point	Differences in Per Cent			
	Fixation Frequency	Pause Duration	Perception Time	Regression Frequency
8-point type	+6.7**	+4.2*	+10.5*	+7.8
6-point type	+1.8	+7.9*	+ 9.9*	+6.7

* Significant at the 1 per cent level.
** Significant between the 2 and 5 per cent level.

regressions for the smaller type, the difference was not significant. In the second comparison, the slower reading of the 6-point type is represented by a longer pause duration and perception time. Although there was a greater frequency of fixations and regressions, the differences were not significant.

The eye-movement patterns in reading 6 and 8-point type in comparison with the optimal 11-point size are essentially alike. The differences for both 6 and 8 point versus 11 point indicate a reduction in reading efficiency. Reduced visibility of the smaller type sizes appears to be the main factor producing the less efficient oculomotor behavior.

Summary

1. Leading has an important effect on the legibility of type. While effective for improving the legibility of all sizes of type, leading has considerably less influence on 12-point type than on the smaller sizes.

2. The opinion that a smaller sized type leaded would be more legible than a larger sized type set solid was found to be false. The 10-point type set solid was read just as rapidly as 8-point type with 2-point leading. It is worth noting that readers preferred 10 point set solid over the 8 point with 2-point leading.

3. Extensive investigation of 6, 8, 9, 10, 11, and 12-point type set in various line widths and leading made it possible to direct the attention of the printer to safety zones for each type size. By "safety zone" is meant the limits of variation in line width and leading that may be used for a given type size without appreciable loss of legibility.

4. The zones of safety listed below give the limits within which the printer may utilize a particular type size with the assurance that he is maintaining satisfactory legibility. These safety zone limits do not mean that all the typographical arrangements listed, as well as those in between, are most suitable for printing. If the printer is to cater to the preferences of his readers, he will employ a moderate line width with appropriate leading selected from those typographical arrangements within the zone of safety for that type size. Readers definitely dislike very short and very long lines as well as material set solid.

Safety Zones for Six Commonly Used Type Sizes:

6 Point

14-pica line width with 2 to 4-point leading
21-pica line with 1 to 4-point leading
28-pica line with 2 to 4-point leading

8 Point

14-pica line with 2 to 4-point leading
21-pica line with 2 to 4-point leading
28-pica line with 1 to 4-point leading
36-pica line with 2 to 4-point leading

9 Point

14-pica line with 1 to 4-point leading
18-pica line with 1 to 4-point leading
30-pica line with 1 to 4-point leading

10 Point

14-pica line with 1 to 4-point leading
19-pica line with 2 to 4-point leading
31-pica line with 2-point leading (marginal)

11 Point

16-pica line with 1 to 2-point leading
25-pica line with or without leading
34-pica line with 1 to 2-point leading

12 Point

17-pica line with 1 to 4-point leading
25-pica line with or without leading
33-pica line with 1 to 4-point leading

8. Spatial Arrangements of the Printed Page

IN PYKE'S 1926 comprehensive survey (92) of the literature on legibility of print, there is little that is relevant to the ordinary reading situation with respect to spatial arrangement of the printed page. What is given is from casual observation and inference rather than from careful experimentation. One author claimed that there should be indentation of lines at the right side of the page and no hyphenation. Dearborn (22) was opposed to any marked indentation at either end of lines. He believed that it would upset the motor rhythm of eye movements in reading. A British Committee in 1912 favored approximate but not absolute uniformity of line width with the idea that it would foster reading rhythm. Somewhat opposed to this is the statement by the same group that indentation helps the unconscious swing (apparently of eye movements) which is necessary for good intelligent reading. The only other opinion that relates to spatial arrangements, and which is unimportant, is concerned with spacing between letters and between words.

There were a large number of comments on the use of margins. Suggestions varied from advising use of wide margins to considering them superfluous. But most writers were in favor of some margins to improve accuracy of fixation pauses within the line and to prevent the eye from *swinging off the page* at the end of a line. Fairly wide margins are considered important for esthetic appearance and for legibility. Inter-column white space is favored over rules.

Size of Full Page

Experiments to determine the relation between size of page and legibility would seem impossible. Presumably, the size of page adopted for any specific piece of printing is a matter of practical and esthetic judgment. A survey of printing practice will show whether or not publishers and printers are in agreement with reference to desired page sizes. If choices are based on some uniform set of principles, practical, esthetic, or otherwise, which have proved to be of lasting value, one should find general agreement. A survey (79), published in 1940 included a measurement of page size of 1,500 journals and textbooks. To some degree, each of the general classes of printing tended to employ characteristic page sizes. For the most part, the textbooks fell into three groupings: dimensions of 4 by 7, 5 by 7, and 5 by 8 inches. Although the foreign scientific journals concentrated largely on page sizes of 5 by 8 and 6 by 9 inches, they ranged all the way from 4 by 7 to 9 by 12 inches. A similar scatter was found for the American scientific journals, but the greatest concentration of usage for page size occurred at 6 by 9, 6 by 10, and 7 by 10 inches. The greatest difference of all occurred in the page sizes of American nonscientific magazines with two major groupings at 6 by 9 and 8 by 11 inches.

The seeming general agreement about desirable page sizes is more apparent than real. In the tabulation it was necessary to use coarse units of 1 inch. Within each 1-inch unit, scarcely any agreement was discernible. For instance, the 27.8 per cent of textbooks listed in the 5 by 7 inch category were distributed evenly over a large number of intervals differing from each other by only 1/16 inch in either height or width. All these facts suggest that it would be desirable for publishers, printers, and paper manufacturers to arrive at an agreement on page sizes that would minimize waste of paper stock.

Size of the Printed Page. A survey (79) revealed that there was as much diversity of practice in the size of printed area of a page as in the size of the full page. Size of the printed area on a page is, of course, coordinated with size of the full page. Width of the four margins of the page is also involved.

Margins

As noted above, comments on the usefulness of margins have been frequent, but prior to 1940 no research to determine the effect of varying margin widths on legibility was published. About the only worthwhile suggestion among the many opinions dealt with the width of the inner or gutter margin. It was pointed out that this margin in books should be wide enough so that the inner end of the line of print is not obscured by the curvature of the paper. Strangely enough, no printer has taken this sound advice seriously (see experiment cited below). Recommendations with regard to width of top, outer and bottom margins tend to be rather vague. The most definite recommendation cited by Pyke (92) is that of Jacobi, made in 1912. He argues that the inside or gutter margin should be narrow, the top margin should be next in width, the outer margin should be next, and the bottom margin the widest.

Style manuals approach the problem of margins from the viewpoint of the total size of the paper page and the proportion of this full page that should be occupied by the type. Apparently the rule for page sizes dates from the early days of printing when the size was determined by the number of folds in the sheets of paper used. Thus, since sizes of sheets of paper vary, printing practice with respect to page size itself varies. Although somewhat indefinite about total page size, style manuals tend to assert that the area occupied by the type on the page should cover 50 per cent of the total page.

Careful measurements of page size and printed area in 400 textbooks made it possible to determine whether printers consistently follow the advice of the style manuals (79). The ratios of printed area to full page size ranged from .29 to .76, i.e., 29 per cent to print and 71 per cent to margins at one end of the distribution, and 76 per cent to print and 24 per cent to margins at the other end of the distribution. The average book devoted about 52.8 per cent of the full page to printed area and 47.2 per cent to margins. In other words, although there is marked diversity in practice, printers on the average hold closely to the 50 per cent white space (margins) rule.

The ordinary reader is not aware of the "50 per cent rule." Each of 928 college students was asked to estimate the percentage of the total page devoted to the main body of printed material in the typical textbook or book of fiction. Over 90 per cent of the subjects believed that 60 per cent or more of the total page was devoted to printed matter. The most frequent estimate was about 75 per cent. In other words, the average reader believes that three-fourths of a book page is devoted to the printed area and only one-fourth to margins. This is an "illusion" effect of about 25 per cent overestimation since actual practice closely follows the 50 per cent rule.

The existence of this illusion was tested experimentally (77) with a carefully organized psychophysical design. The stimulus material consisted of black centers on white backgrounds and white centers on black backgrounds. A sample is shown in Figure 8.1. The cards were made in a graded series of proportions (ratio of printed area to whole page).

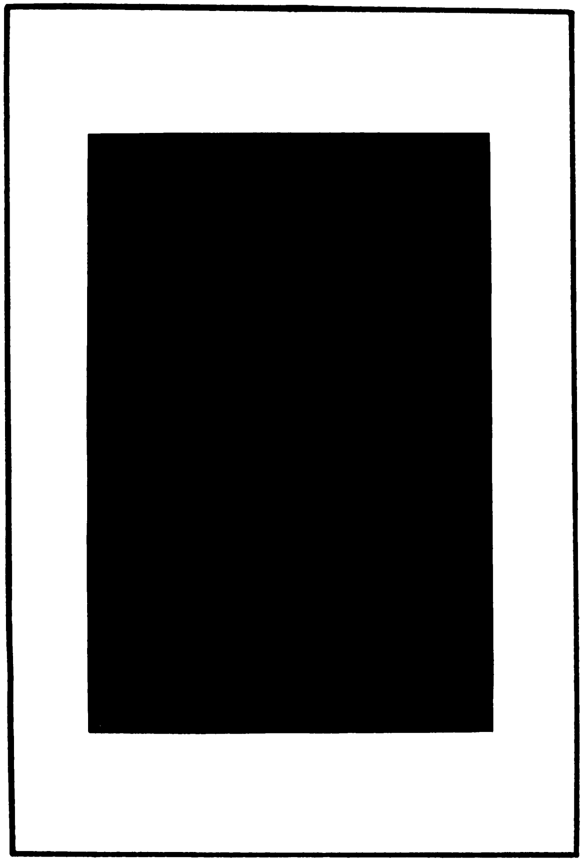

FIG. 8.1—Part-whole proportion illusion. The black area is 50 per cent of the total area although it appears to occupy 68 per cent of the total area.

The results show that the 300 subjects, on the average, overestimated the center area in relation to the total card area by 18 per cent. It made no difference whether the central area of the card was black on white or white on black. These results prove the existence of a part-whole proportion illusion. This illusion undoubtedly affects reader judgments of the area of a book page taken up by print.

After informing a large group of 928 subjects that the general rule of publishers was to devote 50 per cent of the total page to the white space in the margins, they were asked whether the practice was justified. A majority of 62 per cent believed that the practice was justified because of legibility, 27 per cent on esthetic grounds and 1.7 per cent because of tradition. About 9.3 per cent considered the practice not justified because the extra paper for margins increases the cost of books. It seems that the majority of people who use books believe that margins are an important factor in legibility.

Printing Practice in Use of Margins. In printing, margins vary greatly. Whether the resulting diversity is brought about because of an attempt to produce a more pleasing page (esthetics) or by an unconscious departure from the 50 per cent rule is uncertain. Perhaps both factors are involved.

The results of the survey of printing practice with regard to use of margins (79) need not be described in detail. There was *great diversity* of usage both in journals and books. Nevertheless, there were some trends evident. In general, printers revealed an inclination to make the bottom margin the widest, for the top to be next, the inside next, and the outside margin the narrowest of all, but only slightly narrower than the inside one.

Two Experiments. Is material printed with ample right and left margins read more rapidly than material printed without any margins at the ends of the lines of print? If the views of various writers on the topic are true, margins should promote legibility. Particularly, the positive views of Dearborn (22) are relevant. He favored margins because he believed peripheral color stimuli, such as the color of a desk top or other background, would produce a reflex effect diminishing accuracy of fixation pauses in reading. According to him, the wider the margin the more such peripheral color stimuli would be kept out. Another writer, quoted by Paterson and Tinker (79), states that the outside margin and the gutter or inside margin must confine the attention repeatedly as a person reads one line after another. These views are based on the presumption that mechanical devices, such as margins, are necessary to control eye movements while reading.

To study the effect of margins, the standard material was set up with 7/8-inch margins on the right and on the left of the column of print. The speed of reading this standard material was compared with the speed of reading material of comparable difficulty without margins at either end of the lines. The material was set in 10-point type in a 19-pica line with 2-point leading in single-column printing. The results for 190 readers showed no significant speed difference in reading with or without the use of margins. The conclusion is that margins as such do not promote greater legibility. It is clear that margins on a flat page must be justified, if justified at all, solely in terms of esthetics.

A second experiment, completed by Tinker (142), has a bearing on appropriate width of gutter margins. Two subgroups of 52 readers each were used. For the speed of reading, materials were printed in 10-point type in a 19-pica line with 2-point leading. In addition, 20 five-letter words were employed for visibility measurements taken with the Luckiesh-Moss Visibility Meter. All reading test forms and words were equated for difficulty. Two reading stands were used: (a) An 8-inch cylinder which could be set in any position from horizontal to vertical, and (b) a flat surface set at 45 degrees to the table top. The position of the subject's head was held constant. The speed of reading and

TABLE 8.1—Effects of Curved Text on Legibility

Position of Curved Copy Compared With Standard Flat at 45°	Differences in Per Cent*
Speed of Reading	
Curved at 45°	— 7.2
Curved at 0°	—36.5
Curved at 90°	—11.4
Visibility of Words	
Curved at 45°	— 9.73
Curved at 0°	—20.0
Curved at 90°	—39.1

* The speed-of-reading scores were in terms of seconds required to read accurately 15 paragraphs. Therefore, the plus differences (longer time) have been listed in this table as minus to represent the slower reading. All differences in the table are significant at the 1 per cent level.

visibility of words were recorded for material on the flat surface held constant at 45 degrees (standard), in comparison with three positions on the curved surface, i.e., cylinder at 45 degrees to table, at 0 degree or horizontal, and at 90 degrees or vertical. The results are shown in Table 8.1.

The results are clear cut. Reading the curved text in all three positions significantly reduced the legibility of print. Similarly, visibility of curved print is significantly poorer than that on a flat surface. Furthermore, the amount of deleterious effect is large. Probably the reduction of speed of reading the curved text is largely due to the reduced visibility of the printed words. Possibly the need for constant changes in visual accommodation in reading the curved text also may be involved.

The curvature of the text employed in this experiment is a close approximation to the curvature found on the pages of large books and bound volumes of journals when these books and journals are open. The results obtained here indicate that the marked curvature of lines of print near the inner or gutter margin of such volumes without doubt adversely affects legibility. If much wider margins were used, the situation would be greatly improved. The practice of maintaining narrow inner margins in large books and journals should be abandoned.

Single Versus Multiple-Column Printing

It is not necessary to conduct experiments as such on the legibility of single versus multiple-column printing. The problem reduces itself to one involving legibility of particular sizes of type with optimal line widths and leading. These factors have been discussed in earlier chapters. In addition, printing practice and reader preferences are involved. Data on these will now be presented. Results of the printing practice survey (79) are presented in Table 8.2.

The results in Table 8.2 reveal that in the early 1930's multiple-column printing was restricted almost entirely to American scientific and American nonscientific journals. Where more than two columns were used in the nonscientific magazines, they were chiefly confined to the large flat type of magazine. Only 7 per cent of the American nonscientific

TABLE 8.2—Printing Practice: Single Versus Multiple-Column Printing*

Kind of Printing	Single Column	Double Column	Triple Column	Quadruple Column
	(Per Cent)	*(Per Cent)*	*(Per Cent)*	*(Per Cent)*
100 Amer. nonsci. jour.	7.0	60.0	32.0	1.0
200 Amer. sci. jour.	73.5	26.0	0.5	0.0
200 foreign sci. jour.	97.5	2.5	0.0	0.0
1000 textbooks	99.8	0.2	0.0	0.0

* This survey was completed a few years prior to 1940. Since then double-column printing has been used more frequently in textbooks and journals. Note that scores are in percentages.

magazines employed single-column composition. Use of multiple-column printing permits financial economy and furnishes large display space for full or partial page advertisements.

It is noteworthy that over one quarter of the American scientific journals were using double-column printing in the early 1930's. Five years later about 5 per cent more had adopted the double-column composition. Since 1940 many more have followed this trend. Now it is also common to find textbooks in double-column print.

There are many relatievly important reasons for employing double-column composition in scientific journals: (a) More words can be printed on a larger page which saves total margin area per 100 words. (b) Fewer running heads are needed. (c) It is possible to make more economic use of space devoted to figures, tables, and formulas, many of which can be confined to one of the columns without reducing legibility. (d) Relatively large tables, cuts, and lengthy formulas can be printed across both columns. In a single-column arrangement it might be necessary to print the cuts and tables sidewise, or to print a long formula on two lines which would break up its unity. (e) In many instances, double-column composition would avoid "tipping in" large tables and cuts by virtue of the larger page available. (f) Most of the above five advantages apply equally well to the printing of textbooks.

Reader Opinions. Samples of single and of double-column printing were submitted to 241 college students (79). The samples were taken directly from *Psychological Abstracts*, one whole page when single-column printing was used in the early issues, and one page at a later time when double-column composition was employed. Zinc etchings were made from each page and the samples printed from these. Each reader looked at each of the samples as they were placed side by side and decided which printing arrangement he would prefer to read. It was found that 60.5 per cent of the group of readers preferred the double-column arrangement.

One might well assume that persons directly concerned with printing would tend to agree among themselves more closely than the 241 college students already sampled. It was possible to repeat the study with 38 typography experts and printers attending a meeting of their craftsmen. Surprisingly enough, the division of opinion in this group was precisely the same as for the college students, i.e., 60.5 per cent preferred the double-column arrangement and 39.5 per cent the single column. The fact that both the printing expert and the general reader express a strong preference for a double-column typographical printing arrangement seems to justify the increasing tendency to employ double-column printing in both journals and books.

Inter-Columnar Space and Rules

Whenever multiple-column printing is employed, there must be a decision made on whether to use a space, a rule, or both between columns. Newspapers generally use inter-columnar rules while magazines ordinarily employ space without rules between columns of print. Do these practices mean that inter-columnar rules are necessary when the columns are relatively close together as in newspapers, but undesirable or not necessary when adequate space is available as in magazines? Is printed material in one arrangement more or less legible than in the other? These questions can be decided only by experiment.

Printing Practice in Journals and Magazines. The practice of 51 American scientific journals and 57 American non-scientific magazines with respect to inter-columnar arrangements was ascertained for their 1936 publications. In only one of the 108 journals and magazines was there a rule between

Rule with no space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

¼ pica on each side of rule

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

½ pica on each side of rule

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

½ pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

1 pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

2 pica space between columns

1. Mary was sitting on the seashore one hot day in June. She said to her mother, "If only I had

16. This band of men and women set sail for the new world where they could live in peace. There

FIG. 8.2—Space and rules between columns, Scotch Roman, 10 point, 19 picas, 2-point leading.

columns of print. There was little variation in the amount of inter-columnar space used in the scientific journals: 49 employed 1-pica space, one a ½-pica space, and one a 1½-pica space. There was a greater diversity of practice by the nonscientific magazines. Eight used ½-pica space, 34 used 1-pica space, 10 used 1½ picas and five used 2 picas.

Experimental Results. A speed-of-reading technique was employed to determine the effect of various inter-columnar arrangements on legibility (79). The variations used in the experiment are illustrated in Figure 8.2. Mere examination of the samples would lead most printers and even others to conclude that the use of an inter-columnar rule without any white space would seriously and adversely affect legibility. Many might even consider that a ½-pica space without a rule would not be enough. It might seem reasonable to suppose that, on reaching the end of a line, the eyes would tend to jump across to the next column and thus cause confusion which would slow up reading speed.

In the experiment, the standard was set in 10-point type in a 17-pica line with 2-point leading and an inter-columnar space of 2 picas. Speed of reading the standard was compared with speed of reading each of the six typographical arrangements listed in Table 8.3. There were 80 readers in each sub-group, 480 in all.

TABLE 8.3—Space and Rules Between Columns of Print

Space and Rules Between Columns Compared With Standard 2-Pica Space	Differences in Per Cent*
½-pica space	+0.5
1-pica space	—0.2
2-pica space (control)	0.0
Rule with ½-pica space on each side	—1.4
Rule with ¼-pica space on each side	+0.2
Rule without space	—1.4

* Minus signifies less legible than standard.

The data reveal that material with any particular inter-columnar arrangement is read just as fast as any other. The small differences are only what may be expected from chance variation. In other words, all inter-columnar arrangements used in this experiment are equally legible. Again, what seems obvious from casual observation is contradicted by the hard facts derived from experimental investigation. It is worth noting in passing, that in 1957 the Santa Barbara, California, *News-Press* began to use a rule between columns of print without extra space. There was no serious objection to this arrangement from the readers.

Reader Opinions. Although variations of the inter-columnar arrangement has no adverse effect on legibility, readers do have definite preferences (79). Samples of the printed material were presented to 224 subjects for ranking according to judgments of relative legibility. The results are presented in Table 8.4.

On the average, the readers preferred most of all a rule with a ½-pica space on each side for an inter-columnar arrangement. This arrangement is rarely found in journals and magazines. Next came a 2-pica space and a 1-pica space grouped close together. The differences between ranks 1, 2, and 3 are probably not significant. The other three arrangements were ranked relatively low. Printing practice does not run entirely counter to preference since readers do tend to

TABLE 8.4—Reader Preferences for Inter-Columnar Arrangements

Space and Rules Between Columns	Average Rank	Rank Order
½-pica space	4.5	5
1-pica space	2.7	3
2-pica space	2.5	2
Rule with ½-pica space on each side	2.1	1
Rule with ¼-pica space on each side	3.8	4
Rule with no space	5.4	6

rank the 1-pica inter-columnar space arrangement relatively high.

Paragraphing Arrangements

In printing, the universal practice is to separate major "thought units" mechanically by indenting the beginning of the first line of every paragraph. This is known as regular indentation.

As a by-product of the Tinker-Paterson (79) experiments, the effect of paragraphing on speed of reading was measured. In the early studies the two equivalent forms of the test material consisted of 30 brief paragraphs of 30 words each. This arrangement introduced far more white space than is ordinarily found on a printed page. Such a setup made it difficult to investigate satisfactorily the effects on legibility of such factors as leading and line width. It became necessary to rearrange the page composition so as to approximate the usual appearance of a printed page. This was achieved by combining five of the short 30-word paragraphs into a given paragraph composition unit. The result was a new 6-unit printing arrangement for each test form that gave the appearance of 6 paragraphs although the same 30 thought units were retained.

A comparison of the speed of reading the 30-unit with the 6-unit arrangement, using 180 readers, showed that the 6-printing unit arrangement was read 7.3 per cent more slowly than the 30-paragraph arrangement. This result indicates that indentation at the beginning of a paragraph in good writing does improve the legibility of printed matter. In the same experiment (79) it was found that the equivalence of the two test forms was maintained in the 6-paragraph arrangement and that the reliability remained consistently high.

Dearborn (22) suggested in his 1906 report that legibility might be improved by indenting every other line at the left. He stated that a small indentation of a few millimeters might be of a distinct advantage in eliminating oculomotor inaccuracies in the vertical plane, i.e., this indentation would increase the accuracy with which the eyes would fixate the beginning of each succeeding line on the return sweep from the end of the preceding line. In his book on reading, Huey (198) also approved this idea.

An experiment was set up to check the effect of indenting alternate lines within paragraphs (79). The standard, set in 10-point type in a 19-pica line width, was compared with material in which every other line was indented 1 pica on the left. Both arrangements were set solid. The results of the comparison for 538 readers are given in Table 8.5.

It appears that indenting every other line at the left is a detriment rather than an aid to legibility. The 3.4 per cent retardation is statistically significant. The wisdom of printing all lines flush at the left, except for the first line of a paragraph, is confirmed by these results.

Vertical Versus Horizontal Printing

The traditional arrangement of written and printed words in our Western civilization has been in straight horizontal lines. Huey (38) was the first person to raise the question of whether a vertical arrangement of words printed in columns might produce a more efficient typographical ar-

TABLE 8.5—Effect of Indentation of Alternate Lines on Legibility

Printing Arrangement	Differences in Per Cent
Regular printing vs. regular printing (control)	0.0
Indentation of alternate lines vs. regular printing	—3.4*

* Significant at about the 2 per cent level.

rangement than the traditional horizontal arrangement. He considered that a vertical arrangement should prove more efficient due to elimination of practically all horizontal eye movements during reading. Furthermore, use of the vertical as well as the horizontal span of vision should make it possible to have more words in clear vision during any fixation pause. In some preliminary experimenting, Huey found some support for his views. He considered that with practice the vertical arrangement might eventually be read faster.

Tinker (138) set up an experiment to investigate the effect of a limited period of systematic, controlled practice in reading vertical materials upon speed of perception and patterns of eye movements. Strictly comparable materials in the two arrangements were used. After practice in reading the vertical arrangement over a 6-week period, both eye movements and speed of reading the vertical improved markedly although they remained constant for the horizontal arrangement. But at the end of the practice, the vertical arrangement was still read significantly more slowly than the horizontal.

There are important obstacles to the use of a vertical printing arrangement: (a) tradition, (b) the marked variation in length of English words, and (c) lack of knowledge concerning optimal typographical arrangements for vertical printing. With the exception of a double-line "block" printing, which is a compromise between the vertical and the horizontal arrangements, the efficiency of vertically arranged printing is apt to remain largely a matter of theoretical interest.

As noted above, a compromise between vertical and horizontal printing is to print material in double-line blocks such as the following:

There	a drop	in the	for someone
was not	of ink	house	had broken. . . .

In reading such an arrangement the reader should be able to utilize both the vertical and horizontal visual span and in this way improve speed and comprehension in reading. If such an assumed advantage were due to grouping the words in thought units, which is necessary for efficient and quick comprehension, the same results might be obtained by spacing regular printing into thought units in the following manner:

There was not   a drop of ink   in the house. . . .

The writer has some unpublished data which deal with a comparison of speed of reading regularly organized print, material organized in the double-line blocks, and material separated into thought units by insertion of additional spacing in regular printing. The material in the speed-of-reading test used by Tinker and Paterson was set up in the three ways just described to produce four equivalent forms of 15 paragraphs each. Sixty college students read the materials in counterbalanced order. The results revealed no significant difference in legibility between regular printing and the material spaced into thought units by additional horizontal spacing. However, the material printed in double-line blocks was read significantly more slowly (12 per cent) than the material in regular printing arrangement. Presumably the material in the square-block printing is much less legible than ordinary printing, at least for readers inexperienced in reading print organized in this manner

Employing a different experimental design, North and Jenkins (68) found no difference in rate of reading between the double-line block arrangement and regular printing but a slight advantage for material separated into thought units.

Summary

1. A survey of printing practice revealed great diversity of page sizes in textbooks and journals. The major portion of textbooks falls into three groupings: 4 by 7, 5 by 7, and 5 by 8 inches. Page sizes of foreign scientific journals are concentrated largely in dimensions of 5 by 8 and 6 by 9 inches. In American scientific journals, the concentration of page dimensions occurs at 6 by 9, 6 by 10, and 7 by 10 inches. There are only two major areas of concentration in the sizes of American nonscientific magazines: 6 by 9 and 6 by 10 inches.

2. It would seem advisable for publishers, printers, and paper manufacturers to arrive at an agreement on page sizes that would minimize the waste of paper stock that must now occur in the printing of books and magazines in such a large variety of page sizes.

3. According to printing practice around 1932, the area of printed matter occupied about 50 per cent of the total page size on the average. Readers are unaware of this fact because of a part-whole proportion illusion. Over 90 per cent of readers tend to believe that 60 per cent or more of the total page is devoted to print. The modal estimate was 75 per cent.

4. Readers believe that ample margins are justified either in terms of esthetics or improved legibility.

5. Experimental results show that material on a flat page with no margins at all is just as legible as material with the usual large margins. A great saving in the printing of books and magazines could be made by considerable reduction of the marginal space (except gutter margin). The use of relatively wide margins must be justified, if at all, in terms of esthetics.

6. Curvature of printed material like that found near the gutter margin of large books and bound journals signifi-

cantly reduces speed of reading and visibility of print. This loss of legibility could be alleviated by use of wider inner or gutter margins which in present printing practice tend to be excessively narrow.

7. In the early 1930's, single-column printing characterized textbooks and foreign scientific journals. American nonscientific magazines were already using multiple-column printing. There was a definite trend toward double-column printing in American scientific journals. This trend is increasing and is now employed in many textbooks. Preferences in a ratio of 3 to 2 by readers and typography experts for the double-column printing justify this trend.

8. Research revealed that six possible inter-columnar arrangements were equally legible. The arrangements were: ½-pica space, 1-pica space, 2-pica space, a rule with ½-pica space each side, a rule with ¼-pica space each side and a rule with no extra space. Readers preferred most of all a rule with ½-pica space on each side. Next and close together, they preferred a 1-pica or a 2-pica space. They disliked the other columnar arrangements. The fact that printers usually employ a 1-pica space between columns means that they use what many readers prefer.

9. The practice of indenting the first line of a paragraph improves legibility by over 7 per cent.

10. The suggestion of reading experts that indenting every other line at the left would improve legibility was found to be false. Actually, such indentation retards speed of reading by a significant amount. The practice should be avoided except for the first line of a paragraph.

11. Words printed in vertical columns are read markedly more slowly than in the customary horizontal arrangement. But a moderate amount of practice improves greatly the rate of reading material in the vertical.

12. Material printed in double-line "square blocks," contrary to some views, is not as legible as regular printing.

9. Color of Print and Background

THE RELATION of color of print to color of background is an important factor affecting legibility of reading material. This is especially true in the broad sense when, as is customary, black, white, and gray are considered colors. Since quality of paper and paper surface are related to the topic under consideration, they will be included. A factor of prime importance running through this whole section is the brightness contrast between print and paper. The discussion will be confined primarily to printing in ordinary reading situations although some reference to uses in advertising will be made.

From 1827 to 1926, there were many viewpoints expressed concerning appropriate color of paper and ink for good legibility (92). For the most part, these were based upon casual observation rather than on experimental data. Some writers favored pure white paper, others preferred some tint, especially a yellow or cream-colored tint. One favored light gray. Generally, preference was given to paper without gloss and opaque enough to prevent print on the back from showing through. A few writers would minimize the importance of paper quality. Little attention was devoted to ink. Apparently the assumption was that black ink would be used. One writer favored deep black ink while another advised that light blue and green ink on white paper should be avoided. Since these views primarily reflect mere opinion, experimental investigation of the subject is needed.

Black Print Versus White Print

The use of white print on a black background is attention-getting to a striking degree, much more so than black print on a white background. The printer who plans to use white print will want to know whether it or black print is more legible in the ordinary reading situation as well as at a distance. He will also want to know the effect of varying type size on the relative legibility of white and black print. The advertiser, the commercial artist, and the editor are also interested in these problems. White print is ordinarily achieved by printing the background black so as to allow the white of the paper to show through as print.

Legibility in the Ordinary Reading Situation

An early and relatively simple study by Starch (100) is relevant here. He had material printed in white on a dark gray background and material in black on a white background. When 40 subjects read the two kinds of print, great differences in rate were obtained. The black type on white paper was read 42 per cent faster than the white on dark gray. This represented a difference of 1.8 words per second, or 108 words per minute. Starch observed that while black, gray, or a colored background are conspicuous by contrast with white print, they also have the disadvantage of being less legible.

Paterson and Tinker (73) employed their speed-of-reading technique to determine the relative legibility of white and black print. To maintain constant conditions, zinc etchings were employed and white enamel paper stock was used for printing both arrangements. The effect of white print on black paper was achieved by printing the background black so that the white of the paper produced the white print. The number of readers was 280. Another 224 readers expressed preferences in terms of legibility. The results are given in Table 9.1.

TABLE 9.1—Black Print Versus White Print

Speed of Reading	
Arrangement Compared With Standard Black on White	Differences in Per Cent
Black on white (control)	0.0
White on black	—10.5

Readers' Opinions	
Kind of Print	Percentage Ranked First
Black on white	77.7
White on black	22.3

There is an advantage in speed of reading of 10.5 per cent in favor of black on white. Also, reader opinion is definitely in favor of black on white; 77.7 per cent rated the black on white more legible. The surprising result is that 22.3 per cent of the 224 readers actually believed that white on black would be read faster than black on white. However, the important point is that the large majority of readers agree with the experimental results which show that black on white is far more legible than white on black.

Taylor (103) reported an eye-movement study of reading black and white print. Reading material was taken directly from the printed tests used in the above experiment. Each of 20 subjects read eight paragraphs in black type, and another eight paragraphs in white type, arranged in a counterbalanced order. The results are shown in Table 9.2. Plus differences indicate an advantage for the black print.

The eye-movement results agree with the speed-of-reading results cited above. Fixation frequency and perception time (combination of fixation frequency and pause duration) were significantly greater for reading the white print. Pause duration was slightly less for the white print but the differ-

Table 9.2—Eye Movements in Reading Black and White Print

Measure	Differences in Per Cent
Total no. of fixations	+11.6*
Average pause duration	− 2.5
Total perception time	+ 8.6*

* Significant at the 1 per cent level. Plus signifies less legibility for the white print.

ence is not statistically significant. Apparently, the slower reading of the white print is due to increased fixation frequency.

Perceptibility of Black and White Print

Two methods have been employed to measure perceptibility: (a) recognizability in peripheral vision, i.e., the distance from the visual fixation point at which a letter or word is recognized and reported correctly; and (b) perceptibility at a distance straight ahead of the subject, i.e., the distance from the eye at which a letter or word is perceived correctly.

In an elaborate early experiment, Kirschmann (39) measured the recognizability in peripheral vision of relatively large block capital letters and geometric forms. He employed a campimeter, which is a flat chart used to map out the visual field. The subject maintains his fixation at the center of the chart while the stimulus, such as a letter or word, is slowly moved in from the periphery until it is recognized. One to four subjects were used in various experiments. In all parts of the investigation, Kirschmann uniformly found that white symbols on a black background were seen farther out in peripheral vision than black symbols on white. One may question these data because of lack of confirmation in later experiments.

The most intensive and exhaustive investigation of the relative legibility of black and white print was reported by Taylor (103). In one section she repeated that part of Kirschmann's study in which block letters were used. She, like Kirschmann, measured recognizability in peripheral vision by means of a campimeter. Four alphabets of simple block capital letters just like those of Kirschmann were employed: (a) letters in black drawn on white cardboard, (b) letters drawn in outline and the background inked in to leave the letters white, (c) white letters cut from tracings on white paper and pasted on black cardboard, and (d) letters cut out of thin white cardboard and pasted on a square of black velvet. The three white alphabets were designated respectively "drawn," "pasted," and "velvet." The "drawn" alphabet was exactly the same size as the black, while the "pasted" and "velvet" alphabets, like Kirschmann's, were slightly smaller. Six university students served as subjects. The results are given in Table 9.3.

The first four entries in Table 9.3 show that the black on white letters were more legible, i.e., the black letters were recognized farther from the fixation point than the three white letters. Kirschmann's results of white versus black are given for comparison.

TABLE 9.3—Relative Legibility of Black and White Letters Seen in Peripheral Vision

Arrangment Compared With Drawn Black	Differences* in Centimeters	Differences in Per Cent
Drawn white	—1.70	—18.2
Pasted white	—2.40	—26.7
Velvet white	—2.90	—30.1
White: all kinds	—2.34	—25.1
White-Kirschmann	+6.30	+16.3

* A minus difference signifies that the white letters approached nearer to the fixation to be recognized and therefore were less legible.

In this first experiment each subject read each alphabet only once. To check on the effects of practice, a second experiment was completed. Each of five subjects read each alphabet, one black and one white, six times in a counterbalanced order, over a period of 12 days. Analysis of the results revealed the following: (a) Practice improved ability to recognize both black and white letters. (b) The improvement was greater for the black than for the white letters so that the absolute difference between the two increased. (c) The percentage differences showed a less marked increase for the later practice periods. (d) In no case was there any tendency for prolonged practice to produce an advantage in favor of the white letters.

All the data in the above experiments fail to confirm the findings of Kirschmann even though his method was duplicated.

Perceptibility at a Distance

In the same series of experiments, Taylor (103) determined the distance at which printed material could be perceived accurately. The stimulus materials consisted of black on white and white on black in various arrangements: (a) 10 capital letters (B C E F G H N Q R S) printed in 6, 8, 10, 12, and 14-point Scotch Roman type; (b) the same 10 letters hand drawn in simple block capitals; (c) the same 10 capital letters printed in Kabel Light (sans serif) type in 6, 10, and 14 point; (d) 20 five-letter words and 20 nonsense combinations of five letters each printed in lower-case 10-point Scotch Roman type; (e) 12 paragraphs of 30 words each from the Chapman-Cook Test (Chapter 2) printed in lower-case 10-point set solid in a 19-pica line width; (f) nonsense combinations of the lower-case letters l and i (ll, li, il, ii) in 6, 10, and 14-point type. This is known as the li test.

Ten to 12 university students, tested individually, served as subjects in different parts of the experiment. By combining the materials in different ways, it was possible to study the effect on legibility of type size, type face, word form, and meaning from context.

Variation in Type Size. Data for variation in type size show that in every comparison (6, 8, 10, 12, 14 point, and block capitals), the white on black was less legible than black on white print. The differences varied from 3.1 to 10.0 per cent. Although the *absolute* difference between the two arrangements tended to increase with size of type, the percentage differences indicate that the inferiority of the white print is independent of type size.

Variation in Type Face. Also using the distance method, Taylor determined the relative legibility of black and white print in 6, 10, and 14-point type sizes for two type faces. Percentage differences between the black and white print are given in Table 9.4 for Scotch Roman (serif) and for Kabel Light (sans serif) types in each type size.

The results show that for Scotch Roman type in all three sizes, the white letters are very definitely less legible than the black. For the Kabel Light type, white and black letters were equally legible in 10 and 14-point type. But for the 6-point type the white letters were definitely less legible than the black. An analysis of the perceptibility scores suggests that in the black on white arrangement the sans serif type suffers

Table 9.4—Relation of Type Face to Legibility of Black and White Type

Type Size	Scotch Roman: Differences* in Per Cent	Kabel Light: Differences* in Per Cent
14 point	—22.0	—0.6
10 point	—23.6	+0.5
6 point	—26.7	—9.1

* A minus difference signifies that the white print was recognized only when closer to the eyes and therefore was less legible.

most from irradiation (the apparent enlargement of a bright object when viewed against a dark background), but in the white on black arrangement, it is the type with serifs that is subject to the greatest blurring from irradiation.

The li Test. To get a minimum of meaning and differential form, the distance method was used to compare black and white print in the form of ll, li, il, and ii. The subject's task was to identify which combination was presented. The percentage differences, black minus white print, are listed in Table 9.5.

The following may be concluded from the data on the li test: (a) Type size is not directly related to the relative legibility of black and white type, except for the fact that the smallest type, 6 point, produces the greatest advantage for the black type. (b) The li test results showed a large and significant advantage for the black type in all three sizes.

Variation in Word Form. The influence of word form was tested by comparing the relative legibility of black and white print in the form of words versus groups of letters in nonsense arrangement. As before, the distance method was used. The results showed that: (a) For both words and nonsense material, the black print was much more legible than white print—17.2 and 22.9 per cent respectively. (b) Words were perceived at a greater distance than the letters in nonsense arrangement. (c) The white nonsense material was more in-

TABLE 9.5—Black Versus White Print: the li Test in Three Type Sizes

Type Size	Standard Scoring: Differences* in Per Cent	Strict Scoring: Differences* in Per Cent
14 point	—42.6	—52.9
10 point	—33.1	—49.5
6 point	—74.8	—79.3

* Minus percentages indicate lesser legibility for the white print.

ferior to the black nonsense than were white words to black words. This appears to be due to the fact that in the absence of word forms, clear perception of details is hindered more when the print is white than when it is black. Relatively fine discrimination of details is required to perceive single letters.

Influence of Meaning. What is the influence of the degree of contextual meaning in the stimulus material upon the legibility of black versus white print? To answer this question, Taylor assembled the data presented in Table 9.6. To previously listed material is added the reading of 12 paragraphs of 30 words each by 20 subjects. Percentages are for scores on black print minus scores on white print.

The data indicate: (a) A decrease in meaningfulness in the stimulus is accompanied by an *increase* in the percentage advantage of black over white print. (b) Differences for legibility of both lower-case nonsense material and capital letters in isolation is about the same. (c) The greatest inferiority of white print occurs with material that lacks meaning or characteristic form, or both, i.e., the li test.

Interpretation. Taylor offers the following explanation of the universally superior legibility of black print: In ordinary type with serifs, like Scotch Roman, the detrimental effects of irradiation from the white background are counteracted by the serifs which tend to preserve the characteristic

TABLE 9.6—Influence of Context on Legibility of Black Versus White Print

Stimulus Material	Differences* in Per Cent
Words in paragraphs	—11.0
Isolated words	—17.2
Nonsense material	—22.9
Isolated capitals	—23.6
Letters: ll - li - il - ii	—33.1

* Minus differences signify poorer legibility for white print.

forms of the letters by emphasizing their corners. But when white letters appear on a black background, irradiation will increase the apparent size of the letters. This will also tend to blur letter outlines, close their open spaces, and fuse their parts, and so reduce legibility. These effects become most marked when the letters are small, when their strokes are relatively wide with respect to letter size, and when there are no auxiliary clues from contextual meaning. These factors should be least noticeable or even absent with sans serif type, especially in the larger sizes (at least 10 to 14 point).

Other Experiments. Holmes (35) determined by the distance method the relative legibility of five-letter words in black and white print. She found a 14.7 per cent advantage in legibility for the black print.

Taylor (103) employed a short-exposure technique to measure span of apprehension for large block letters with various degrees of brightness contrast between letter and background. She found that white letters on a black background were definitely less legible than black on white or dark gray on white.

General Statement. With the exception of the early investigation of Kirschmann, every study undertaken has shown a definite advantage for black print over white print.

The results of these studies lead to the following conclusions. In printing practice it is best, (a) to avoid white type on black for material of any length, (b) when employing white on black to attract attention, to use a minimum amount of text, and (c) to use a relatively large, at least 10 to 12-point, sans serif type to minimize loss of legibility with any white on black typographical arrangement.

Black Print on Tinted Paper

Opinions vary as to the desirability of using white or tinted paper for regular printing. In an early experiment, Griffing and Franz (30) found that due to less brightness contrast between print and the tinted papers, grayish (newspaper), red, and yellow papers were inferior to white paper in promoting legibility.

A detailed investigation dealing with legibility of print on white and tinted papers was reported by Luckiesh and Moss (51) in 1938. They used 5 subjects for visibility, and 20 for speed of reading, rate of blinking, and reader preferences. A description of the papers used follows:

Paper Sample	Per Cent Reflectance	Color Appearance
A	85	White — no appreciable tint
B	70	Light blue-green tint
C	82	Slight sepia-cream tint
D	71	Reddish buff verging on salmon
E	81	Very light sepia tint
F	79	Fairly saturated yellow
G	83	Slight cream tint
H	74	Light yellowish-green tint
I	82	Deep cream tint or very light buff
J	38	Fairly saturated yellowish red or reddish orange

Material from H. G. Wells' *Outline of History*[1] was printed on the various papers with black ink in 10-point Linotype Textype with 3-point leading in a 21-pica line width. While samples A, C, and E have the trade name of "white paper," only sample A has no observable tint. The average visibility scores for five readers follow:

Samples:	A	B	C	D	E	F	G	H	I	J
Av. Score:	4.61	4.19	4.62	4.34	4.38	4.64	4.83	4.43	4.83	2.74

[1] Two vols., The Macmillan Company, New York, 1920–21.

The larger visibility scores indicate greater visibilty. Note that the per cent reflectances, i.e., brightness values, of certain samples are 70 for B, 71 for D, 74 for H, and 38 for J. These, with the exception of sample E, are the samples with smallest visibility scores: 4.19, 4.34, 4.43, and 2.74 respectively. Sample E is the only paper in the group with enamel finish. It is likely that the type used was not suitable for giving a good print impression on enamel paper stock. All other samples except these five have only slight variation in reflectances (79 to 85 per cent) and also show no significant differences in visibility scores, i.e., 4.61 to 4.83 per cent. In general, visibility of print seems related to the reflectance of the paper. However, with the exception of sample J, which has a reflectance of 38 per cent, the variation of reflectances from 70 to 85 per cent probably would have little effect on the legibility of type ordinarily used in books, such as 10 to 12-point type. Quality of paper, such as thickness and surface texture as well as type face and paper reflectance must, of course, be considered to achieve the most legible print (see Chapter 10).

In the same study, Luckiesh and Moss measured speed of reading material printed on papers A, I, F, and J. Only slight differences were discovered. Blink frequency for these same four samples showed relatively more blinks for samples F and J. Rating of the same four paper samples showed that readers preferred the white A and disliked F (yellow) and J (reddish orange). The only clear-cut conclusion drawn by the authors was that the reddish orange paper of low reflectance (J) was found to be inferior by all criteria used.

The visibility of print for 16 samples of tinted paper was determined by Betts (10). Included was a new paper with the trade name of Facilex. No significant differences in visibility of print were discovered.

The influence of surface and tint of paper on speed of reading was investigated by Stanton and Burtt (99). Tints were white and ivory. Trade names of the paper stock used were: Lustro White, Lustro Ivory, Lustro Brilliant-dull White, Cameo Ivory, Old Style Wove White, and Old Style Wove India. The Tinker-Paterson speed-of-reading technique was employed. The results showed no significant differences in speed of reading print on these six papers. The printer is free to choose a tinted paper of these kinds for esthetic values without loss of legibility.

In general, the evidence concerning the effect of tinted paper on legibility warrants the following conclusions: (a) Black print on tinted paper varies somewhat in visibility. This variation is probably unimportant with respect to legibility in the ordinary reading situation. (b) When the reflectance of paper surfaces, white or tinted, is approximately 70 per cent or greater, all materials in black print are read at the same rate, i.e., the tints have no important deleterious effect on legibility. (c) It may be inferred, in terms of Tinker's findings (129) on the cumulative effect of marginal conditions upon rate of perception in reading, that when the reflectance of a tinted paper becomes marginal, such as 60 to 65 per cent, it would be unwise to use type as small as 8 point. Such a combination would undoubtedly result in a serious loss of legibility.

Colored Print on Colored Paper

Since 1930 there has been increased use of color combinations of print and paper in a variety of situations. Among these may be mentioned magazine advertising, posters, car or bus cards, booklets, folders, circulars, road maps and atlases, aviator maps, letterheads, magazine supplements in Sunday newspapers, books for children, books for adults (a recent trend), business documents of various kinds, and many other situations. This widespread practice in the use of color emphasizes the importance of scientific knowledge concerning the effect of various color combinations of type and background on legibility. A colored type which has satisfactory legibility on one background may prove to be illegible when combined with certain other colored backgrounds.

Luckiesh (42), as a result of experiments which he does not describe, lists the order of legibility of 13 combinations of print and background:

1. Black on yellow (best)
2. Green on white
3. Red on white
4. Blue on white
5. White on blue
6. Black on white
7. Yellow on black
8. White on red
9. White on green
10. White on black
11. Red on yellow
12. Green on red
13. Red on green

The amount of difference between ranks is not given. Consequently one does not know how much poorer red on green is than black on yellow or any other combination. Presumably the results were to be applied to advertising or road signs.

Three methods have been employed to study the legibility of colored print: Perceptibility during short exposures (i.e., perceptibility at a glance), perceptibility at a distance, and speed of reading.

Perceptibility at a Glance During Short Exposure. The legibility of material written and printed with colored ink on colored and white paper was studied by Miyake, Dunlap, and Cureton (64). One series of material consisted of black typed numerals (1 to 9) on red, green, yellow, and white paper. A second series consisted of typewriter script impressions traced in red, green, yellow, and white ink on black paper. A short-exposure device was employed to present the stimuli to each of 15 subjects. Scores were in terms of correctly reported numerals. The results in terms of mean scores follow:

Black Type on Colored Paper		Colored Type on Black Paper	
Red	23.00	Red	3.53
Green	26.27	Green	3.67
Yellow	26.80	Yellow	21.20
White	27.00	White	26.94

The most legible combinations were black on green, black on yellow, black on white, and white on black. Very illegible combinations were red on black and green on black. In between and of moderate legibility were black on red and yellow on black.

In a small but carefully controlled experiment, Griffing and Franz (30) determined the length of exposure time necessary for perception of printed words on white, newspaper, yellow, and red papers. It took considerably longer exposures to perceive the words on newspaper and the colored papers than on the white.

The only other short-exposure experiment on colored print was reported by Tinker (114). In Series 1, eight large block letters in nonsense arrangement on each of 32 white cards were presented to 100 subjects. Eight different colors were used: black, orange, violet, blue, red, neutral gray, green, and yellow. All letters on a specific card were the same color. In Series 2, the same colors were used but each letter on a card was a different color. Time and space errors were controlled. The exposure time was 3 seconds. The average number of letters of each color reported correctly was used to rank the colors in terms of their effect on perceptibility. The rankings for the two series are given in Table 9.7.

TABLE 9.7—The Effect of Color on Perceptibility of Block Capital Letters on a White Background

Homogeneous: Series 1		Heterogeneous: Series 2	
Color	Rank	Color	Rank
Violet	1	Black	1
Red	2	Orange	2
Green	3.5	Blue	3
Gray	3.5	Violet	4
Orange	5	Red	5
Black	6	Gray	6
Blue	7	Green	7
Yellow	8	Yellow	8

The differences in scores from one rank to the next were not great. However, when as many as five steps in rank occurred, all the differences were significant in both series. The brightness contrast between letter and background appeared to be one factor determining perceptibility of the letters. To some degree, the greater the brightness difference between a letter and the white background, the more apt it was to be perceived. The difference in ranks for the two series was probably due to the greater effect of attention value of the colors in the heterogeneous series.

Perceptibility at a Distance. Sumner (102) set out to study the relative legibility of 42 color combinations of print and background, and reader preferences for the same combinations. Measurements were made of the maximum distance at which legibility of copy in its entirety was possible. In general, he found that legibility depended upon brightness difference between symbol and background. The three most legible combinations were blue on gray, black on gray, and black on yellow. The three worst ones were black on blue, yellow on white, and blue on black. Ranks for legibility yielded a correlation of + .54 with ranks for preference.

Since fairly large letters and digits were used for stimuli, the results are more applicable to advertising and road signs than to the ordinary reading situation.

An experiment by Preston, Schwankl, and Tinker (91) investigated the effect of variations in color of print and paper on the perceptibility of isolated five-letter words by using the distance method. The same color combinations were used as those employed by Tinker and Paterson (150) in measuring speed of reading (see below). Ruxton's colored ink was used to print words on Rainbow cover stock. There were 10 groups with six college subjects in each group, 60 in all. Each of the color combinations was compared with black print on white paper. The average score in each comparison was for six readers. The differences in Table 9.8 are for the score for a color combination minus the score for black on white.

The data reveal striking differences in perceptibility (legibility). As shown in the right-hand column, all the dif-

TABLE 9.8—Effect of Variations in Color Combinations on Legibility of Printed Words

Color of Ink and Paper	Legibility Rank	Differences* in Centimeters	Diff. / S.E. Diff.
Blue on white	1 (best)	−11.8	3.97
Black on yellow	2	−10.8	2.96
Green on white	3	− 5.4	1.66
Black on white	4	0.0	0.00
Green on red	5	+ 5.7	0.57
Red on yellow	6	+ 9.6	3.66
Red on white	7	+18.8	5.42
Orange on black	8	+20.0	7.49
Black on purple	9	+61.4	23.52
Orange on white	10	+86.4	40.00
Red on green	11	+92.1	24.36

* A minus difference signifies greater legibility (perceived farther from reader) than black on white, and a plus difference signifies poorer legibility than black on white (perceived nearer to reader than black on white).

ferences are statistically significant except those for ranks 3, 4, and 5. In general, the more perceptible combinations had a greater brightness difference between print and paper. The results should correlate well with legibility measured by a speed-of-reading method. As a matter of fact, the correlation with Tinker and Paterson's results (150) is + .864. Apparently the results from both studies are applicable to the normal reading situation.

Speed of Reading

A comprehensive investigation of color combinations of print and background in relation to legibility was completed by Tinker and Paterson (150). They employed their speed-of-reading technique with 850 readers. Ruxton's ink was used to print the reading material on Rainbow cover stock. The names of the 11 combinations of ink and paper employed with their visual appearance are listed in Table 9.9.

All test blanks were printed in Scotch Roman 10-point type in a 19-pica line width set solid. The standard, black on white, was compared with each of the other 10 combinations. The results are given in Table 9.10 in terms of

TABLE 9.9—Color Combinations of Ink and Paper with Observed Color Effects

Trade Names	Observed Effect
Black jobbing on white........	Black on light grayish white
Grass green on white.........	Dark green on light grayish white
Lustre blue on white..........	Dark blue on light grayish white
Black jobbing on yellow.......	Black on yellow (slight orange tinge)
Tulip red on yellow..........	Light red on yellow (slight orange tinge)
Tulip red on white............	Light red on light grayish white
Grass green on red............	Dark grayish green on red (dark tint)
Chromium orange on black....	Dark lemon yellow on dark grayish black
Chromium orange on white...	Light orange on light grayish white
Tulip red on green............	Dark brown on dark green
Black jobbing on purple.....	Black on dark purple (violet)

TABLE 9.10—Legibility of Colored Print on Colored Paper

Color Combination Compared With Standard Black on White	Differences* in Per Cent
Black on white (standard)	0.0
Green on white	— 3.0
Blue on white	— 3.4
Black on yellow	— 3.8
Red on yellow	— 4.8
Red on white	— 8.9
Green on red	—10.6
Orange on black	—13.5
Orange on white	—20.9
Red on green	—39.5
Black on purple	—51.5

* Minus signifies less legibility than black on white.

percentage differences between black on white versus each of the other 10 color combinations.

In every comparison listed in the table, black on white yielded the most rapid reading. The retarding effects of the first three color combinations are relatively slight, ranging from 3.0 to 3.8 per cent. From a practical viewpoint, it is probable that green on white and blue on white are nearly as effective as black on white in promoting rapid reading, i.e., the differences are barely significant between the 2 and 5 per cent levels. The difference for black on yellow barely reaches the 1 per cent level of significance. The retarding effects of the remaining color combinations become more pronounced. The red on yellow, with a 4.8 per cent differential, suggests that it should not be used where speed of reading is an important factor. In the remaining comparisons, the various color combinations produce very illegible text. In fact, the last four combinations retard reading to such an extent (13.5 to 51.5 per cent) that it is inadvisable ever to use them. These are the same four color combinations that showed the poorest perceptibility in the Preston, Schwankl, and Tinker study cited above. As a matter of fact, the subjects had great difficulty in reading the print in the last two color combinations.

When the reflectances of the paper and the brightness contrast between print and paper are considered, the results become understandable. The reflectance of the white paper is above 70 per cent, the black ink about 4 per cent, and the green and blue ink about 8 per cent. The brightness contrast between ink and paper for these three combinations is sufficient to produce adequately legible copy. The brightness contrast between the printing ink and paper becomes progressively less for the succeeding color combinations. As a matter of fact, the legibility of the printed material does not depend primarily upon the colors of ink and paper as such. The legibility is determined primarily by the brightness contrast between the print and background. It is this brightness contrast that determined the visibility or perceptibility of these same color combinations in the study by Preston, Schwankl, and Tinker.

Many persons unfamiliar with colors fail to realize that color contrast and brightness contrast are two totally different things. For instance, red and blue have considerable color contrast but little brightness contrast. Similarly, light orange and white are contrasting colors but show little brightness contrast. In other words, two shades or two tints will show little brightness contrast. In printing with colored ink on colored paper, the ink should be a shade or dark color, and the paper a tint or light color, i.e., one should use a dark ink on a light background.

Another factor that must be considered by the editor or printer is the change in the visual appearance of a color when printed on another color. This becomes obvious by noting the observed effect of color combinations in Table 9.9.

The results of the present study hold only for colored inks printed on colored papers. When both letters and background are printed with different colored ink on a white background so that they do not overlap, the effect is different.

Reader Preferences. Samples of the printing used in the above study were presented to 210 readers. They ranked the 11 samples according to opinions of relative legibility. The results are presented in Table 9.11.

Comparison of the rankings in the table with the rank order for the speed of reading reveals a close correspondence of the two. It would seem that readers make their judgments of relative legibility largely in terms of brightness contrast between print and paper without being influenced by color preference and color contrast. From a practical point of view, the editor will choose colors which produce maximum brightness contrast when combined, if he is to achieve good legibility and reader approval.

Eye Movements. In the speed-of-reading measurements discussed above, red print on a dark green background was read 39.5 per cent more slowly than black on white. Tinker and Paterson (158) ascertained the specific differences in eye-movement patterns underlying this result. Ten paragraphs

TABLE 9.11—Judgments of Relative Legibility of Colored Print on Colored Paper

Color Combination	Average Rank	Rank Order
Black on white	2.1	1 (best)
Blue on white	2.8	2
Black on yellow	2.9	3
Green on white	4.2	4
Red on yellow	5.3	5
Red on white	5.4	6
Green on red	5.7	7
Orange on black	7.6	8
Orange on white	9.1	9
Black on purple	10.2	10
Red on green	10.5	11

of each kind of printing were read by 20 subjects and their eye movements were recorded. The results showed that there was an increase significant at the 1 per cent level in fixation frequency, pause duration, perception time, and regression frequency for the red on green in comparison with black on white print. The differences ranged from 14.5 to 42.6 per cent. These differences indicate that there was a marked disruption of the entire reading process in reading the red on green print. Poor visibility forced the readers to concentrate on details near the threshold of discrimination.

A more elaborate eye-movement study was undertaken by Hackman and Tinker (31). There were 49 readers in seven groups of seven each. A Latin Square experimental design was employed. Seven color combinations of the reading selections used by Tinker and Paterson (150) constituted the reading selections. The color combinations were black on white, green on red, red on green, orange on white, black on purple, red on white, and black on yellow.

Analysis of variance showed that there were statistically significant differences between the color combinations for fixation frequency, pause duration, and perception time. Differences for regression frequency were not significant. The over-all picture (ranks for all measures combined) showed the ranking of the color combinations to be as follows:

Color Combination	Mean Rank	Final Rank
Black on yellow	1.75	1 (best)
Red on white	2.00	2
Green on red	3.00	3
Black on white	3.25	4
Black on purple	5.00	5
Orange on white	6.00	6
Red on Green	7.00	7

Rankings for the separate eye-movement measures showed striking agreement with each other. Therefore, the mean ranking given above is quite representative of the separate rankings. According to the combined rankings for all measures, the most legibile combinations were black on yellow, red on white, green on red, and black on white. Note that in the above data, ranks for these four combinations are grouped closely. The less legible combinations were black on purple, orange on white, and red on green. The mean ranks for these three combinations are well separated from the mean ranks for the more legible combinations.

There is general agreement between these results and the speed-of-reading results cited above, particularly in the placement of the least legible color combinations. Again one finds that degree of brightness contrast between print and paper separates the poorly legible from the more legible printing. On the other hand, eye-movement measures do not give as precise a discrimination between the legibility of color combinations as speed of reading. This further emphasizes the statement made in Chapter 2, viz., the eye-movement method should supplement speed of reading, not take the place of it in studying legibility of print.

Trends in Use of Colored Print on Tinted Papers

The use of light tints of paper for printing appears to have merit. Visibility of print and speed of reading for print on light tints (cream, ivory, pale green, pink, etc.) is as good as on ordinary grades of white book paper when 10 to 12-point type is used. Dark colored inks coordinated with colored tints of paper can be as legible as black print on white paper provided (a) the reflectance of the paper is 70 per cent or greater, (b) the colored ink has a reflectance low enough so that the brightness contrast between print and paper is about 65 per cent (i.e., 1 to 8 ratio), and (c) the size of type is 10 point or larger. There is a trend in printing for use in ordinary reading situations which incorporates these requirements. It is likely that many readers will prefer such an arrangement on esthetic grounds.

Summary

1. Black print on a white background is much more legible than white print on a black background for materials to be read in the ordinary situation. This is due to the larger number of fixation pauses required to read the white on black.

2. Three-fourths of readers prefer to read black on white rather than white type on black.

3. Black letters on white paper are more readily recognized in peripheral vision than white on black.

4. Words in sentences and paragraphs, isolated words, groups of letters in nonsense arrangement, isolated capitals, and discrimination between ll, li, il, and ii all are more perceptible at a distance when printed in black on white than in white on black.

5. A sans serif type face (Kabel Light) printed in 10 to 14-point type is equally legible in black on white and white on black, but in 6-point type the black on white is significantly more legible.

6. It is best for the editor to avoid white type on black background for material of any length. When white type on black is employed to attract attention, the amount of text should be small, and a sans serif type in 10 to 14-point size should be used to minimize the loss of legibility which ordinarily occurs with the white on black arrangement.

7. The visibility of black print on tinted paper varies somewhat. If the tinted paper has a reflectance of 70 per cent or more, as most tints do, there is no appreciable loss of legibility when black type as large as 10 point is used.

8. Printed material is perceived at a glance more readily as the brightness contrast between print and paper becomes progressively greater.

9. The greater the brightness contrast between print and background, the easier it is to perceive, at a distance, colored print on colored paper.

10. Rate of reading materials printed in different combinations of colored ink and colored paper varies greatly. The more legible combinations are those with greater brightness contrast between print and paper. This can be achieved by use of a dark ink on a light color (a tint). Dark ink on shades or dark colors of paper should be avoided.

11. Rate of reading and perceptibility at a distance yield comparable scores for colored print on colored paper.

12. The rank order of reader preferences for colored print on a colored background corresponds closely to the scores for both speed of reading and perceptibility at a distance.

13. Variation in the efficiency of eye movements in reading colored combinations of ink and paper correspond closely to speed-of-reading data. When legibility is very poor, the eye-movement patterns are disrupted greatly.

14. It is possible to coordinate colored print with color tints of paper so that legibility and pleasingness is maintained at a satisfactory level.

10. Printing Surfaces

A VARIETY OF OPINIONS concerning the kind of printing surfaces which are thought to promote legibility of print have appeared in the literature from 1883 to 1926. None is based upon experimental data. The opinions have been brought together by Pyke (92). These may be listed according to the date at which they appeared.

1. 1883: Printing paper should have a thickness of not less than 0.075 millimeters.

2. 1896: Paper surface should be matt.

3. 1896: Minimum thickness of paper should be 0.075 millimeters.

4. 1898: Printing paper should have a hard surface that is little ribbed. It should be durable, unglazed, and handmade.

5. 1910: Printing paper should be pure white but without gloss. The thickness and surface should be such that the print on one side will not show through to the other side, and so that the printing will not affect the evenness of the surface on the other side.

6. 1911: Printing paper should be unglazed, free from shine, and opaque.

7. 1912–15: The paper should have no glaze and should be pressed to avoid easy soiling, and have a ribbed surface. The thickness should be such that print does not show through. To avoid injurious effects, the specular glare (like

a mirror) should not be over 56 per cent and the diffuse reflection not less than 44 per cent. With poorly diffused artificial light, glare effects become greater.

8. 1912: The quality and the texture of printing paper is a much less significant factor than has been supposed, provided the lighting and the angle of the printed surface to the incident light are such as to avoid specular reflection.

9. 1915: Printing paper should possess a highly diffuse reflecting power, little gloss, and the print on the back should not show through. Glazing of any kind is deleterious optically. The glossy effect of ink should, in general, be maintained below ½ per cent.

10. 1916: Paper should be as white as possible, the ink perfectly black and dead in color. The paper should be neither too rough nor glossy. Pink and red paper are harmful to vision.

11. 1925: To take a clean impression and to avoid easy soiling, paper should be without gloss. In addition, the paper should be sufficiently thick and opaque to prevent print on the reverse side from shining through or from marring the surface smoothness.

Summary of Opinions. Prior to the experimental studies, the opinions of writers concerning paper surface emphasized the following points: White, unglazed paper with a matte (rough) surface is favored although the surface should not be so rough that it prevents a good print impression or is easily soiled; the paper thickness should be such that print on the reverse side does not show through; but at least one writer minimizes the importance of paper surface, provided the lighting for reading is properly diffused.

Experimental Studies

Three methods have been employed to investigate the effect of paper surface on legibility of print: (a) the distance method, (b) speed of reading, and (c) visibility.

Distance Method Experiments. In Roethlein's experiment (93), groups of letters of nine different type faces were printed upon both coated white paper (glazed), and a rough-finished, very slightly yellowish paper. The average distance at which the letters were perceived on the coated paper was 144.9 centimeters and on the rough-finished paper, 145.0 centimeters. Individual differences were small. The subjects expressed no definite preference for either kind of paper. In this experiment, therefore, quality and texture of paper had no differential effect on legibility of print.

Webster and Tinker (169) employed the distance method to study the effect of variations in paper surface on legibility of print. They recorded the distance from the eyes at which five-letter words could be perceived. The words were printed in Scotch Roman lower-case type on white paper. The 64 words for the standard were printed on eggshell paper stock (matte surface), and another 64 equivalent words were

TABLE 10.1—Effect of Paper Surface on Legibility

Paper Surface Compared With Eggshell Standard	Differences		Critical Ratio
	CM*	Per Cent	
Artisan enamel	—0.12	—0.08	0.03
Flint enamel	—2.32	—1.66	1.01

* Minus signifies less legibility than on eggshell paper stock.

printed on artisan enamel and on flint enamel. The U.S. Bureau of Standards reported the following percentages of glare for the three paper surfaces: eggshell, 22.9 per cent; artisan enamel, 85.8 per cent; and flint enamel, 95.1 per cent. Perceptibility for print in the standard setup (eggshell) was compared with print on each of the other two paper surfaces. There were 15 subjects, five of whom made 128 readings in each comparison. The data are given in Table 10.1.

The results indicate that no significant differences were found with variation in paper surface. The alleged eyestrain from reading printed material on glazed paper, when it does occur, must be due entirely to continuous reading in light not uniformly diffused.

Speed-of-Reading Experiments. Two experiments on printing surfaces were reported by Paterson and Tinker (79). In the first, speed of reading material printed on eggshell (dull finish) was compared with speed of reading material on white enamel (glossy finish). There were 190 readers. A difference of 1.6 per cent in favor of the white enamel was found. This difference is not statistically significant.

In the second experiment, speed of reading material printed on artisan enamel (85.8 per cent glare) and on flint enamel (95.1 per cent glare) was compared with reading print on eggshell (22.9 per cent glare) paper stock. The latter was rough-surface paper, the artisan enamel was somewhat more than moderately glossy, and the flint enamel was very shiny. There were three groups of 85 readers each, 255 in all. The results are given in Table 10.2.

The results show that material printed on paper with a moderately high degree of gloss is read as fast as material on eggshell with a low degree of gloss. Material printed on paper of extremely high gloss, the flint enamel, was read slightly more slowly than material on the rough-surface paper

TABLE 10.2—Effect of Paper Surface on Legibility

Paper Surface Compared With Eggshell Standard	Differences in Per Cent
Eggshell (control)	0.0
Artisan enamel	+0.4
Flint enamel	—2.9*

* Significant between the 2 and 5 per cent levels. Minus signifies less legible than eggshell.

(eggshell). However, this difference is less than 3 per cent and barely reaches significance between the 2 and 5 per cent levels. The indications are that materials with a moderately high degree of gloss, measuring about 86 per cent glare, have no deleterious effect on legibility provided the illumination present is well diffused. The results of Stanton and Burtt (99) discussed in Chapter 9, and some additional material of Paterson and Tinker to be presented in Chapter 11, are in harmony with the above findings.

Reader Opinions. How do readers respond to the appearance of print on paper with different degrees of gloss? Samples of print on eggshell, artisan enamel, and flint enamel were presented to 224 readers. They ranked the samples according to their opinions of relative legibility. The results are listed in Table 10.3.

It is clear that most readers dislike the idea of reading print on glossy paper, especially the severe degree of gloss exemplified by flint enamel. Three-fourths of the readers prefer the eggshell, a moderately rough surface.

The antagonism to glazed or glossy paper presumably is derived from reading carried on under unsatisfactory conditions of illumination. Even moderately glazed paper produces specular glare when the light is not well diffused and when the page of reading material is held at a certain angle so that the reflected light shines directly into the reader's eyes. Unfortunately, direct, poorly diffused illumination continues

TABLE 10.3—Paper Surfaces Ranked for Relative Legibility

Paper Surface	Average Rank	Percentage Votes for First Place
Eggshell	1.3	75
Artisan enamel	1.9	19
Flint enamel	2.8	6

TABLE 10.4—Visibility of Print on Nine Grades of "White" Paper

Paper Sample	Per Cent Diffuse Reflectance	Trade Name
A	74.3	70 lb. Linotype News
B	80.6	80 lb. A. and G. Special Finish
C	77.2	70 lb. Oxford Super
D	77.3	70 lb. Bedrock Bond
E	83.4	80 lb. Polar Superfine
F	84.5	80 lb. North Star Dull Coated
G	79.0	80 lb. Oxford Antique
H	80.6	65 lb. Hammermill Cover Ripple
I	70.9	32 lb. Newsprint

to characterize many reading situations. With adequately diffused illumination, there would be little or no glare from glossy paper.

Visibility of Print and Quality of Paper. Luckiesh and Moss (59) investigated the visibility of print on various qualities of paper. Nine different grades of so-called white papers frequently used in printing were chosen. They are described in Table 10.4. Although designated as white, the samples varied in appearance from white to light gray to bluish gray to warm or sepia gray. The surfaces also varied from dull to fairly glossy.

The text was printed in black ink in 12, 10, 8, and 6-point Linotype Textype on each kind of paper. Measurements were made with the Luckiesh-Moss Visibility Meter.

The authors summarize the results as follows: (a) With the exception of samples A, C, and I, the variation in visibility of print was relatively small for each of the type sizes. For all 9 samples the visibility of type was not radically different in any one type size. (b) The possible advantage of extreme "whiteness" in paper is relatively unimportant with regard to visibility of print. Such papers, which may differ measurably in reflectance (percentage of incident light reflected) and surface character, do not materially affect visibility of print if good black ink and type are used.

Thickness of Paper

There are no experimental data concerning the effect of thickness of paper on legibility of print. As noted above, various writers have advocated relatively thick paper which is opaque enough so that print on the reverse side will not show through. There is good reason for this suggestion. When print on the reverse side shows through, the "shadows" blur the print on the front side. With lightweight or thin paper, these shadows become fairly prominent. Any showing through will reduce visibility of print. It may be more economical to print a lengthy book on thin paper, but from the viewpoint of vision it is an indefensible practice. The same criticism holds for journals and nonscientific magazines printed on relatively thin paper. The use of double-column printing on sufficiently opaque paper is one way to keep the thickness of a journal or book within desirable limits.

Summary

1. Prior to experimental work, the opinions of writers were in favor of white, unglazed paper with a matte surface for printing. The use of paper thick and opaque enough to prevent print on the reverse side from showing through was advocated.

2. Measurement of perceptibility of print at a distance revealed no advantage for a rough paper surface over a moderately glazed surface or an extremely glazed surface.

3. Speed of reading material printed on flint enamel (extremely glazed) paper is retarded by a small but statistically significant amount. But material with a moderately high

glaze (86 per cent glare factor) was read just as rapidly as material on a dull-surfaced paper. Three-fourths of readers prefer a dull printing surface. Very few like print on extremely glazed paper.

5. Visibility of print on dull and glossy "white" papers frequently used for printing varies somewhat but not enough to be seriously detrimental to legibility.

6. Although no experimental evidence is available, it seems logical and reasonable that paper should be thick and opaque enough so that print on the reverse side will not show through. Shadows from print on the reverse side tend to blur print on the front side.

7. In general, glazed, hard surface paper should be used sparingly for printing. Although glaze does not affect perceptibility at a distance, extreme glaze does retard speed of reading somewhat. Furthermore, few people prefer print on glazed paper.

8. Glare from glazed paper occurs whenever the illumination is not well diffused. Since relatively few reading situations have ideal diffusion of light, printers should avoid glazed paper except for special situations such as window posters, bus cards, circulars with little printing, and a few pages in a book or magazine to accommodate half-tone illustrations. To avoid glare from poorly diffused light and to meet reader preferences, it is best for the editor, whenever possible, to specify a dull-finished, opaque paper for printing.

11. Cumulative Effect of Combining Nonoptimal Typographical Arrangements

It is not difficult to surmise that when two or more nonoptimal typographical arrangements are combined, the deleterious effect on legibility should be greater than the influence of a single nonoptimal arrangement. But there are three relevant problems that cannot be solved by guessing. In the first place, are the adverse effects due to nonoptimal conditions cumulative, or is the combined effect less than the sum of the separate effects? Secondly, what happens when two or more marginal conditions occur together? The term "marginal condition" refers to a printing arrangement or level of illumination that is on the borderline between optimal and nonoptimal, or a condition which reduces legibility somewhat, but not by a rigid standard of statistical significance, i.e., at the 1 per cent level. Examples of such marginal conditions are 10-point print on flint enamel, grass green printing ink on "white" paper, 11-point type set solid in a 34-pica line width, or 8-point type set in optimal line width and leading. In the third place, will the effects of a combination of nonoptimal printing arrangements confirm the results of previously cited studies on the legibility of print? If so, one would have impressive additional evidence with regard to the soundness of previous determinations. At the same time, the new evidence could demonstrate the dangers of incorporating two or more nonoptimal typographical factors in a given printing arrangement.

The interested person does not need to search far to find various combinations of nonoptimal printing. For instance, in some government and other pamphlets there is material printed in relatively small type, in long lines, on too thin paper stock, or a nonoptimal combination of colored print on colored paper printed in all capitals, or white print on a black background printed in too small a type size. These are only a few examples of the numerous nonoptimal combinations that frequently occur.

Experimental Results

In three studies, Paterson and Tinker avoided impossible printing arrangements by keeping within reasonable limits so far as printing practice is concerned. Their problem was to discover whether or not a number of typographical factors, each adversely affecting legibility of print, would operate with increasing deleterious effects when combined. Specifically, they wanted to know whether combining two factors, each reducing legibility 5 per cent, would produce a 10 per cent reduction (cumulative effect), a 15 to 20 per cent reduction (synergistic effect), or an approximately 5 per cent reduction (nonadditive effect). Still another possibility was that the two nonoptimal arrangements would be worse than either one alone, but the combined effect would not be a 10 per cent loss and thus not strictly cumulative.

Ten-Point Type. In the first study (79), the standard in an optimal arrangement of Scotch Roman type in a 19-pica line with 2-point leading was compared with each of seven nonoptimal arrangements as shown in Table 11.1. All type was set in 10 point. The speed of reading method was employed using 744 readers.

The results in Table 11.1 have been arranged in an order going from the standard as an optimum to various changes in leading, print, and background, paper stock, and type face

TABLE 11.1—Effect of Combining Nonoptimal Printing Arrangements: 10-Point Type

Typographical Arrangement					
Line Width (Picas)	Leading in Points	Type Face	Print and Background	Paper Stock	Differences* from Standard in Per Cent
19 (control)	2	Scotch Roman	Bl. on Wh.	Enamel	0.0
44	2	Scotch Roman	Bl. on Wh.	Enamel	— 7.5
44	0	Scotch Roman	Bl. on Wh.	Enamel	—10.1
44	0	Scotch Roman	Bl. on Wh.	Eggshell	— 8.2
44	2	Scotch Roman	Wh. on Bl.	Enamel	—14.5
44	0	Scotch Roman	Wh. on Bl.	Enamel	—18.4
44	0	Scotch Roman	Wh. on Bl.	Eggshell	—18.7
44	0	Cloister Black	Bl. on Wh.	Eggshell	—22.3

* Minus signifies less legibility than the standard set in 10-point Scotch Roman type in a 19-pica line width with 2-point leading.

All differences are significant at the 1 per cent level.

that are nonoptimal. In the second comparison the only change is an increase in line width from 19 to 44 picas. This reduced legibility by 7.5 per cent. In the third comparison the print was set solid with the line width at 44 picas. The retarding effect was 10.1 per cent. The fourth comparsion kept the line width at 44 picas, but employed eggshell paper stock instead of enamel. The loss in legibility was 8.2 per cent. These results for comparisons 2, 3, and 4 indicate that the three typographical variations introduced reduce legibility by approximately the same amount. In other words, with such a long line width, leading has only a slight (statistically insignificant) beneficial effect. The kind of paper used was immaterial. These results are in harmony with, and thus strengthen, the previously reported finding that leading is not very important for very long lines in 10-point type.

The next comparison reveals the effect of printing white on black in the 44-pica line width. The retarding effect is 14.5 per cent. This effect is more severe than the results for white on black in a 19-pica line width, reported earlier. The greater loss in legibility may be attributed to the combined effect of an excessively long line width coupled with white print on black paper.

In the next two comparisons the white on black printing arrangement is set solid, and in one of these the paper stock shifts from enamel to eggshell. Both comparisons show a retarding effect of about 18.5 per cent. The lack of leading produced a slight retardation (about 4 per cent), but change in paper stock resulted in no variation.

The final comparison in this table involves Cloister Black type printed black on white in a 44-pica line width set solid. The loss in legibility is 22.3 per cent. This appears to be a particularly bad typographical arrangement.

In general, the results in Table 11.1 mean that the combination of nonoptimal typographical factors produces a deleterious effect on legibility which is additive, but falls somewhat short of being strictly cumulative. Therefore, from the standpoint of legibility, the combination of deleterious factors results in a progressively poorer typographical arrangement.

Two other studies were completed in which nonoptimal combinations were compared with a standard optimal arrangement of 10-point Scotch Roman type set in a 19-pica line width with 2-point leading on enamel paper stock.

Eight-Point Type. One study (79) employed 8-point type set in a 40-pica line width with variations in leading, black on white and white on black printing, paper stock, and type face. There were 744 readers. The variations were similar to those used in the 10-point type study. The losses in legibility due to the nonoptimal combinations when compared to the standard optimal arrangement ranged from —9.9 to —22.7 per cent. Changes in leading (2 point to set solid) and in paper stock had no significant effects. But white print on black in the 8-point, 40-pica line produced a severe retardation of about 20 per cent. The deleterious effect of Cloister Black was equally bad or worse, showing a legibility loss of 22.7 per cent.

Six-Point Type. The third study (79) involved nonoptimal combinations of 6-point type compared with the optimal setup for the 10-point type used in the two investigations described above. The following results were obtained for the 6-point type in the various nonoptimal combinations: (a) The 34-pica line width with 2-point leading on enamel paper stock reduced legibility by 6 per cent. In view of the previously reported results (Chapter 7), this loss was due partly to the small size of type and partly to the long line width. (b) The material in a 34-pica line set solid on enamel paper stock showed a loss of 14 per cent. Apparently leading for this size of type in a long line is important. Merely removing the 2-point leading produced an additional loss of 8 per cent. (c) With the same line width set solid on eggshell paper stock, the loss of legibility was only 10.4 per cent. Thus, the black on white arrangement for 6-point type is more legible on eggshell paper stock than on enamel. (d) When this small type was printed with 2-point leading on enamel paper stock in white print, the reduction in legibility from the standard arrangement became 17.3 per cent. This change from black on white to white on black increases the loss in legibility from 6 to 17.3 per cent. (e) When the leading was removed from the white print on a black background, there was a further loss of 4.9 to 22.2 per cent. Again it was found that leading is important for 6-point type in this 34-pica line width. (f) Shifting from enamel to eggshell paper stock for the white on black arrangement set solid made little difference. The difference from the standard was 23.1 per cent compared with the 22.2 per cent for the enamel paper stock. (g) In the final comparison, Cloister Black type face, black on white print set solid in a 34-pica line width on enamel paper stock, produced, in comparison with the optimal standard arrangement, a loss of 26.2 per cent in legibility. Thus, changing from Scotch Roman (white on black) to the Cloister Black type face (black on white) added a further significant loss in legibility, i.e., approximately 3 per cent worse than the Scotch Roman. When compared with black on white Scotch Roman type (third comparison above), the change to Cloister Black reduced legibility an additional 15.8 per cent, i.e., from 10.4 to 26.2 per cent. (h) In general, the nonoptimal combinations of 6-point type revealed the important factors influencing legibility to be line width, leading, paper stock for black print, white versus black print, and Cloister Black type face versus Scotch Roman.

The interpretations of the results with 8 and 6-point type are similar to those for 10-point type. Combinations of nonoptimal typographical arrangements produce losses in legibility that are additive but not cumulative.

Eye Movements. As noted in the preceding section, material set in the nonoptimal combination of 6-point type set solid in white print with a 34-pica line width on enamel paper stock was read 22.2 per cent more slowly than the optimal setup of 10-point type in black print with 2-point leading in a 19-pica line width on enamel paper stock. Paterson and Tinker (83) determined the change in eye-movement patterns responsible for this retardation. Ten paragraphs in each typographical arrangement were read by 20 subjects while eye movements were recorded. The results are given in Table 11.2.

The results show that this nonoptimal typographical arrangement was read with significantly more fixations, longer pause duration, longer perception time, and more regressions. With the exception of pause duration, the percentage differences were relatively large. It is noteworthy that regression frequency increased nearly 100 per cent. The eye-movement patterns for the nonoptimal arrangement indicate a marked disorganization of oculomotor behavior in comparison with patterns for the optimal setup. These results provide helpful information to supplement the speed-of-reading data.

Marginal Printing Arrangements. The effect of combining marginal printing arrangements is relevant to the present

TABLE 11.2—Eye Movements in Reading Optimal and Nonoptimal Typography

Optimal Versus Nonoptimal	Fixation Frequency	Pause Duration	Perception Time	Regression Frequency
Per Cent Differences	+19.8*	+6.24†	+27.29*	+93.3*

* Significant at the 1 per cent level.
† Significant at the 5 per cent level.
Plus signifies less legibility for the nonoptimal arrangement.

discussion. Tinker (129) found that combining marginal conditions of type size, type form, and illumination level produced a markedly nonoptimal visual task. A marginal condition is considered one that reduces legibility by a small amount that is not significant at the 1 per cent level, or one that is on the borderline between satisfactory and unsatisfactory from the viewpoint of visual discrimination. It is important, therefore, not only to avoid combinations of nonoptimal printing arrangements, but also to avoid combinations of marginal arrangements.

Summary

1. When nonoptimal printing arrangements were compared with an optimal typographical setup, there was a progressive loss in legibility due to decreases in size of type, increases in line width, decreases in the amount of leading, change from Scotch Roman to Cloister Black type face, and substitution of white on black for black on white printing. Paper surface was a relatively unimportant factor except for black print in the 6-point type. Leading was most important for the 6-point type in the 34-pica line width used.

2. The results obtained in these studies of three sizes of type provide proof that the progressive introduction of undesirable variations in two or more typographical factors is accompanied by ever greater loss in legibility. However, the combined effect of two or more such factors is not strictly cumulative. In other words, the nonoptimal factors work together but their combined effect cannot be predicted exactly from a knowledge of their separate effects.

3. Eye-movement patterns for reading the nonoptimal typographical arrangement reveal marked disorganization of oculomotor behavior in comparison with the reading of the optimal setup.

4. It is advisable to avoid combinations of marginal typographical arrangements. A combination of two or more marginal conditions will produce a significant loss in legibility.

5. The general conclusion, in view of the material presented in this chapter, is that the printer should never combine either nonoptimal typographical arrangements or marginal arrangements. Such practice will only diminish to a striking degree the legibility of print.

12. Newspaper Typography

SOME OF THE FINDINGS reported in previous chapters are applicable to newspaper typography. Among these factors affecting legibility in both book printing and newspaper printing are type form, size of type, line width, leading, color of print and background, and printing surfaces. Some of these findings have been coordinated for use by newspapers by Mitchell J. Anthony in the pamphlet *Just the Type* (177).

Newspaper printing represents a rather specialized application of typography. Newspapers employ type faces especially designed for their printing. Type size and line widths used tend to be smaller than those used in book printing. Type forms appropriate for headlines present special problems. The use of mixed type forms in body type raises problems of legibility. In view of these and other related problems, the research on newspaper typography will be discussed in this chapter as a coordinated unit.

Printing Practice

In 1935 Tinker and Paterson (159) made a survey of newspaper printing practices among United States daily newspapers and repeated it for the same papers in 1942. Returns were received from 89 papers in 1935, and from 87 papers in 1942. Data were obtained on newspaper type faces (body types), size of type, width of line, and leading used on front pages and on editorial pages. Comparison of the results for 1935 with those of 1942 reveals the changes which took place over a period of seven years.

Newspaper Body Types. The body types used and the changes made over a seven-year period, 1935 to 1942, are shown in Table 12.1 as a representative sample of U.S. papers.

The data show the following: (a) The most popular body types for front page use were Ionic, Ideal, Excelsior, and

TABLE 12.1—Body Types Used by U.S. Newspapers

Body Types	Times Used on Front Page		Times Used on Editorial Page	
	1935	1942	1935	1942
Ionic	30	22	20	16
Ideal	28	21	22	17
Excelsior	14	17	13	12
Regal	5	13	4	10
Century	2	1	7	10
Old Style	2	0	3	1
Textype	2	0	1	0
No. 2	2	0	0	0
Roman	1	0	4	1
Classic	1	0	2	1
Modern	1	0	1	0
Cheltenham	1	0	2	0
Antique	0	0	5	3
De Vinne	0	0	4	2
Bodoni	0	0	1	1
Opticon	0	5	0	6
Paragon	0	2	0	1
Corona	0	2	0	2
Linotype 2	0	1	0	1
Mergenthaler 2	0	2	0	1
Intertype 655	0	1	0	1
Spartan	0	0	0	1

TABLE 12.2—Type Sizes Used by U.S. Newspapers

Size of Type	Times Used on Front Page		Times Used on Editorial Page	
	1935	1942	1935	1942
12	0	0	4	2
10	0	0	23	29
9½	0	0	0	1
9	0	0	10	12
8½	1	2	0	3
8	17	30	32	28
7¾	0	1	0	0
7½	16	20	3	3
7	45	31	16	9
6¾	6	3	1	0
6½	4	0	0	0

Regal. (b) The same type faces, plus Century, were most popular on the editorial page. In all, 22 different body types were employed for printing on the front and editorial pages. (c) Ionic and Ideal type faces were used by 25 per cent fewer papers in 1942 than in 1935. Excelsior and Regal were used more frequently in 1942. Among the new type faces, Opticon appeared most frequently.

Size of Type. Data for use of type sizes employed by the newspapers are given in Table 12.2.

This table reveals the following trends: (a) On the front page the most frequently used type sizes were 7, 7½, and 8 point; on the editorial page, 7, 8, 9, and 10 point. (b) There was a trend toward use of larger type sizes in 1942. On the front page the most prominent shift was from 7 to 8 point, although 7 point was still used most frequently. On the editorial page the shift was away from 7 and 8 point toward 9 and 10-point type. However, 8 and 10 point were the most frequently used both in 1935 and 1942.

Line Width. Line widths used on the front page were concentrated at a 12-pica width, with 12½-pica width a poor second. On the editorial page, the line widths were concentrated at 12, 15, 16, 18, and 24½ picas, with 16 and 18 picas most popular. From 1935 to 1942 there was no important change in line width on the front page. On the editorial pages, 15 and 15½-pica lines were used more frequently and 12, 16, and 24½-pica lines less frequently in 1942.

Leading. On the front page, the amounts of leading most frequently used were 1, ½, 0, and 2 point in that order. One-point leading was most popular (about one-third used it). The editorial page used mostly 1 or 2-point leading. From 1935 to 1942 there were only slight changes in use of leading. One-point leading was still the favorite on page one in 1942, and 2 point on the editorial page.

The general trends in newspaper printing from 1935 to 1942 were: (a) a considerable change in type faces, (b) a tendency to use larger type sizes, (c) little change in line widths, and (d) only slight changes in leading.

Legibility of Newspaper Type Faces

As shown in the preceding section, a variety of type faces is used for body type in the printing of newspapers. Nine newspaper type faces, some relatively new, were investigated for relative legibility by Tinker and Paterson (157). They were Ionic No. 5, Ideal, Excelsior, Regal No. 1, Century Expanded, Textype, Ionic No. 2, Paragon, and Opticon. Samples are presented in Figure 12.1. The speed-of-reading technique was used with 900 college students as subjects. All test material was printed in 7-point type set solid in a 12-pica line width on newsprint paper stock. The Ionic No. 5 face was used as a standard. Speed of reading material set in each of the 9 type faces was compared with speed of reading

Standard: Ionic No. 5

11. When my mother saw the marks of muddy shoes on the floor, and all over the n ce clean be s, she was surprised to see how careful the children had been. 12. When the little boy

Paragon

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor liv-

Control: Ionic No. 5

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Excelsior No. 2

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Opticon

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Ideal

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Regal No. 1

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Ionic No 2

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living

Century Expanded

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living in a city

Textype

11. Frank had been expecting a letter from his brother for several days; so as soon as he found it on the kitchen table he ate it as quickly as possible. 12. A certain doctor living in a city near here

FIG. 12.1—Samples of styles of newspaper type. All copy is set in 7-point solid, 12 picas wide.

material set in the standard Ionic No. 5. The results are presented in Table 12.3.

The entries in Table 12.3 have been arranged in order from the type face showing the greatest difference from the standard Ionic No. 5 to the one showing the least difference. It will be noted that the four most legible type faces are

TABLE 12.3—Legibility of Newspaper Type Faces

Type Face Compared With Ionic No. 5 Standard	Differences From Standard in		Diff. / P.E. Diff.
	Paragraphs	Per Cent	
Ionic No. 5 (control)	0.00	0.0	0.00
Opticon	+1.08	+7.8	7.49
Regal No. 1	+0.90	+6.4	6.36
Century Expanded	+0.83	+6.1	5.33
Paragon	+0.80	+5.6	5.84
Excelsior	+0.76	+5.3	5.11
Ideal	+0.66	+4.6	4.96
Ionic No. 2	+0.54	+3.9	3.79
Textype	+0.30	+2.2	1.74*

* All differences except the last one are significant at the 1 per cent level. Plus signifies greater legibility than the standard. In certain tables from here on the critical ratio is given. This is either the difference divided by the probable error of the difference, or difference divided by the standard error of the difference. For the former, a ratio of 3.3 or greater indicates significance at the 1 per cent level; a ratio of 2.5 to 3.2 significance between the 2 and 5 per cent levels. For the latter, a ratio of 2.2 or greater indicates significance at the 1 per cent level; a ratio of 1.7 to 2.1 significance between the 2 and 5 per cent levels.

Opticon, Regal No. 1, Century Expanded, and Paragon. Excelsior is nearly as good. Ideal and Ionic No. 2 are slightly less legible but still significantly more so than the standard. Textype and Ionic No. 5 are not significantly different from each other in legibility, and stand at the bottom of the list. In general, Opticon and Regal No. 1 appear to have outstanding legibility. Textype and Ionic No. 5 have relatively poor legibility.

Leading

The use of some leading is rather common newspaper practice. For body type, the amount of leading employed in 1942 (159) ranged from ¼ to 2½ points with ½, 1, and 2 points most popular. Fourteen of the 89 newspapers used no leading.

The main purpose of using leading is to improve the

TABLE 12.4—Influence of Leading on Legibility of Newspaper Type

Amount of Leading Compared With Set Solid Standard	Differences From Standard in Paragraphs	Differences From Standard in Per Cent	Diff. / P.E. Diff.
Set Solid (control)	0.00	0.00	0.00
1-pt. leading	+0.52‡	+3.52	2.83†
2-pt. leading	+0.18	+1.20	1.35
3-pt. leading	+0.41	+2.74	2.30
4-pt. leading	+0.73	+4.82	4.36*
5-pt. leading	+0.63	+4.31	3.37*
7-pt. leading	+0.42	+2.76	2.87†
9-pt. leading	+0.32	+2.08	1.76

* Significant at the 1 per cent level.
† Significant between the 2 and 5 per cent levels.
‡ Plus signifies more legible than standard.

legibility of the textual material. Paterson and Tinker (86) investigated the influence of 0, 1, 2, 3, 4, 5, 7, and 9-point leading on the legibility of 7-point Ionic No. 5 newspaper type face set in a 12½-pica line width on newspaper stock. Their speed-of-reading technique was used with 680 university students as readers. The speed of reading each set of material with a different amount of leading was compared with speed of reading the standard set solid. The results are given in Table 12.4.

Inspection of the data shows the following: (a) All material with leading was read faster than text set solid. (b) The largest and most significant differences were for the text in 4 and 5-point leading. (c) One-point leading improved legiblity as much as larger amounts except for the 4 and 5 point.

Reader Opinions. Samples of the printed materials with different amounts of leading were ranked for relative legibility by 221 subjects. The results are presented in Table 12.5. Text with 4 and 5-point leading was judged to be most legible. This agrees with the speed-of-reading results. The

TABLE 12.5—Effect of Leading on Legibility of Newsprint According to Reader Opinions

Leading	Mean Rank	Rank Order
Set solid	7.31	8
1 point	5.95	7
2 point	4.57	5
3 point	3.30	3
4 point	2.96	1.5
5 point	2.97	1.5
7 point	4.01	4
9 point	4.87	6

material set solid was judged to be least legible. This shows that readers prefer some leading.

The fact that 1 point or more of leading improves legibility of newsprint and that readers prefer some leading over set solid has practical implications. One point (or more) leading is indicated for 7-point newspaper type with 12½-pica line width. This would also hold for a 12-pica line since variations in line widths from 12 to 12½ to 13 picas do not significantly affect legibility of newspaper type (86).

Line Width and Leading

The survey of newspaper printing practice cited above showed that (a) Excelsior type face was more than holding its own over a period of years; (b) the use of 8-point type was rapidly increasing; (c) use of a 12-pica line width was almost universal on the front page, although a 24-pica line was often used on the editorial page; and (d) ½, 1, and 2-point leading were most common. This led Tinker and Paterson (161) to use the variables shown in Table 12.6 in their study of the effect of line width and leading on the legibility of newspaper type. Their speed-of-reading method was used with 2016 subjects. Speed of reading material in each of the 24 typographical arrangements listed in Table

TABLE 12.6—Influence of Line Width and Leading on Legibility of 8-Point Newspaper Type

Line Width	Set Solid	½-Point Leading	1-Point Leading	2-Point Leading
6	−10.5	−10.0	−7.9	−9.7
12	+ 0.3	− 0.4	+0.4	0.0
18	+ 0.3	− 0.3	+3.1	+2.9
24	− 5.1	− 4.2	−2.1	−4.3
30	− 2.1	− 3.3	−4.6	−0.3
36	− 5.3	− 3.5	−3.1	−1.6

Plus signifies better legibility than the standard and minus signifies poorer legibility than the standard. All differences of 2.6 per cent or greater are statistically significant.

12.6 was *compared with the standard set in a 12-pica line width with 2-point leading.* The differences are given in percentages. All material was printed in 8-point Excelsior newspaper type on newspaper stock.

Examination of the data reveals the following trends: (a) When 8-point newspaper type is set in a 6-pica line width, there is a marked loss of legibility irrespective of leading. (b) With a 12-pica line width, leading has no effect on legibility for this 8-point type. (c) One and 2-point leading improves legibility of 8-point newspaper type in an 18-pica line width by about 3 per cent. (d) For the 24-pica line width, printed material is less legible than the standard whether there is leading or not. (e) Text in the 30 and 36-pica line widths when set solid, or with a ½ or 1-point leading, is less legible than the standard. With 2-point leading the legibility is about the same as that of the standard. (f) The result for the 24-pica line width with 2-point leading reveals a discrepancy that could not be accounted for. (g) In general, satisfactory legibility is achieved for 8-point newspaper type in line widths of 12 and 18 (presumably 12 to 18) picas, and the 18-pica line width with 1 or 2-point leading is best of all. (h) Readers judged text with generous amounts of leading to be more legible and to be more pleasing for each width of line considered. Therefore, when a 12 or 12½-pica line width is selected for 8-point type, 1 or 2-point leading should be used. This will coincide with readers' preferences.

Size of Type

There has been relatively little investigation of size of type as such for newsprint. However, some of the data discussed in Chapters 5 and 7 are relevant: (a) Material in 6 and 8 point in a 19-pica line width is less legible than text in 10 point. (b) Material in an 8-point type and 19-pica line width is less legible than text in 9 and 10-point type. (c) Material set in 8-point type in a 19-pica line width with 2-point leading is as legible as text in 10 point set solid. (d) Material in 6 and 8-point type with optimal leading and line width is less legible than text in 9 to 12-point type in optimal typographical arrangements.

Newsprint Versus Book Print. It has already been mentioned that a reader makes a rapid adaptation to reading newsprint after reading materials in larger type sizes in magazines and books. The question naturally arises whether or not newsprint is less legible than book print. The Paterson and Tinker survey of newspaper printing practice cited above revealed that the most frequently used type sizes in newspaper printing were 7 and 8 point. They also found (Chapter 5) that 10-point type was popular for book printing.

An experiment (85) was conducted to investigate the relative legibility of 10-point Cheltenham book type set in a 19-pica line width with 2-point leading on eggshell paper stock, and (a) 8-point Opticon newsprint set in a 12-pica line width with 1-point leading, and (b) 7-point

Cheltenham Book Type:
10 point with two point leading

26. James fountain pen went dry when he was doing his homework for school. He was very cross because until he got some more glue he could not continue his work. 27. The boys saw coming towards them an old woman, bent with sorrow, dressed in deepest black. They thought, turning from their play to watch her pass, how happy she looked. 28. On

Opticon Newsprint:
8 point with one point leading

26. James' fountain pen went dry when he was doing his homework for school. He was very cross because until he got some more glue he could not continue his work. 27. The boys saw coming towards them an old woman, bent with sorrow, dressed in deepest black. They thought, turning from their play to watch her pass, how happy she looked. 28. On

Ionic No. 5 Newsprint:
7 point with one point leading

26. James' fountain pen went dry when he was doing his homework for school. He was very cross because until he got some more glue he could not continue his work. 27. The boys saw coming towards them an old woman, bent with sorrow, dressed in deepest black. They thought, turning from their play to watch her pass, how happy she looked. 28. On Sunday Mr.

FIG. 12.2—Samples of book type and newsprint type used in study of relative legibility.

TABLE 12.7—Legibility of Newsprint Versus Book Print

Standard 10-Pt. Cheltenham Compared With:	Differences in Paragraphs	Differences in Per Cent	Diff. / P.E. Diff.
10-pt. Cheltenham (control) ..	0.00	0.00	0.00
8-point Opticon	—0.92†	—4.27	5.37*
7-pt. Ionic No. 5	—1.01	—4.79	5.90*

* Significant at the 1 per cent level.
† Minus signifies less legible than the standard book type.

Ionic No. 5 newsprint set in a 12-pica line width with 1-point leading, both on newsprint paper stock. The appearance of these types is given in Figure 12.2. These typographical arrangements are optimal for each of the type sizes used. The book print served as a standard and each of the two newspaper setups was compared with it. The Tinker-Paterson speed-of-reading method was used with 270 readers. The results of the comparisons are given in Table 12.7. The evidence in the table shows that the newsprint in both 7 and 8-point type is significantly less legible than the 10-point book type.

Reader Opinions. Samples of the three typographical arrangements were judged for relative legibility and for

TABLE 12.8—Reader Opinions of Relative Legibility and Pleasingness of Newsprint and Book Type

Kind of Type	Average Rank	Rank Order
Opinions of Relative Legibility		
10-pt. book type	1.65	1
8-pt. newsprint	1.68	2
7-pt. newsprint	2.68	3
Opinions of Pleasingness		
10-pt. book type	1.47	1
8-pt. newsprint	1.70	2
7-pt. newsprint	2.83	3

pleasingness by 117 readers. The results of the judgments are given in Table 12.8.

Examination of the data reveals that the ranking for legibility was 10-point book type, 8-point newsprint, and 7-point newsprint. Note that the average ranks of the book type and 8-point newsprint are approximately the same, but that the 7-point newsprint is definitely less preferred. The rankings for pleasingness show the same rank order as for legibility, but there is a greater separation between average ranks.

Again the 7-point newsprint is definitely less pleasing than the others. As has been noted before, pleasingness tends to agree with judged legibility; in this study, both judged legibility and pleasingness tend to agree with the measurement of legibility.

The lesser legibility of the newsprint in comparison to the book type is apparently due to two factors: (a) the smaller size of the newsprint, and (b) the smaller degree of brightness contrast between print and paper for the newsprint. Both of these factors make it more difficult for the reader to discriminate the printed characters in the newsprint.

Size of Type, Leading, and Context. Hovde (36, 37) attempted to measure the influence of type size, leading, and context on legibility of Intertype Ideal News Face Type. Sixteen combinations of type size and leading were used. The type size varied from 6 to 8 point by steps of 1/4 or 1/2 point. The leading varied from none to 1 point by 1/4-point steps. *Normal* rate of reading was used. The 16 samples of reading material were *estimated* to be of equal difficulty and of the same level of continuous interest. The 300 readers employed were also asked which arrangement appeared easiest to read. The readers were divided into three groups: Group A read the selections in one (random) order, and Groups B and C read the materials in a reverse order. Scores were in words read per minute for each selection.

The general conclusions reached by Hovde were as follows: (a) Context is a more important factor in determining legibility than type size and leading when rate of reading is used as a criterion of legibility. (b) Readers preferred the larger type sizes and the material with the greatest amounts of leading.

The validity of the author's conclusions concerning legibility may be questioned. Several requirements of a good experimental design were not fulfilled: (a) The samples of reading material were not equated for difficulty. (b) A normal rate of reading which he used will not yield consistent differences even when significant differences in legibility are present. The emphasis in the instructions directed the attention of the readers toward meaning and away from speed. (c) The statistical treatment of the data may be questioned, especially the interpretations of the obtained correlations. Furthermore, Hovde speaks of correlation coefficients as percentages, which is erroneous.

Simultaneous Variation of Type Size, Line Width, and Leading. A comprehensive study of the effect of simultaneous variation of size of type, width of line, and leading on legibility of newspaper type was completed by Tinker and Paterson (160). Their speed-of-reading technique was employed with 820 readers.

All materials were printed in Excelsior newspaper type face on newspaper stock. The standard was set in 8-point type with 2-point leading in a 12-pica line width. Speed of reading material in each typographical arrangement was compared with speed of reading material in the standard, optimal, 8-point newsprint arrangement. The typographical arrangements and the results of the comparisons are given in Table 12.9.

TABLE 12.9—Type Size, Line Width, and Leading for Newspaper Type

Typographical Setup Compared with Standard	Differences in Paragraphs	Differences in Per Cent	Diff. / P.E. Diff.
8 pt., 12 pica, 2-pt. leading....	0.00	0.00	0.00
9 pt., 12 pica, 2-pt. leading....	—0.27*	— 1.90	1.78
9 pt., 18 pica, 2-pt. leading....	—0.37	— 2.65	2.17
9 pt., 43 pica, set solid	—2.02	—14.40	12.50†
8 pt., 18 pica, 2-pt. leading....	—0.89	— 6.13	5.63†
7 pt., 6 pica, set solid	—1.41	— 9.80	8.90†
7 pt., 12 pica, 1-pt. leading....	—0.27	— 1.93	1.97
7 pt., 12 pica, 2-pt. leading....	—0.01	— 0.07	0.06
6 pt., 6 pica, set solid	—1.78	—12.54	11.59†
6 pt., 12 pica, 2-pt. leading....	—0.98	— 6.53	5.39†

* Minus signifies less legible than the standard. The first item constitutes the control group.

† Significant at the 1 per cent level.

The results may be summarized as follows:

1. *Typographical arrangements of equal legibility*:

   8 point, 12 pica, 2-point leading
   9 point, 12 pica, 2-point leading
   9 point, 18 pica, 2-point leading
   7 point, 12 pica, 1-point leading
   7 point, 12 pica, 2-point leading

2. *Typographical arrangements significantly less legible than the standard set in 8 point, 12 pica, 2-point leading*:

   9 point, 43 pica, set solid
   8 point, 18 pica, 2-point leading
   7 point, 6 pica, set solid
   6 point, 6 pica, set solid
   6 point, 12 pica, 2-point leading

Reader Preferences. Samples of the 10 typographical arrangements were ranked according to judged legibility and pleasingness. The resulting rank orders are listed in Table 12.10.

TABLE 12.10—Judged Legibility and Pleasingness of Ten Typographical Arrangements of Newspaper Type

Typographical Arrangement	Judged Legibility Average Rank	Judged Legibility Rank Order	Opinions of Pleasingness Average Rank	Opinions of Pleasingness Rank Order
8 pt., 12 pica, 2-pt. leading	3.43	3	2.98	3
9 pt., 12 pica, 2-pt. leading	2.62	2	2.66	1.5
9 pt., 18 pica, 2-pt. leading	2.25	1	2.66	1.5
9 pt., 43 pica, solid	6.31	7	6.87	7
8 pt., 18 pica, 2-pt. leading	3.36	4	3.44	4
7 pt., 6 pica, solid	8.60	9	8.79	9
7 pt., 12 pica, 1-pt. leading	6.21	6	5.92	6
7 pt., 12 pica, 2-pt. leading	5.17	5	4.73	5
6 pt., 6 pica, solid	9.60	10	9.76	10
6 pt., 12 pica, 2-pt. leading	7.55	8	7.20	8

The order of judged legibility followed quite well the speed-of-reading data. The three arrangements judged most legible (ranks 1, 2, 3) were among the ones read most rapidly and equally fast. Also, the setups judged least legible were three which significantly retarded speed of reading. In the same table, the rank order for pleasingness is almost identical with the rank order for judged legibility. Examination of the typographical arrangements most preferred indicates that the choices are probably made in terms of type size, leading, and line width. Readers like the larger type sizes, generous (2 point) leading and moderate line widths.

The data on legibility and readers' opinions provide the newspaper publisher with valuable practical information. If the editor wishes to cater to reader preferences and at the same time maintain satisfactory legibility, he will print his newspaper in 8 or 9-point type in a line width of 12 or 12½ picas with 2-point leading. Although the 7-point type in a 12-pica line width with 1 or 2-point leading is also as legible as the typographical arrangements listed just above, the 7-point type is not liked nearly as well.

Newspaper Headlines

The problem of whether to publish newspaper headlines in all-capital letters or in lower-case type has been argued by newspaper men, editors, and psychologists. After Tinker and Paterson (147) demonstrated that the reading of continuous text in all capitals was about 12 per cent slower than text in lower case, it was argued that this finding did not apply to newspaper headlines. Solution of the problem awaited experimentation.

Single-Column Headlines. Breland and Breland (16) compared the legibility of single-column newspaper headlines printed in capitals and in lower case, where the initial letters of the important words were the only ones capitalized. The materials consisted of 120 five-word newspaper headlines of uniform length and type face taken from *The New York Times.* The single-column headlines were printed in 24-point Cheltenham boldface extra-condensed type in two lines on regular newspaper stock. Each of the 120 headlines was printed twice, once in capitals and once in lower case. They were mounted on cardboard of proper size to be exposed singly for short controlled periods of time, i.e., 1/20 second. The distance of the exposed headlines from a subject's eyes was 15 inches. The order of presenting the capitals and lower-case headlines was counterbalanced to control practice effects. For 22 subjects there was an 18.9 per cent loss in legibility in reading the all capital versus lower-case headlines.

Paterson and Tinker (84) report a study from Warren's thesis of single-column headlines read during a brief exposure of about 1/5 second, at a distance of 5½ feet. This is about the distance one encounters in reading a headline over someone else's shoulder or across a breakfast table. The same headlines in capitals and in lower case used by Breland

and Breland were employed in the new study, and the headlines were exposed by the same apparatus. Only the time of exposure and distance from the subject were different. There were 40 subjects.

Under the conditions of the experiment, the lower case and the all-capital headlines were equally legible. The percentage difference was only 0.3 per cent. Therefore, from the viewpoint of the headline writer, neither kind of headline seemed to have any advantage over the other when viewed 5½ feet away.

Banner Newspaper Headlines. In the second part of the Warren study cited above, the relative legibility of capitals versus lower-case printing of multi-column or banner headlines was determined. One hundred headlines selected from old issues of Minneapolis papers were printed directly on 28 by 7¼-inch white cardboard in 60-point Memphis Boldface type, 50 in all capitals and 50 in lower case. There were five words in each headline. A counterbalanced design was used to equate practice effects. Exposure time was 1 second. A group testing method was employed. Subjects sat 6 feet, 2 inches, to 17 feet, 1 inch, from the exposure frame. The total number of subjects was 46 seated in 4 rows in the classroom. In Table 12.11 each comparison is the score for lower case versus the score for upper case (capitals).

TABLE 12.11—Legibility of Banner Headlines: Lower Case Versus Upper Case

Row	Distance to Exposure Stand		Number of	Differences
	Center	End of Row	Readers	in Per Cent
1	6′2″	7′11″	12	— 5.3*
2	9′10″	10′9″	12	+ 2.6
3	13′4″	13′8″	10	+ 4.8
4	16′10″	17′1″	12	+19.8*

* Statistically significant. Minus signifies poorer legibility for upper-case printing.

The results show that the lower-case headlines were significantly more legible than the upper case at the first-row distance of 6 feet, 2 inches, to 7 feet, 11 inches. This is about the distance from which one would glimpse a headline in everyday life, as on a bus or when passing a newsstand. It is likely that newspaper publishers do not expect their banner headlines to be read at distances much beyond 7 feet.

The results of Warren's study are not in conflict with those cited above. The Breland and Breland study revealed a striking superiority of single-column lower-case headlines over upper-case headlines when perceived at the *normal reading distance* of 15 inches. These same headlines were equally effective in both upper case and lower-case type when glimpsed at a distance of 5½ feet. But one should keep in mind that single-column headlines are not intended to be read at such a distance. In the second part of her study, Warren again found that the legibility of lower-case banner headlines was superior when read at a distance of 6 to 7 feet, which is about the maximum distance at which banner headlines are expected to be read. Therefore, in situations where single or multiple-column headlines are supposed to be read, it is clear that lower-case headlines are distinctly superior to upper-case headlines.

Mean scores for subjects sitting in rows 2 and 3 are slightly in favor of upper-case printing, but the differences are not statistically significant. In row 4, the mean score for the upper-case headlines is significantly greater than for lower-case headlines. The mean scores (not shown in the table) decreased consistently from row 1 to row 2 to row 3 to row 4. In other words, the greater the distance, the more difficult it was to read the headlines. Particularly at the 17-foot distance, the subjects were forced to pick out a word here and there during the 1-second exposure. It is doubtful if banner headlines are intended to be read at such a great distance. As shown by Tinker (115), capital letters of the same *point size* are perceived at a greater distance than lower-case letters. At the 16 to 17-foot distance the readers were able to identify enough of the upper-case letters during the relatively long exposure time of 1 second to pick out a few more words than from the lower-case headlines. At 16 to 17 feet, both upper and lower-case letters are difficult to identify, as shown by the low scores by subjects in row 4. Because capital letters are larger, they were somewhat easier to identify. The conclusion indicated by the above studies is that single and multiple-column newspaper headlines, in those situations where they are meant to be read, are more legible when printed in lower-case type.

Additional Evidence. English (24) reports an investigation of the legibility of four newspaper headline types. Materials were set in three line, single-column headlines in 14, 24, and 30-point type on newsprint paper stock. Bodoni, Karnak, and Tempo type faces were used in upper and in lower-case settings. A carefully organized experimental design permitted adequate controls and an accurate estimation of the effect of various factors. There were 45 subjects for the legibility study, and 50 for the reader preferences. The printed material was exposed at 14 inches from the reader for 450 milliseconds, i.e., just short of ½ second.

The average number of words read for each design of type face was: Bodoni, 5.18; Karnak, 4.33; and Tempo, 5.38. The difference between the Bodoni and Tempo scores was not statistically significant, but the differences between Karnak and each of the other two faces were significant. In other words, Bodoni and Tempo type designs were equally legible, and both were more legible than Karnak.

Statistical analysis indicated that variation in type size had no noteworthy effect on the speed of reading the headlines.

In another part of the study, the average number of words read set in Cheltenham upper case, regular lower case, and condensed lower case was: all capitals, 433; regular lower case, 522; and condensed lower case, 511. The legibility of the varieties of lower case was significantly greater than for the all capitals. The differences amounted to 15 to 18 per cent. These findings are comparable to the 18.9 per cent differential found by Breland and Breland cited above.

The proportion of times that Karnak was preferred to Tempo type face was not significant, but for Tempo over Bodoni it was significant. The mean proportions were: Karnak .57; Tempo .56; and Bodoni .37. Reader preferences were considered not to be a reliable index of legibility.

Interpretations. The results consistently show that newspaper headlines read at customary distances from the eyes are significantly more legible printed in lower case than in all capitals. At least three reasons for the superior legibility of the lower-case print may be mentioned:

1. The printing surface required for upper-case headlines is much greater than for the same headlines set in lower case in the same point size. For instance, a 60-point banner headline is 37.5 per cent longer when set in upper case than when set in lower case. Hence, more fixation pauses per headline are required to read the upper-case printing.

2. The word form is far more characteristic when words are printed in lower case than when they are printed in all capitals. See Figure 4.2 in Chapter 4 and the accompanying discussion of word form as a factor in legibility. In addition, one should note that the upper half of a printed line furnishes more clues to word form when set in lower case than when set in all capitals. This is shown in Figure 12.3.

3. Reading habits favor lower case since practically all our reading is devoted to material printed in lower case rather than in upper case.

FIG. 12.3—This illustrates that the upper half of a printed line furnishes more clues to "word form" when printed in lower case.

It seems perfectly clear, if one is concerned with maintaining satisfactory legibility, that upper case should be abandoned except for an occasional use to attract attention through novelty. Even in billboard posters and highway-sign printing designed to be read at a distance, it would be preferable to rely on lower case rather than on capitals. This is not contrary to the data cited above as long as the point size of the lower case is increased. In the cited experiments, the lower case and the upper-case printing was in the same type point size. The printer can increase the point size of lower case by a considerable amount and still not use more horizontal space than upper-case letters would occupy. Furthermore, with lower-case printing, the word form clues would aid quicker perception of the words. In fact, it is difficult to think of a single situation in which display words or messages would not be more quickly and easily recognized than when printed in lower case.

Mixed Type Forms. Data from the Tinker and Paterson study (162) cited in Chapter 4 are relevant here also. Both medley arrangements of regular lower-case type, italics, all capitals, boldface type, etc., significantly retarded speed of reading. The regular lower-case printing was judged to be more legible than either medley arrangement.

Reductions in Size of Newspaper Print

The preservation of newspaper accounts of historical events has become a serious problem, due to the rapid deterioration of ordinary newsprint paper stock and limitation of filing space in libraries. To what degree can ordinary newspaper print be reduced in size on more durable paper stock without undue loss of legibility? One of the most effective methods of reproducing newspaper material is the planographic offset printing process. Tinker and Paterson (151) determined the loss in legibility which occurred when this offset printing process was employed to reduce newsprint. Their speed-of-reading technique was employed with 360 readers. Examples were set in Ionic newspaper type and were reproduced in the original size, and in 80, 50, and 30 per cent of original size by the planographic offset printing process. Speed of reading print in each reduction was compared with the original size which was 6¾ point on 7-point body in a 12½-pica line width. The results are given in Table 12.12.

The results indicate that newsprint may be reduced to 80 per cent of original size by the planographic process without

TABLE 12.12—Effect of Reducing Size of Newspaper Type

Standard Compared With:	Differences in Paragraphs	Differences in Per Cent	$\frac{\text{Diff.}}{\text{P.E. Diff.}}$
Same size (control)	0.00	0.00	0.00
Reduced to 80 per cent	− 0.30*	− 1.95	1.76
Reduced to 50 per cent	− 2.01	−12.33	12.56†
Reduced to 30 per cent	−11.19	−74.25	53.29†

* Minus signifies less legible than the standard (full size).
† Significant at the 1 per cent level.

significant loss of legibility. When reduced to 50 per cent of original size, there is a 12.33 per cent loss in legibility which is statistically significant. The material reduced to 30 per cent of the original was almost impossible to read. There was a 74.25 per cent loss in legibility. From the practical point of view, reductions of newspaper type should not exceed about 50 per cent. Although the material reduced 50 per cent is read about 12 per cent slower, it can still be read. On the average, the subjects read 13.71 paragraphs, or 411 words in 1¾ minutes. The reading of materials of this size is a difficult but not an impossible task. However, it is likely that a few hours of reading such material without use of some magnifying equipment would lead to severe eyestrain.

Summary

1. Special attention needs to be directed to certain aspects of newspaper printing that are not met in book and journal printing.

2. A large variety of type faces are used for body type in newspaper printing practice. In 1935 to 1942 the most popular body types were Ionic, Ideal, Excelsior, Regal, and Opticon. The most frequently employed type sizes were 7, 7½, and 8 point. A line width of 12 picas was most often used. The leading commonly used was 1, ½, 0, and 2 point, in that order.

3. The legibility of commonly used type faces varies considerably. Textype and Ionic No. 5 were found to be significantly less legible than eight other body type faces.

4. Leading improves the legibility of 7-point newspaper type. Although readers prefer 4 or 5 points of leading, from the practical viewpoint 1 or 2 points are satisfactory for 7-point type in a 12 to 13-pica line width. Readers dislike material set solid.

5. Leading has no effect on the legibility of 8-point type in a 12-pica line width, but 1 or 2-point leading improves legibility of this 8-point print in an 18-pica line width. Leading has little if any effect on the legibility of long (30 to 36 pica) or very short (6 pica) line widths printed in 8-point newspaper type.

6. Both 7 and 8-point newspaper print in optimal line widths and leading are significantly less legible than 10-point book type in an optimal typographical arrangement.

7. Seven, 8, and 9-point newspaper type in optimal line width and leading are equally legible.

8. Readers prefer 10-point book print over newspaper print and consider it more pleasing. They prefer, and consider more pleasing, 8 and 9-point type with 2-point leading in a 12-pica line width over practically all other typographical arrangements of newsprint. The one exception is 9-point type in an 18-pica line width with 2-point leading. Eight-point type in an 18-pica line width with 2-point leading, and 7-point type in a 12-pica line width with 2-point leading are preferred next. Six-point type and both very short and very long lines are much disliked.

9. From a practical viewpoint, newsprint set in 8 or 9-point type in a 12 or 12½-pica line width with 2-point leading will maintain a high level of legibility and satisfy reader preferences.

10. Single-column headlines at the normal reading distance of about 15 inches from the eyes, and banner headlines read at 6 to 8 feet away are significantly more legible printed in lower-case type than in upper case (all capitals).

The primary factor involved in the greater legibility of the lower-case headline type is the characteristic word forms which provide clues to easy and quick perception of words as units. These clues are almost entirely absent in all-capital printing.

11. Type faces used to print newspaper headlines vary in legibility. Bodoni and Tempo are equally good and significantly more legible than Karnak.

12. Newsprint can be reduced in size by the planographic offset process to only about 80 per cent of the original without serious loss of legibility.

13. Any considerable tendency to use a medley arrangement of type forms within paragraphs in newspaper printing significantly reduces legibility.

13. Formulas and Mathematical Tables

THE READING OF FORMULAS and mathematical tables presents certain unique problems of legibility beyond the simple application of the research results on legibility of digits which were discussed in Chapter 3. Some opinions derived from casual observation have been presented during the years since 1827. Before summarizing these, certain questions may be raised concerning the legibility of numbers, formulas, and mathematical tables.

Are numbers or words read more efficiently in mathematical problems? Do the size and position of exponents and subscripts affect reading proficiency? Are numerals and formulas read as combined units, or is each symbol read as a separate item? Are Old Style or Modern digits more legible? What is the relative legibility of mathematical signs? What is the relative legibility of Roman and Arabic digits? What is the effect of size on the legibility of numbers used in mathematical tables? What is the effect of varying the spacing and rules in mathematical tables? What is the effect of paper quality on the legibility of tables?

Charles Babbage, writing in 1827 (Tinker, 137), expressed a preference for numerals of uniform height (Modern) rather than those with ascenders and descenders (Old Style). In a report (215) of the Committee on Type Faces, it is recommended on the basis of collected opinions that: (a) Modern or modernized Old Style numerals (without ascenders and descenders) be used in mathematical tables; (b) type size should be up to 8 point; (c) there should be adequate space between lines; and (d) these extra spaces should be inserted after every fifth row. Milne (211) considered the Old Style numerical symbols, in which many of the characters have heads and tails, to be more legible than those of uniform height (Modern).

At this point, the reader should review the material on legibility of digits presented in Chapter 3. The relevant highlights may be restated briefly here. (a) In the practical reading situation, as when grouped in context of a mathematical problem or in mathematical tables, Modern (all the same height) and Old Style (with ascenders and descenders) numerals are both read with the same accuracy and speed, i.e., they are equally legible. (b) Arabic numerals are read significantly faster and much more accurately than Roman numerals.

Reading Numerals in Problems

Reading of several digits in a group is a more severe visual task than reading words. Terry (106) found that during a first reading (or skimming) of a problem, numerals were only partially read but on the second analytical reading, up to 5 fixation pauses were employed to read a 7-digit numeral. In general, with adult readers, less than half as many digits as letters (in words) were perceived during one fixation pause. The average pause duration for numerals was 40 per cent greater than that for words, and the per cent of regression fixations was greater for numerals than for words. The author attributed the greater difficulty in perceiving numerals to the fact that words are read as familiar wholes while numerals are perceived digit by digit.

The eye-movement records revealed that isolated numerals, placed either in rows or columns, were invariably grouped to some degree as they were read either silently or aloud. One-digit sub-groupings appeared more frequently in 1, 3, and 7-digit numerals. Two and 3-digit sub-groupings tended to appear in reading numerals of greater length. It seems that numerals are more difficult to read than words because each digit must be identified and related to the other digits in the numeral. The eye-movement records suggest that the ordinary straightforward progress in reading breaks down when a numeral of more than 1 or 2 digits is encountered in context.

Numerals Versus Words for Efficiency in Reading. In view of the above results, the question arises whether numerals in the form of printed words or as Arabic digits in the context of arithmetical problems yield greater reading efficiency. Eye movements were recorded by Tinker (108) to obtain an answer to this question. Four simple arithmetical problems were set up. In two of the problems the numerals were printed as Arabic digits, and in two problems as words. A counterbalanced order was used to control practice effects and differences in difficulty. Four subjects were used in Part 1 in which the eye movements were photographed, and 40 in Part 2 of the experiment in which the eye movements were counted by direct observation. In Part 1 the problems with Arabic numerals were read on the average with 22.0 per cent fewer fixations, 2 per cent fewer regressions, 20.4 per cent longer pause duration, and 11.7 per cent less perception time. In Part 2 the problems with Arabic numerals were read with 22.6 per cent fewer fixations and with 22.7 per cent less time. The results in the two parts of the experiment are in close agreement. The problems with Arabic numerals are read with fewer fixations and a shorter perception or reading time. The results indicate that the compactness achieved by employing numerals rather than words brings about faster reading when other conditions remain constant. This will tend to hold even though, as noted above, numerals ordinarily require more fixations than the accompanying words of the text. For instance, compare the spread of "24942" with "twenty four thousand nine hundred forty two." Short numerals of one or two digits tend to be read with one fixation. Thus "24" could be read with one fixation but "twenty-four" might require two.

Legibility of Mathematical Signs

As part of a larger study, Tinker (111) investigated the relative legibility of mathematical signs. The results are not particularly applicable here because the signs were mixed in with letters and digits. However, it may be worth noting that the more legible signs were: $\bigcirc$, $\bigtriangledown$, $\square$, $=$, and Σ; the less legible ones: π, $\div$, and $\pm$. Characteristic outline and size apparently foster better legibility of the signs.

Reading Formulas

As noted above, digits in numerals tend to be read as separate characters or symbols. Each digit has to be identified and related to the other digits in the numeral. Does a similar thing occur in reading formulas, or is there some tendency toward configuration in reading a formula; i.e., are the characters such as numbers, letters, mathematical signs, and the like organized into larger units of perception than one finds in reading a series of digits in a numeral? Tinker (110) investigated this problem, using a short-exposure technique. The formulas were presented for 1/10 second. There were five subjects. The formulas and equations were cut from an algebra text and mounted on cards for presentation to the subjects. The number of symbols in the formulas ranged from 3 to 15. A total of 305 formulas was employed. The subjects also read series of letters in nonsense arrangement.

The average number of items in formulas perceived correctly was 5.21, and for the letter series only 2.96. The longest formula read correctly had 12 items; the longest letter series had 7 letters, hence the average span for symbols in formulas was nearly double that in the letter series. Mathematical signs which give structure to a formula or equation were perceived more readily than letter and digit symbols. The conclusion is that there is a tendency toward configuration in reading formulas.

Tinker (107) also employed another approach to investigate the reading of mathematical formulas. In any use of formulas and equations, the problem is to set as much material as possible in a given space without sacrificing maximum legibility.

In this investigation an attempt has been made to evaluate the legibility of certain parts of mathematical formulas by comparing the reading time of the digits 1 to 5 and the letters n, m, x, y, and t, when occurring in the body of formulas, with the reading time given them when they occur as exponents and subscripts. These comparisons are designed to throw some light on the relative legibility of the parts considered when the reading is done under approximately normal reading conditions. Seven students with considerable background in mathematics were subjects. The formulas were taken from algebra texts. The apparatus uncovered the stimulus material and left it in view. Then the subject responded by means of a voice key. The time from uncovering until the response was made was recorded on a smoked paper.

Results of the experiment are as follows: (a) In the body of formulas, letters were read slightly faster than digits, but as exponents or subscripts the letters were read slower. This indicates that the legibility of these letters decreases with decrease in size at a greater rate than it does for the digits.

(b) Although digits and letters could be located as quickly when used as exponents or as subscripts, they were recognized more rapidly in the body of the formulas where they were larger. (c) It was found that position as well as size was a factor in the lesser legibility of exponents and subscripts. (d) Parts of fractions were found and read more slowly than symbols all in one line. (e) In general, the main factors affecting legibility of characters in formulas appeared to be size of symbol, alignment of the characters (fractions, exponents, and subscripts), and relative legibility of letters chosen for symbols.

Eye Movements in Reading Formulas. The nature of eye movements in reading algebra formulas and in reading chemical formulas in context was studied by Tinker (109). The results supplement and confirm the data described above. A formula in an algebra problem makes greater demands on the eye than the accompanying text. Such formulas require more fixations, a longer pause duration, more regressions, and a much longer reading time. The trends were similar in reading chemical text which included formulas.

Legibility of Mathematical Tables

Casual inspection of several mathematical tables will reveal great variation in the typographical arrangements employed in use of type size, type face, grouping of numerals down columns, space and rules between columns, and arrangement of column headings. It would seem obvious that some of these factors should influence legibility of the tables. In some tables, economy of space appears to be the sole consideration with no attention devoted to legibility factors. Prior to 1954 there were no reports of experimental data on this subject.

Reports of two investigations are now available. In the first, Tinker (137) determined the relative legibility of five

Table	Columnar Arrangement									
A	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	
B	No.	Square	Cube	Fourth Power	$\frac{1}{\sqrt{N}}$	Square Root	Cube Root	$\frac{1}{N}$		
C	No.	Square	Cube	Square Root	Cube Root	Circum.	Area	No.		
D	No.	Circum.	Area	Square	Cube	Square Root	Cube Root	Reciprocal		
E	No.	$\frac{1000}{\text{No.}}$	Square	Cube	Square Root	Cube Root	Circum. of Circle	Area of Circle		

FIG. 13.1—Arrangements of columns in five mathematical tables.

mathematical tables in terms of the speed with which subjects could find the squares, square roots, and cube roots of numbers. Printed tables were chosen which permitted comparisons between type size, type faces, and arrangements of columns and rows of numerals. The tables were designated A, B, C, D, E. The arrangement of the columns in the tables is given in Figure 13.1. Time to find a square, square root, or cube root was recorded: (a) when a table was open at the beginning and the subject then found the correct page and the item in the table, and (b) when the page on which the item appeared was open before the subject. There were 20 subjects for Part 1, and another 20 for Part 2. The number to be looked up was presented on a 3 by 5-inch card, and the subject found the square, square root, or cube root as quickly as possible. There were 10 numbers for each kind of item for each table. The 10 stimulus numbers included one from each hundred up to a thousand such as 86, 141, 216, 324, 434, 538, 663, 728, 836, and 982. The mean time in seconds to locate the squares, square roots, and cube roots in the five mathematical tables is given in Table 13.1.

When the subject found the correct page as well as the

TABLE 13.1—Time To Find Squares, Square Roots and Cube Roots in Five Mathematical Tables

Table	Square Mean: Sec.	Square Root Mean: Sec.	Cube Root Mean: Sec.
	Subject Finds Page		
A	5.18	5.04	....
B	5.24	5.77	5.20
C	5.52	5.70	5.90
D	6.34	6.43	6.06
E	5.49	6.30	6.06
	Page Given Subject		
A	2.99	2.90	....
B	2.74	2.90	2.77
C	2.74	2.92	2.96
D	3.71	3.50	3.41
E	3.02	3.06	2.90

item (square, etc.), the significant differences between means for the tables were:

Square: D slower than A, B, C, and E.

Square roots: B, C, D, and E slower than A; B and C slower than D.

Cube roots: C, D, and E slower than B.

When given the page, the significant differences between means for the tables were:

Squares: D slower than A, B, C, and E.

Square roots: D slower than A, B, and C.

Cube roots: D slower than B and E.

A brief description of the mathematical tables will facilitate the interpretations.

Table A had a 6 by 9-inch page. Numerals were printed in an 8-point Modern type set solid with successive groups of five entries down the columns separated by 8-point leading. The first column which listed the base numbers was in boldface, and the remaining numerals were in ordinary lightface. Columns were separated by a 1-pica space with no rule. Paper was opaque white with a mat surface.

Table B had a 5¾ by 8½-inch page. The numerals were printed in 8-point Old Style type (ascenders and descenders) set solid with 8-point leading between each group of five entries down a column. The numerals in the first column which lists the base numbers were in boldface and the other entries in ordinary lightface type. There was a ¾ to 1-pica space between columns. The paper was opaque white mat.

Table C had a 3⅞ by 6¾-inch page. The numerals were printed in a 6-point Modern type set solid with a 6-point space after each tenth entry down a column. There was a 1-pica space between columns. The paper was opaque white mat.

Table D had a 3¾ by 6¾-inch page. The numerals were printed in a 6-point Modern type set solid with no grouping of items down the columns, but each fifth item in a column was in a moderately dark boldface. There was a ½ to 1-pica space with a rule between columns. The paper was gray and so thin that print on the reverse side showed through.

Table E had a 4⅛ by 6½-inch page. The numerals were printed in a 6-point Modern type set solid with 6-point leading after each 10 entries down a column. Numerals in the first column which listed the base numbers were in boldface. There was a ½ to 1-pica space with a rule between columns. The paper was thin so that print on the reverse side showed through but not as much as in Table D.

Errors, which were few and inconsistent, need no further consideration. The results when the subject had to find the page show that the print in Table D tended to be most illegible of all and that print in Table A appeared most legible. Print in Tables B and E was less legible than in A.

When the book of mathematical tables was opened at the proper page, the print in Table D proved to be least legible of all.

Considering the typographical arrangements of the tables used, the experimental evidence indicates the following:

a. Old Style and Modern type faces are equally legible.

b. Numerals in 8 point are more legible than those in 6 point.

c. Separation of entries down a column into groups of five or ten items promotes legibility.

d. A 1-pica space between columns seems better than a rule.

e. Paper which is not fairly white and which lacks opacity reduces legibility.

f. Additional suggestions which seem relevant in promoting legibility of mathematical tables include: use of boldface printing in the first column which lists the base numbers, use of opaque white matte paper, and avoidance of an excessive number of columns in a table, such as reciprocals, areas, etc., in addition to squares, square roots, cubes, and cube roots.

There were a number of uncontrolled factors in the above study. In a more carefully designed experiment, Tinker (145) investigated the effect of type size, arrangement of numerals in columns, and space between columns versus space plus rules. Four pages of a mathematical table were printed side by side in a Modern type face on each of the two sides of 70-pound sulphide white mat paper. A 1¼-inch space separated each page from the others. There were 50 entries per column. Print in the column listing the base numbers was boldface, and ordinary print was used in the others. The four pages listed 200 numerals plus squares, square roots, cubes, and cube roots for the numbers 200 to 499. Nine studies were completed during the investigation.

There were 24 to 30 subjects in each study, 246 in all. The time taken to find squares, square roots, cubes, and cube roots was recorded. The comparisons involved in each of the studies follow:

Study 1. Six point versus 8-point type with numerals grouped by fives in columns: The differences were always in favor of the 8-point type but were not statistically significant.

Study 2. Grouping of numerals in columns for 6-point type: The results indicated that grouping both by fives and by tens was more effective than set solid, and the grouping by fives tended to be better than grouping by tens.

Study 3. Grouping of numerals in columns for 8-point type: In general, grouping by fives or by tens was more effective than set solid, with some advantage for the grouping by fives.

Study 4. Space between columns versus space plus rules for 6-point type set solid: No significant differences.

Study 5. Space between columns versus space plus rules for 6-point type grouped by tens: Results were in conflict. Space seemed best in one comparison, space plus a rule in two, and no difference in one.

Study 6. Space between columns versus space plus rules for 6-point type grouped by fives: Space alone was better in two comparisons, space plus a rule in one, and no difference in one.

Study 7. Space between columns versus space plus rules for 8-point type set solid: There were no significant differences.

Study 8. Space between columns versus space plus rules for 8-point type grouped by tens: Space plus rule between columns was best in two comparisons. The other two differences were not significant.

Study 9. Space between columns versus space plus rules for 8-point type grouped by fives: In two comparisons, the space plus a rule between columns was best. The other two were not significant.

The results of the nine studies may be summarized as follows:

1. When numerals are grouped by fives in columns, both 6 and 8-point type were about equally effective in promoting quick location of powers and roots. The 8 point was slightly superior but not significantly so.

2. Grouping numerals by fives or by tens facilitated quick finding of roots and powers, with grouping by fives proving a somewhat superior arrangement.

3. In general, it seemed to make little difference whether a 1-pica space or a 1-pica space plus a rule separated columns of numerals in mathematical tables.

Summary

1. Numerals in mathematical problems make a greater demand on vision than the words of the accompanying text. The numerals require more fixations, a longer pause duration, and more regressions. The greater difficulty in reading numerals is due to the fact that, while words are read as familiar wholes, numerals tend to be read digit by digit. Apparently the straightforward progress in ordinary reading breaks down when a numeral of 3 or more digits is encountered in context.

2. Nevertheless, numerals printed in Arabic digits rather than in words promote faster reading of mathematical problems, largely because less horizontal space is used in the printing.

3. The more legible of the mathematical signs are either larger, or have strikingly differentiating shapes, or both.

4. In reading formulas, there is some tendency toward subjective grouping; i.e., some of the items are read as unitary groups rather than character by character.

5. Exponents and subscripts in formulas are less legible than the symbols in the body of the formula. The legibility of letters used as exponents decreases with decrease in size at a greater rate than legibility of digits used as exponents. This is perhaps because many letters used in formulas are about the least legible in the alphabet.

6. As with numerals in context, both mathematical and chemical formulas in context make a greater demand on vision than the accompanying words of the textual material.

7. Modern numerals (all the same height) and Old Style numerals (with ascenders and descenders) are equally legible in mathematical tables.

8. Experimental evidence reveals the following facts concerning the legibility of mathematical tables:

a. Modern numerals (all digits the same height) and Old Style numerals (with ascenders and descenders) are equally legible.

b. Numerals in 8-point type are more legible than those in 6 point.

c. Separation of entries down a column into groups of five or ten items by means of a space of 6 to 8 points increases legibility. There is a slight advantage of the five-item group over the ten.

d. Separation of columns by a 1-pica space, or a 1-pica space plus a rule, appears equally good for promoting optimal legibility.

e. Use of nearly white, mat surface opaque paper stock produces better legibility than off-white (grayish) paper which is thin enough to allow print on the reverse side to show through.

9. The following suggestions for maintaining satisfactory legibility of mathematical tables are relevant.

a. Numerals in the column which lists the base numbers should be printed in boldface.

b. Excessive complexity introduced by including columns for reciprocals, area, circumference, and others, in addition to powers and roots of numbers, should be avoided. In general, the more columns there are in a table, the less legible the materials become.

14. Special Printing Situations

THERE ARE A NUMBER of special typographical arrangements, some of which are similar to book reading and others which are quite different. A variety of research reports have dealt with the legibility of print or writing employed in these situations. Each kind of printing or writing will be considered in turn.

Typewritten Material

Greene (28) reports an investigation of the legibility of typewritten material. The text to be read was lithoprinted from typed material on white bond paper. Three factors were studied: size of type, leading, and line width. A speed-of-reading technique was employed, somewhat similar to that of Tinker and Paterson (see Chapter 2).

Size of Type. Four type sizes, 14, 12, 10, and 7 point were printed in a 41.5-pica line width. No information on leading is given. Scores were in number of items read in 10 minutes. There were 68 to 104 readers for each comparison. He found no reliable tendency for one size of type to be read more rapidly than another.

Leading. Only the 10 point and the 7-point type were used in the leading study. In the 10-point material, 3-point leading was used and in the 7-point material, 1.2-point leading. Two line widths were employed with each size of type, i.e., 41.5 and 21 picas. The leaded material for the long lines was read significantly faster than the set solid. For the short lines, the trend was also toward leading for faster reading, but the differences were not statistically significant.

Line Width. Speed of reading material typed in 41.5 and 21-pica line widths was compared for 10 point and 7-point typewriter type. The 10-point material was set solid and also with 3-point leading and the 7 point was set solid and also with 1.2-point leading for each line width used. In comparing the speeds of reading material in the various line widths, no significant differences were found, but there was a slight and rather consistent tendency for the shorter lines to be read faster.

In interpreting these results, the reader should realize that the line widths employed were rather extreme for typewritten material, i.e., approximately 7 inches and 3½ inches. Consequently the conclusions cannot be applied to typewriter print in general. Any conclusions must be limited to the conditions of the experiment.

Linotyped Versus Typewritten Material

The relative legibility of linotyped versus typewritten material was also studied by Greene (29). The method employed was similar to that in the above experiment. Material in two sizes of type, 7 and 10 point, was set in American Typewriter type and also in Ionic Linotype. The 10-point type was printed in a 14-pica line and the 7 point in a 12-pica line width. All material was set solid. In all the comparisons the obtained differences were small and statistically insignificant. It would appear that Ionic Linotype and American Typewriter type are equally legible, either in 7-point type set solid in a 12-pica line width, or in 10-point type set solid in a 14-pica line width.

The results of this experiment, like the one above, must be viewed with caution. In the second experiment (29) the line width of 14 picas, or about 2⅓ inches, for the 10-point type seems extremely short for typewritten material. This factor prevents any generalization from being extended beyond the conditions of the experiments. Secondly, and perhaps most important, one essential control was missing in both experiments. The test materials for the "control" group comparison should have been systematically distributed throughout the test forms for the experimental group comparisons in each study. This would have assured the same testing conditions for readers in the "control" group as in the other groups. Since this essential control was absent, the differences found by Greene for his control groups may well have been merely sampling errors. Tinker and Paterson (153), in a study of 24 random samples (control groups) of 80 to 176 readers each, found sampling errors of up to a 6.5 per cent difference in speed of reading "equal" forms of their test material.

Typewriting, Manuscript, and Cursive Script

The relative legibility of typewriting, manuscript, and cursive script was determined by Bell in two investigations. In the first study (4) he used a speed-of-reading method of measurement. The typewriting provided reading material somewhat comparable to print. Manuscript letters are like engineering lettering, but like typewriter characters, the letters within a word are not joined together. The cursive letters within a word are joined together and differ from both typed and manuscript letters in form. Specimens of easy reading material were prepared in each kind of lettering (a) by a nonexpert (manuscript and cursive) and (b) again by an expert penman. The various materials and results for

TABLE 14.1—Mean Differences and Critical Ratios for Reading the Nonexpert Specimens

Reading Materials	Manuscript Minus Typewriting		Cursive Minus Typewriting		Cursive Minus Manuscript	
	Diff.	D/S.E.d.	Dif.	D/S.E.d.	Diff.	D/S.E.d.
Easy Prose: Time..	24.60	5.23	64.00	12.19	39.40	8.46
Letters	11.52	11.41	5.12	4.06	– 6.40†	5.33
Nonsense: 1 Syll...	6.00	5.00	10.48	9.03	4.48	3.45
Nonsense: 3 Syll...	1.84*	2.88	8.00	12.12	6.16	9.33

* Significant at the 4 per cent level. All other differences are significant at the 1 per cent level.

† Minus difference indicates that the first item of comparison was superior.

the nonexpert specimens are given in Table 14.1. Single letters, one-syllable nonsense words, and three-syllable nonsense words were used in addition to the connected discourse. Scores are in seconds.

The data derived from the reading of 120 subjects show that: (a) All materials were read significantly faster in typewriting than in manuscript or cursive script. (b) All materials except single letters were read significantly faster in manuscript than in cursive script. Single letters were read more rapidly in cursive script than in manuscript. There was no difference in comprehension scores (not given in the table).

With the expert specimens read by 60 readers, the trends were slightly different. Typewritten text was read significantly faster than manuscript when the text was easy prose and letters, and faster than cursive script for all materials. There was no significant difference between typewriting and manuscript in the reading of nonsense syllables. But manuscript was read significantly faster than cursive for all materials (prose and nonsense syllables) except single letters. Again there were no significant differences in comprehension.

In general, (a) typewriting is more legible than manuscript or cursive script, and (b) manuscript is more legible than cursive script in the meaningful prose specimens.

Typewritten letters and nonsense syllables were found to be less legible than cursive script. These results emphasize the need for caution in inferring legibility of print in connected discourse from the legibility of single letters.

In his second investigation, Bell (5) recorded eye movements while 18 subjects read difficult material in typewriting, manuscript, and cursive script. The lettering was done by a skilled penman. The results revealed no significant differences in eye-movement measures between typewriting and manuscript. But eye-movement measures during reading were consistently in favor of typewriting as compared with cursive script. Likewise, the eye movements indicated that manuscript was read consistently more rapidly than cursive script. The conclusions are: (a) Typewriting and manuscript are more legible than cursive script, and (b) there is no difference in the legibility of manuscript and typewriting. Comprehension of the difficult prose brings in an uncontrolled variable in Bell's second study. He correctly suggests that the results of the earlier investigation, in which easy prose was used, yields a truer picture of the relative legibility of typewriting, manuscript, and cursive script.

Handwriting

Turner (165) obtained specimens of manuscript and cursive handwriting from children in grades 2 through 6. With the exception of the material from the second grade, the manuscript writing was read faster than the cursive writing. In another part of the study, Turner found that manuscript writing (letters in nonsense arrangement) was significantly superior to cursive writing in terms of the number of brief exposures required to read the materials. The general conclusion is that the legibility of manuscript writing is significantly greater than that of cursive writing. It is suggested that this superiority of the manuscript writing is due to the independence of the letters, good spacing between words, and economy in line space.

In another experiment, a large number of handwriting specimens were obtained from students in elementary school, junior high school, and college by Pressey and Pressey (90). Specific illegibilities were tabulated and then grouped into several classes. The percentage of characteristic illegibilities were:

Words crowded	20
Too angular	15
Rewriting	13
Breaks between letters	13
Loops too long	10
Letters crowded	7
Poor spelling	5
Crowding at side of paper	5
Miscellaneous	12
Total	100

Letters of the Alphabet Causing Most Trouble. The only capital letter that caused much trouble was *I* (90). Of the lower case letters, *r* caused 12 per cent of all the specified illegibilities. The letter *n* had the next largest number. Six lower case letters, *r, n, e, a, d, o,* accounted for about 50 per cent of all illegibilities.

Malformations of certain letters affected legibility. Making *n* like *u, r,* like *i, e* closed, *d* like *cl,* and *o* like *a* accounted for 25 per cent of the total number of errors.

A Second Experiment. Newland (67) collected handwriting specimens from elementary and high school pupils and from college students. Analysis revealed that many of the illegibilities were common to the three groups of students but that some were common to only one or two of the groups.

The irregularities of four letters, *a, e, r,* and *t,* contributed nearly 50 per cent of the illegibilities. The older the subjects, the less legible became their handwriting. The adults wrote three times more illegibly than the elementary school children. Relatively few forms, as *d* like *cl* and *a* like *u*, accounted for about 50 per cent of the illegibilities. Writing *e* like *i* resulted in 15 per cent of all illegibilities.

Four types of difficulties in letter formation produced over 50 per cent of the illegibilities. They were failure to close letters, closing looped strokes, looping nonlooped strokes, and using straight up strokes rather than rounded strokes. It is suggested that correction of these bad letter formation habits would decrease the illegibilities by 50 per cent.

Illegibilities in Writing Numerals. Samples of materials including written Arabic numerals from a large number of school children (arithmetic papers) and adults (sales slips, personal checks, luggage check reports) were obtained by Newland (66). Analysis of the data showed the following results: (a) Adults write illegible numerals twice as frequently as school children. (b) Certain digits are written illegibly more often than others. In descending order, 6, 5, and 7 were written illegibly by the elementary groups; 5, 7, and 4 by the junior high group; and 5, 0, and 2 by the adult group. Illegible writing of digits increased from the elementary to the adult group. Only the digit 4 was more legible in the older group.

Stencil Duplicated Materials

Only one investigation of legibility in this area has appeared in print. Luckiesh and Moss (54) employed average and superior grades of stencil duplicated materials on white paper with a reflection factor of 84 per cent. Visibility measurements were made with the Luckiesh-Moss Visibility Meter. Frequency of reflex blinking was also recorded during the first and last 5-minute periods of 30 minutes of reading of each kind of material. There were 12 subjects. Rate of reading was also obtained.

The average quality of duplicated material was 70.6 per cent as visible as the superior quality. During the 30 minutes of reading, the rate of blinking increased 7 per cent more for the average quality of duplication than for the superior quality. Speed of reading the material with average duplication was 6 per cent slower than for the superior.

Print in Comic Books

Reading the printed material in the ordinary comic book is a severe visual task. The lettering tends to be poor and of small size. Both the printing and the paper are usually of poor quality. In addition, the print often appears on a colored background of relatively low reflectance which reduces the brightness contrast between print and paper and further reduces the visibility of the printed words. However, a few publishers of comics apparently now print their comic books in larger type on fairly white paper with a higher reflection factor.

Luckiesh and Moss (61) have compared the visibility of print used in comic books of average and superior typography. Two groups of 24 specimens each were chosen for study. The average group consisted of the run-of-the-mill comics most of which presented the more severe visual tasks. The superior group was made up of comic books whose publishers had improved the quality of lettering, paper, and printing. In addition, a standard specimen of 12-point Bodoni Book type, well printed with nonglossy ink on nonglossy white paper of excellent grade was used in all comparisons. Visibility measurements were made with the Luckiesh-Moss Visibility Meter. The material was examined under 20 foot-candles of light. The results are presented in Table 14.2.

TABLE 14.2—Visibility of Print in Average and Superior Comic Books Compared With 12-Point Bodoni Type. Each Score Is an Average for 24 Specimens.

Kind of Comparison	Average Group	Superior Group	12-Point Bodoni Type
Actual visibility	3.2	6.7	9.0
Per cent visibility	36.0	74.0	100.0
Equivalent type size*	5.6	9.8	12.0
Foot-candles for equal visibil.†	150.0	30.0	20.0

* Equivalent type size as derived from the visibility scores signifies the type size in points of the print in comic books in comparison with 12-point standard.

† Foot-candles for equal visibility signifies how many foot-candles of light are needed to make the comic book print equal to the 12-point standard under 20 foot-candles.

The results show that the visibility scores for the comic book print are much inferior to those for the 12-point type. If the standard 12-point type is called 100 per cent, the print in the superior comics is only 74 per cent as visible, and in the average comics only 36 per cent as visible. In terms of equivalent type size in relation to the 12-point standard, the print in the superior comics would be read as easily as 9.8-point type, and in the average comics only as easily as 5.6-point type. Taking the 12-point type under 20 foot-candles as a standard, to be equally visible the print in the superior comics would have to have 30 foot-candles, and in the average comics, 150 foot-candles of light. The authors conclude that the lettering of comic books should be improved by increasing the size and quality of lettering, the space between the lines, and the brightness contrast between print and paper.

Tinker (120) discusses the factors which determine legibility of print in comic books. In addition to the points emphasized by Luckiesh and Moss in the above experiment, Tinker calls attention to the unfortunate practice of using all-capital printing (lettering) in the large majority of comics.

As pointed out in Chapter 4, all-capital printing in comparison with lower-case type reduces legibility by a large and significant amount. When the all-capital lettering is combined with small size of type, and small brightness contrast between print and paper, the visual task of the reader is severe indeed. A marked improvement in legibility of comic books could be made by employing lower-case lettering of sufficient size. This lower-case lettering looks like engineering lettering, or manuscript writing, or like a sans serif type such as Kabel Light.

Projected Materials

There are two somewhat different problems here: (a) The reading of microfilmed type is enlarged and projected on a white surface so that the print is about normal book size or the size of the original print. A microfilm apparatus such as the one put out by the Spencer Lens Company is used. (b) In the other situation, microfilm print is projected on the ceiling for bed patients to read. Here the projected print is rather large.

As part of a larger investigation, Carmichael and Dearborn (20) recorded eye movements electrically (see Chapter 2) while subjects read projected microfilm, and also while they read the material directly from a book. The Spencer microfilm apparatus was used for the magnification and projection. The reading time was 6 hours for each kind of material. There were 20 subjects, 10 adults and 10 high school students. The procedure was well controlled in all respects. For adults there were no significant differences in the eye-movement patterns between reading books and reading the projected microfilm. But for high school pupils, the microfilm was read less effectively than the books in terms of eye movements and comprehension. However, these high school readers did not reveal any significant decrement in the six hours of reading the microfilm.

It is worth noting in passing that there were no significant changes in any eye-movement measure during the six hours of reading by either adults or high school subjects while reading books or microfilm. In other words, the six hours of continuous reading was done without discoverable "cost" to the organism. The authors suggest that one practical educational inference that seems justified from the study is that there seems to be no basis for the belief that requiring long periods of reading on the part of high school or college students may be injurious to the visual mechanisms of such students, if they have reasonably satisfactory eyes to begin with.

Microfilm for Bed Patients. Reading material can be provided for bed patients by projecting microfilm on the ceiling with the print considerably enlarged. Anderson and Meredith (2) investigated the relative legibility of microfilm print projected on the ceiling and of book print. The book print was 11-point Linotype Granjon type in a 25-pica line width, which is often used in novels. Each of 20 subjects read from the book for 2 hours, and at another session read the microfilm-projected material, taken from the same book, for 2 hours. For 1 hour of the microfilm reading the surrounding illumination in the room was 3 foot-candles intensity, and for the other hour there was no surrounding light except what was reflected from the projection itself. The order of subjects was systematically varied. During the ceiling reading, the subjects lay on a standard hospital bed. The regular reading position was used for the book reading. The mean scores in words per minute are given in Table 14.3. Scores were obtained for each 15 minutes of reading as well as for the two hours.

The data show that the microfilm was read 12.8 per cent more slowly than the book material. This difference is sta-

TABLE 14.3—Rates for Reading a Standard Book Print Versus Microfilm in Words per Minute and Per Cent

Comparison	Mean: Book	Mean: Microfilm	Differences in Words per Min.	Differences in Per Cent
Book vs. microfilm	436	380	—56	—12.8*

* Significant at the 1 per cent level.

tistically significant. Differences for the successive 15-minute periods (not given in the table) revealed consistent and significant differences in favor of the book reading. The average rates of reading both book print and microfilm projection continued to increase until the very end of the two-hour period. There was no real evidence of fatigue for reading either the book or microfilm print. The rate of reading the microfilm was proportionately no slower at the end of the experiment than that of reading the book.

Only during the first 15 minutes of reading the microfilm material was there a significant difference in favor of no surrounding light. The averages for 60 minutes revealed no significant difference, although still in favor of no surrounding light. But most of the subjects expressed a preference for reading the projected material without any surrounding light.

The general conclusions are: (a) Although projected materials are read more slowly than materials in good book print, they may be employed for bed-ridden patients without undue visual fatigue. (b) Reading such projected material is facilitated if there is no surrounding light.

Dictionary Printing

Taylor (105) suggested a modified typographical arrangement to facilitate finding words in a German-English Dictionary. In looking up a word like *schmelzwerk,* attention is first focused upon the initial letter and the pages are turned to "s." Once the "s's" are found, the words beginning with "sch" are then located. Mental attention focuses upon "melz" and the eye strives to find these letters which have been concealed behind "sch" making them difficult to lcoate. No aids such as heavy-face type, italics, or capitals assist in this search. Taylor feels that it would be considerably more convenient if all syllables or letters common to the series were eliminated after they once have been given. A similar practice is used for numerals in logarithmic tables and Taylor suggests this sort of modification for dictionary listings as follows:

Usual System	*Proposed System*
schmelz	schMELZ
schmelzarbeit	ARBEIT
schmelzbar	BAR
schmelzhafen	HAFEN
schmelzwerk	WERK
schmer	schMER
schmergel	GEL
schmerhaft	HAFT

Taylor feels that such a system would make German dictionaries a pleasure to read and that eyestrain would be reduced. His proposal should have an experimental check. In an unpublished study, the writer of this report failed to find any significant advantage for the typographical arrangement suggested by Taylor. Since only a few graduate German students were subjects, the check was perhaps inadequate.

American Dictionaries. Glanville, Kreezer, and Dallenbach (26) investigated the relative legibility of two styles of typography commonly used in dictionaries. Records were made of accuracy of perceiving, speed of locating, and reader preferences in the two dictionary styles: (a) dictionary vocabulary words printed in 6 point boldface, and text in 6-point Roman; (b) vocabulary words set in 12-point boldface, and text in 6-point Roman. In Part 1, which dealt with speed of perception, 50 university students were subjects; in Part 2, concerned with speed of locating words, 50 school children in the 6th and 8th grades, and 50 adults were subjects.

The materials consisted of four series of 100 words each, printed in the two type sizes with both a white background and a background of text of definitions. The words were cut from dictionaries and mounted on cards for presentation to the subjects. All aspects of the experiment were carefully controlled. In Part 1, the stimulus words were presented to the readers by means of the Dodge Tachistoscope (see Chapter 2). The results are presented in Table 14.4.

The words in 12-point type were perceived consistently and significantly better than those in the 6 point. The over-all average reveals an advantage of 107.82 words for the 12-point type which is about 47 per cent better than for the 6 point.

In an over-all comparison, about 5 per cent more words were perceived on a blank background than on a printed background. Also it was found that with increase in exposure time, the differences in accuracy of perceiving 6 and 12-point type tended to become much smaller. Hence the

TABLE 14.4—Influence of Type Size on Quick Perception of Dictionary Words (*Exposure time is in milliseconds (MS) and score in words perceived*)

Background	Exposure Time (MS)	6 Pt.: Av. Words	12 Pt.: Av. Words	Differences* in Words	Diff. / S.E. Diff.
Blank	60	26.38	73.64	47.26	12.27
Blank	210	91.84	98.78	6.94	4.92
Printed	60	23.92	67.14	43.22	10.96
Printed	210	87.30	97.70	10.40	5.84
Total		229.44	337.26	107.82	

* All differences are significant at the 1 per cent level.

authors believe that with an exposure time of 1/3 to 1/2 second, the difference between the large and small type sizes would become negligible.

In the second part of the experiment, time was recorded in seconds to locate 10 words in each of two dictionaries, one with words printed in 6-point boldface and the other with words in 12-point boldface type. Slightly more time was required to find the words in the dictionary printed in 6-point type. Although the differences were small (3.59 and 7.35), they were statistically significant for both the children and the adults.

Preferences. In Dictionary A, the words were printed in 6-point boldface type, and in Dictionary B the words were printed in 12-point boldface type. Preferences were as follows:

(a) *Adults*

Choice as easier to use: 76 per cent for B, 6 per cent for A, 18 per cent no difference.

Preferred: 78 per cent for B, 10 per cent for A, 12 per cent no preference.

Pleasingness: 46 per cent for B, 40 per cent for A, 14 per cent no difference.

(b) *Children*

Choice as easier to use: 72 per cent for B, 10 per cent for A, 18 per cent no difference.

Preferred: 78 per cent for B, 4 per cent for A, 18 per cent no preference.

Pleasingness: 52 per cent for B, 18 per cent for A, 30 per cent no difference.

In general, the preferences indicated by both adults and children were strongly in favor of the dictionary with words in large type as to ease of use, preference for using, and pleasingness of appearance.

The evidence presented in this investigation seems to be convincingly in favor of the 12-point boldface type for dictionary words. They can be perceived more quickly than the words in smaller type, they can be located faster, and they are strongly perferred. Publishers of dictionaries should take account of these findings.

Items in Bibliographies

Pratt (89) determined the optimal position for a number or letter suffix to a date in bibliographical references for best legibility. Five different positions of suffixes to dates were used:

1. The letter suffix was on the line and not separated from the date by a space, i.e., 1904a.
2. The letter suffix was on the line and separated from the date by a space, i.e., 1904 a.
3. The letter suffix was above the line and not separated from the date, i.e., 1904^{a}.
4. The letter suffix was above the line and separated from the date by a space, i.e., $1904\ ^{a}$.
5. The number suffix was on the line and separated from the date by a decimal point, i.e., 1904.1.

Portions of titles of scientific articles were printed after each date. Different dates and suffixes, both letters and numbers, were prepared and arranged in columns.

The materials were presented in a short-exposure apparatus. The subject's task was to find a particular date and suffix as quickly as possible. The time between presentation of material and the subject's response was recorded. There were 16 subjects in one group and six in another group. Total number of presentations was 660.

The results showed that there were only slight differences between arrangements 1, 2, 3, and 5, i.e., ranging from 1.822

to 1.976 seconds. But the time to perceive the item in arrangement 4 was shorter than any of the others, i.e., 1.503 seconds. Pratt concluded that the most legible position for a suffix to dates in bibliographical references was one in which the letter suffix was above the line and separated from the date by a space, i.e., 1904 [a].

Telephone Directories

The large number of listings required in the telephone directory of a large city presents a serious practical problem. To what degree can a directory be condensed and at the same time be legible enough to insure the greatest possible accuracy of reading? Baird (3) attempted in 1917 to get an answer to this question for the New York Telephone Company.

Four typographical arrangements for a page of a telephone directory were printed for a comparative study:

A. The existing three-column arrangement on a 9 by 12-inch page was employed to compare with the other setups. The printing in this arrangement was: (a) lower-case 6-point type set solid with capitalization of names, and (b) boldface type for the exchange name and telephone number. This arrangement was termed "three-column page, ordinary."

B. The second arrangement was four columns per page but otherwise the same as No. 1. It was called "four-column page, ordinary."

C. In the third arrangement, every alternate line was indented slightly at the left end. Otherwise it was the same as B. The indentation was supposed to help the reader follow through from name to telephone number without error due to moving up or down one line. This was called "four-column page, indented."

D. The fourth arrangement was like the second (B) in every respect except that 1/72 inch (1 point) of leading was inserted between successive lines. Later in the report the author mistakenly calls this ½-point leading. This was called "four-column page, leaded."

The materials were presented to 32 subjects in a counter-balanced order to control practice effects. Each subject looked up 30 names and the corresponding telephone numbers. Time was recorded from when the booklet was opened until the exchange and number were pronounced.

The average time for finding correct numbers for the four arangements were:

A. Three-column page, ordinary, 10.36 seconds
B. Four-column page, ordinary, 10.69 seconds
C. Four-column page, indented, 10.14 seconds
D. Four-column page, leaded, 9.28 seconds

Indentation increased legibility about 5 per cent, and 1-point leading increased legibility by about 13 per cent. Thus the results show that the four-column leaded page is much more legible than any of the other arrangements. This arrangement was adopted by the New York Telephone Company. The new directory was not only more legible, but because of the increase from 3 to 4 columns its bulk was reduced by approximately 20 per cent, a decrease of about 200 pages.

Another study of the legibility of the telephone directory was reported by Lyon (62) in 1924. No description of the experimental design and no quantitative data were presented. The statements made by Lyon follow: (a) In a four-column directory, 6-point type set solid is as legible as 6-point with 1-point leading, but the leaded material *appears* more legible. (b) For two- and three-column directories, 7-point type is adequate. Since no 7-point type face seemed suitable, one was designed by opening up the characters of an enlarged 8-point type so as to provide as much white space as possible in the interior of the letters. This newly designed type was then recast in 7-point size. The author says the new type can be used set solid, which produces 10 lines to the inch, or with 1-point leading, which prints 9 lines to the inch. However, he claims there is no appreciable gain in legibility by use of the leading.

These results reported by Lyon are difficult to evaluate because information on the experimental design is lacking. It is difficult to believe that 1-point leading has no effect on legibility of a telephone directory. In ordinary reading of material in 7-point newsprint in a 12-pica line, 1-point leading improves legibility significantly. In any case, the user of telephone directories prefers some leading.

Library of Congress Cards

The original reproduction in book form of the Library of Congress Catalog of Printed Cards by the photolithoprint process was judged by librarians to have unsatisfactory legibility. The chief sources of difficulty in reading the reproduced cards were excessive reduction in type size, blurring, and reduction of brightness contrast in the offset material.

To obtain objective data on this essential question, Bryan (17) designed an experiment to determine the relative legibility of the printing of the original cards and that on the offset reproductions. The stimulus materials consisted of Library of Congress cards and the book reproductions of these cards. One set of cards and reproductions were printed in English and one set in selected foreign languages. The cards were set in 12, 10, and 8-point type and were reduced in the reproductions to about 7, 6, and 5 points respectively. The subjects were 24 professional catalogers divided into three groups according to age. Their task was to transcribe a given amount of material from Library of Congress cards and from reproductions onto worksheets. Necessary controls were provided in the procedure. The materials were divided into two parts, A and B, arranged to obtain equivalence of content. A questionnaire was used to obtain attitudes and opinions on the relative legibility of the cards and the reproductions. This was filled out at the end of the experiment. Time and error scores were recorded for the transcriptions.

Results

1. No significant differences were found between results for the two sets of material, A and B.
2. The English material was consistently somewhat easier to transcribe than foreign material on both cards and reproductions. Many of the differences were statistically significant.
3. In general, the older catalogers worked somewhat more slowly than the younger ones, but not significantly so.
4. The smallest size of type led to significantly more errors in transcribing than the largest type, but the differences between the large and medium sizes tended to be statistically insignificant.
5. The number of errors and the net output per minute was in most comparisons significantly in favor of the Library of Congress cards in contrast to the reproductions. This held for all type sizes.
6. The net output per minute for the reproductions was about 85 per cent of that for cards. Workers made 9 times as many errors working with reproductions as with the cards.
7. The majority of the catalogers were convinced that it would be a mistake to substitute reproductions for the cards.
8. Bryan feels that it is impossible to say whether use of reproduced materials with the inefficiencies entailed is justified until a careful study is made to determine the extent of such use.

To most librarians, the data of this study will indicate that, with the present method of reproduction, it would be a mistake to employ the book reproduction of the cards rather than the Library of Congress cards themselves.

Timetable Typography

Scott (95) reports a study to test the relative legibility of railroad timetables printed in two sizes of type. Point size is not given but inspection showed a difference of about 1 point. Both setups had some boldface printing. The boldface type gave the appearance of being somewhat larger than the light Roman print. There were six subjects.

A full page of each of the two timetables was read orally as fast as possible. The combined results for all six subjects are given below:

Total time to read small type	147 minutes, 11 seconds
Total time to read large type	129 minutes, 42 seconds
Excess time required for small type	17 minutes, 29 seconds
Per cent time lost by using small type	13.3 per cent
Total errors for reading small type	132
Total errors for reading large type	91
Excess errors for small type	41
Per cent increase of errors for small type	45.0 per cent

Additional evidence from the reading of the six subjects showed that the heavy type (boldface) could be read 12.6 per cent faster than the lighter type. This compares favorably with the 13.3 per cent difference in favor of reading the material in the larger type. The author concludes that the timetable in the slightly larger type, both regular and boldface, was easier to read and less subject to error than the smaller type. The timetable in the larger type was preferred by the readers.

Printing of Backbone Titles

Backbone titles are printed in various alignments on books and magazines. Gould, Raines, and Ruckmick (27) compared the relative rates of reading titles printed vertically from top to bottom and from bottom to top with the stimuli presented at different eye levels. A shelf adjustable at 4, 5, and 6 feet from the floor was built. A dummy, 26 by 2 centimeters, carrying a book title was placed among a score of books. The titles consisted of 38 names of standard publications printed on heavy white paper. Later, the dummy was arranged to hold six or more titles at a time. The shelf holding the titles was exposed by a shutter device. Time was taken from exposure of the material until the title was read aloud. There were 14 subjects.

The results showed that the bottom to top direction was most favorable for reading when the shelf was above the level of the eyes. At eye level, there was no appreciable difference between the two directions. Below eye level, there was a slight difference in favor of the top to bottom direction of printing. Answers to a questionnaire showed 48 of 92 preferred the bottom to top direction and 34 favored the reverse direction for backbone titles. The authors concluded that there is no decisive evidence that one arrangement is more legible than the other.

A second investigation of the legibility of backbone titles has been reported by Burtt, Beck, and Campbell (19). Words made of ¼-inch gummed black block letters were presented one at a time in a short-exposure apparatus. Twenty words were prepared in each arrangement, upward, downward, and downward with all the letters upright. Words of 5, 7, 9, and 11 letters were used, equally divided among the three arrangements. The number of correct responses was the score. There were 30 subjects in this part of the experiment.

In a second part of the investigation, series of words were presented simultaneously to the subject. The task here was to find a designated word in as short a time as possible after the stimulus material was uncovered.

The results revealed the following trends for errors in Part 1 (short exposure):

A. Average errors reading upward: 6.10.

B. Average errors reading downward: 3.56.

C. Average errors reading downward: letters upright, 4.33.

The differences between A and B and A and C are statistically significant, but not between B and C.

In Part 2, the average response time to find words was:

A. Reading upward: 2.51 seconds.

B. Reading downward: 2.24 seconds.

C. Reading downward: letters upright, 2.04 seconds.

Arrangement A, reading upward, was inferior to the other two. On the average, B was 10 per cent superior to A, C was 18 per cent superior to A, and C was 9 per cent superior to B.

All parts of the experiment confirm the result that arrangement A, reading upward, was inferior to arrangements B and C. Since B, reading downward, is more legible than A, it should be the one used. The authors suggest that arrangement C, reading downward with letters upright, should receive more consideration for general use since it appears to have good legibility. However, this arrangement would probably not be appropriate for titles of more than one word because familiar word forms are completely destroyed by this arrangement. In general, the findings for single words, as in this experiment, have little application to legibility of backbone titles which usually run to several words.

An investigation by Tinker (141) reports data relevant to the problem of printing backbone titles. As part of his experiment, he determined the rate of reading material in a vertical alignment from bottom to top and from top to bottom. He also determined visibility of printed words in these two arrangements. In brief, the results showed that print can be read as well upward as downward. Visibility of words revealed the same trend. The implication is that backbone titles on books and magazines would be equally legible whether printed upward or downward.

Summary

1. Variation in the size of typewritten material, from 7 to 14 point, has little effect on legibility of long lines of 41.5 picas.

Leading improves the legibility of typed material in both long and short lines.

Short typewritten lines tend to be consistently more legible than very long lines.

2. American Typewriter type and Ionic Linotype appear to be equally legible when printed in 10-point type set solid in a 14-pica line width, and when printed in 7-point type set solid in a 12-pica line width. Generalizations cannot be extended beyond these printing arrangements.

3. Typewriting is more legible than manuscript and cursive script, and manuscript is more legible than cursive script.

4. A number of factors cause handwriting to become illegible. The only upper-case letter that creates difficulty is I. Of the lower-case letters, r and n are particularly bad. Six lower-case letters, r, n, e, a, d, and o, account for about 50 per cent of illegibilities. Legibility of handwriting decreases as people grow older. The writing of adults is only one-third as legible as that of elementary school children.

5. Adults write less legible numerals than school chil-

dren. The digit "4" is the only digit more legible in adult writing. In general, the most illegible of written digits are "5" and "7."

6. A superior quality of stencil duplicated material is significantly more legible than that of average quality. The superior quality material is more visible and is read faster.

7. The print in comic books is extremely illegible. The legibility could be improved by: (a)Using larger type, a better quality of lettering, and more space between lines of print; (b) increasing the brightness contrast between print and paper; (c) using a better quality of paper; and (d) employing lower-case lettering rather than all capitals.

8. Microfilmed type projected to normal print size by a good projector is as legible as ordinary book print. Microfilm projected to the ceiling in a large size for bed patients is significantly less legible than good book print, but apparently the reading of such microfilm for two hours does not produce visual fatigue.

9. The printing of dictionary words in 12-point boldface type has several advantages over 6-point boldface type: The dictionary words in the large type are more readily perceived, they can be found in the dictionary more quickly, and users of dictionaries prefer them.

10. The most legible arrangement of a suffix to dates in bibliographical references is one in which a letter suffix is above the line, and separated from the date by a space, i.e., 1904 [a].

11. One-point leading appears to improve significantly the legibility of 6-point type used to print telephone directories. This is disputed, but whether 6 or 7-point type is used in directories, 1-point leading is indicated because it makes the type look more legible and it is preferred by users of the directories.

12. The book reproduction of Library of Congress cards in a reduced size by the photolithoprint process results in extremely illegible print due to the small size of the print, blurred copy, and small brightness contrast between print and paper. Errors increased ninefold in working with the reproduced materials.

13. The legibility of timetables is greatly improved by increasing the size of type from 6 to 7 point and by employing some boldface print.

14. The backbone titles on books and magazines are just as legible printed from bottom to top as from top to bottom.

15. Illumination for Reading

A DISCUSSION of the hygiene of reading should include consideration of all factors which may influence comfortable, healthful, and efficient functioning of the eyes in the reading situation. It is obvious that illumination is one of the more important of these factors. Hence it is desirable to supplement our discussion of the legibility of print with an examination of the basic requirements of illumination for reading.

The provision of lighting which will be satisfactory for easy, comfortable, and efficient vision is essential whether one is working in the school, the home, the library, the office, or industry. For a large portion of the population, both children and adults, reading as a leisure-time activity or in the working situation, or both, occupies a considerable part of the day. The provision of satisfactory lighting is especially important because it is well established that faulty illumination frequently leads to eyestrain which may be accompanied by reflex functional disturbances of other organs. Sometimes defective vision is held to be directly traceable to faulty illumination. Economy and artistic effect are of purely secondary significance in comparison with maintaining healthful working conditions for visual tasks and in comparison with the conservation of eyesight.

During recent years a lighting consciousness has been forced upon most of those who perform visual tasks and upon those who control the environment in which visual work is performed. Although this interest in lighting has been stimulated by popular articles and by reports of educators and medical men, the more fundamental information has appeared in the experimental literature. This literature is not readily available to most people nor easily interpreted by them. The tendency, therefore, when lighting specifications are needed for a particular situation, is to consult pamphlets on recommended practice. Five of these are available (182, 200, 201, 212, 237). Although there is much valuable information in these booklets, some of the material, especially that dealing with intensity of illumination, is out of line with experimental findings. The (English) schedule of recommended values of illumination intensities listed in Weston's book (237) is not only more conservative but also more in line with the results of well-controlled experimentation. The task of this chapter is to present a generalized statement of the results, derived from sound experimentation, that are relevant to the illumination requirements for reading. Three aspects of lighting will be considered: quality or color, brightness or intensity, and distribution of illumination. At appropriate places, experimental evidence will be introduced to support statements made.

Spectral Quality of Color of Light

Color of Paint. Certain colors and tints of colors are preferred over other colors and tints. Some colors carry the meaning of warmth, others appear cool. Some are exciting, others subduing. To achieve the most pleasing living and working environment, these psychological factors must be considered.

The role that color in decoration (paint) plays in promoting adequate illumination is considerable. Much of the usable illumination in an enclosed space should come from the reflection of light from the ceiling, walls, and furnishings. Furthermore, the color of the decoration and of human complexions is affected by the color of the light from the illuminant. Consequently, some attention must be given to both the color of decoration and the reflection factor of the paint. Also, one must consider coordination of illumination and decoration. This will be done near the end of the chapter.

The literature on color of light from various illuminants has been brought together by Tinker (224) and by Luckiesh (206). In general, no kind of artificial light is superior to well-diffused daylight. Light from the common illuminants and daylight is complex, as it is composed of a series of several wave lengths. Since the commonly used artificial illuminants produce light varying in spectral or chromatic quality, each of these will be considered in turn.

Sodium Versus Tungsten Light. For all practical purposes, sodium light is monochromatic yellow. Tungsten light from the ordinary tungsten filament bulb has considerable yellow and smaller amounts from other parts of the spectrum. Various studies show that sodium (spectral yellow) light is slightly more effective than tungsten filament light for very fine discrimination at or near the threshold of vision. But, for seeing objects well above the threshold as in reading, there is no advantage for either of these lights. For example, visibility of 8 to 10-point book print is the same under tungsten and under sodium light.

Mercury Arc Light Versus Tungsten Filament Light. Some early views held that mercury arc light was superior to ordinary tungsten filament light. But more recent experiments show that both visual acuity at all levels of illumination intensity (5 to 125 foot-candles) and visibility of book print are the same under mercury arc and under tungsten filament light. These findings have been confirmed in additional experiments.

Fluorescent Versus Tungsten Filament Light. These two kinds of light are equally efficient in promoting effective and easy seeing. The question has been frequently raised concerning possible harmful effects to the organism from fluorescent light. Careful experimentation has led to the conclusion that the ultraviolet, infrared, and visible radiant energy coming from fluorescent lamps is not injurious to the human organism. Nevertheless, many readers prefer incandescent illumination to fluorescent.

In General. No illumination in common use is better than any other for reading or for other situations which involve critical seeing. Other things being equal, it makes no difference whether light comes from the sun, tungsten filament lamps, a mercury arc, fluorescent lamps, or from some combination of these.

Intensity of Illumination

The intensity of light is measured in foot-candles. One foot-candle is the amount or level of illumination at a distance of 1 foot from a standard candle (about the same as an ordinary candle). Examination of the literature (224, 206) reveals that the intensities of light recommended for effective vision are derived to a large degree from studies of illumination for threshold discrimination. Notable examples are experimental measurements of visual acuity and of visibility. Inferences based upon such data are employed for recommending light intensities for reading and for various other visual tasks.

Some Experimental Data. A study referred to repeatedly was reported by Lythgoe (209). He measured visual acuity at brightness levels ranging from 0.018 to 1275 foot-lamberts.

One foot-lambert is the brightness of a perfectly diffusing and reflecting surface illuminated by one foot-candle of light (206, p. 730). It takes somewhat more than 1 foot-candle to produce 1 foot-lambert on ordinary book paper. Visual acuity rose rapidly to about 12 foot-lamberts, and then more slowly to 1275 foot-lamberts. In part of another experiment, Weston (171) studied visual efficiency for perceiving details of a test object with a visual angle of 3 minutes, about the size of details in 10-point type at the normal reading distance. He employed illumination intensities ranging from 0.5 to 512.0 foot-candles. Performance rose rapidly to about 32 foot-candles, and then very slowly to the 512 foot-candles. There were no statistical evaluations of the differences between mean scores in either of these experiments.

Visibility of print shows similar trends. Tinker (144) found consistent and significant increases in visibility of words in 10-point type on white paper in progressing from 5 to 400 foot-candles. At 400 foot-candles, the visibility score was 424 per cent greater than at 5 foot-candles. On the basis of such results, it has been recommended that 50 to 100 foot-candles be used for the more severe and sustained reading tasks and 20 to 50 for ordinary casual reading.

Other Studies. In a study that comes closer to the reading situation, Kunz and Sleight (40) determined the effect of target brightness on normal and subnormal visual acuity. Twelve subjects had visual acuity above 1.0 (normal) and 12 below 1.0. The target brightness values employed were 3.16, 10, 31.6, 100, 316, and 1,000 foot-lamberts. For the group with subnormal vision, there were no significant increases in acuity scores beyond 31.6 foot-lamberts. In contrast, for the group with normal vision, there were no significant gains in acuity beyond 10 foot-lamberts. However, there were minor and insignificant gains up to the 1,000 foot-lamberts for both groups. The authors point out that adequate lighting for seeing details is between 10 and 30 foot-lamberts for those with normal vision, and somewhere between 30 and 40 foot-lamberts for those with subnormal vision. Note that these suggestions are for discriminating details. The 10 foot-lamberts would be about 12.5 foot-candles, and the 30 foot-lamberts would be about 38 foot-candles, shining on ordinary white paper. For reading book print the foot-lambert levels would be lower, probably about 15 to 25 foot-candles for those with normal vision, and around 35 to 40 foot-candles for those with subnormal vision (see below).

Simonson and Brozek (cited by Tinker, 133) investigated the effects of illumination level on visual performance in a very severe task of perceiving series of very small printed letters, each of which remained in view for only a brief interval. Illumination levels were 2, 5, 15, 50, 100, and 300 foot-candles. There was no significant increase in performance beyond 50 foot-candles. This vsual task was much more severe than ordinary reading.

Reading Experiments. Tinker (116) has called attention to the hazards and lack of validity of specifying light intensities for reading on the basis of plotted curves or reader preferences. Curves of visual acuity or visibility data plotted on a logarithmic scale are misleading because the curve makes small and statistically insignificant differences appear large and important. Readers tend to prefer a light intensity for reading that is near the level to which they are momentarily adapted. This was proven in another study (119). When subjects were visually adapted to 8 foot-candles, they tended to choose either 8 or 12 foot-candles for reading. But when adapted to 52 foot-candles they tended to choose 52 foot-candles for reading. In other words, reader preference for level of illumination is not a safe guide for specifying the intensity of light that is most satisfactory. The experimenter can get a preference for almost any intensity by adapting the subject to that intensity prior to the choice.

It is also improper and invalid to compute illumination intensities for a specified per cent of maximum visual performance and apply this to the reading situation. Tinker has shown that use of the Weston-Crouch technique (132) to determine the light needed to read 7-point newspaper print resulted in about 250 foot-candles for 100 per cent accuracy. Actually, the material was read with 99.7 per cent accuracy under 7 to 20 foot-candles. For reading 10-point book type, the formula indicated about 100 foot-candles for 100 per cent accuracy, but the material was read with 99.7 per cent accuracy under 3 to 10 foot-candles. It seems reasonable to suggest that illumination intensities for reading should be determined in the reading situation. Several investigations have done this.

In an initial experiment, Tinker (118) determined the effect of illumination intensities upon speed of reading and upon visual fatigue. The illumination levels used were 0.1, 0.7, 3.1, 10.3, 17.4, and 53.3 foot-candles. The reading material of the Tinker-Paterson method was printed in 10-point type set solid in a 19-pica line width on eggshell paper stock. When visual adaptation was controlled, there was no significant increase in speed of reading for increases of light intensity above 3.1 foot-candles. Visual fatigue was investigated by the "li" test of C. E. Ferree and G. Rand *(Trans. Illum. Eng. Soc.*, Vol. 22, 1927, 52–75). The results were in complete agreement with the speed-of-reading determinations. There was no evidence of increased fatigue for intensities above 3.1 foot-candles of light during two hours of reading.

In another experiment (121), the relation between light intensity and speed of reading 7-point newspaper printed material was determined. The same general method as in the above experiment was used. Illumination intensities ranged from 1 to 100 foot-candles in seven steps. The maximum speed of reading occurred with an illumination intensity between 7 and 20 foot-candles.

The third experiment (134) was concerned with light intensity for effective reading of 6-point italic type. The Tinker-Paterson speed-of-reading technique was employed. The reading material was printed in 6-point italic Excelsior type face in a 12-pica line width with 1-point leading on eggshell paper stock. Speed of reading this material was compared with speed of reading 10-point type in a 20-pica line width with 2-point leading, an optimal typographical arrangement. Although this was a regular reading situation, it constituted a relatively difficult reading task in terms of the visual discrimination required. The illumination intensities were 1, 10, 25, and 50 foot-candles. Speed of reading the material in 6-point italic increased up to 25 foot-candles intensity of light, but not beyond this point. The findings in several other experiments summarized by Tinker (224) agree with the results just cited: Critical levels (levels above which there was no improvement in performance with increase in intensity level) for reading and study by children, 4 to 6 foot-candles; for sorting mail, 8 to 10 foot-candles.

The Role of Age. By the time a person reaches the bifocal age, he needs brighter light for adequate vision even in ordinary reading. With less legible print, such as small sizes of type or low contrast between print and paper, relatively higher intensities will be required.

Effects of Reduced-Brightness Contrast Between Print and Paper. There is considerable literature on this subject. One of the most extensive studies is reported by Weston

(172). The task in this experiment was to find and cross out as rapidly as possible the Landolt rings (rings with gaps of different sizes) with the gap in a particular position. Gaps of 1, 3, and 6 minutes visual angle were used in one part of the experiment and 1.5, 3.0, and 4.5 minutes in another part. The brightness differences or contrast between print and paper in Part 1 were 0.76, 0.32, and 0.23 (i.e., 76 per cent, etc.); in Part 2, 0.87, 0.50, 0.35, and 0.25. The illumination intensities used in Part 1 were 0.8, 4, 20, 100, and 500 foot-candles; in Part 2, 0.5, 2, 8, 32, 128, and 512 foot-candles.

The 3-minute visual angle size is about the size of details to be discriminated in reading 10-point type, and a 2-minute size would be about the size of the details to be discriminated in reading 6-point type.

For the 3-minute visual angle in Part 1 of the experiment, the over-all performance was practically independent of illumination changes above 4 foot-candles except for the smallest brightness contrast, where there were no important changes in performance for intensities above 20 foot-candles. In Part 2 there was no important change in performance with the 3-minute angle above 8 foot-candles for the best contrast. For the three poorer contrasts, there were no important changes in performance above 32, 32, and 128 foot-candles for brightness differences of 0.50, 0.35, and 0.25 respectively. In the two parts of the experiment, both brightness contrast and illumination intensity affected performance over a rather wide range for the 1 and 1.5 minute visual angle but these need not concern us because the details were smaller than those met in ordinary reading.

One other experiment will be cited. Tinker (144) investigated the influence of light intensity on speed of reading 10-point Excelsior book type in a 20-pica line width with 2-point leading, with variation in brightness contrast between print and paper. The brightness differences were

0.756, 0.581, 0.348, and 0.217. Illumination intensities used were 5, 25, 50, 100, 200, and 400 foot-candles.

The results reveal the following trends: (a) For material printed on white paper (brightness difference of 0.756), there were no significant differences in speed of reading with 5 to 400 foot-candles of light. (b) Speed of reading material with brightness differences of 0.581 and 0.348 between print and paper increased up to 25 foot-candles but not beyond. (c) When the brightness contrast was only 0.217, it took an increase from 5 up to 100 foot-candles to produce a significant increase in speed of reading. (d) The conclusion is that with black print on average "white" paper, high intensities of light are not necessary. When the brightness difference between print and paper drops below 0.60, brighter illumination is needed for adequate vision.

Recommended Practice in Lighting

The critical or marginal levels of light intensity discovered in the above experiments are not recommended levels. Tinker (129) has demonstrated that use of a critical level of light intensity combined with typography which is marginal in legibility results in a cumulative effect which reduces speed of reading to a marked degree. Intensity of light must be enough above the critical level to avoid such an effect. Hence, there must be a margin of safety in any recommended practice. The following recommendations take into account the experimental findings and the need of a margin of safety. The values suggested are those which should be maintained. This means that initial installations should be somewhat higher in intensity. When dealing with illumination for effective and easy reading, the findings based upon visual acuity and visibility measurements and those computed by some formula should be discounted somewhat. To be valid, the recommendations should be based upon experiments which involved actual reading or are closely related to reading.

Light Intensities Adequate for Reading

1. For sustained reading of books or magazines printed in at least 10-point type with satisfactory leading: 15 to 25 foot-candles.

2. Illumination for ordinary schoolrooms: 20 to 30 foot-candles.

3. Illumination for sustained reading of small print such as 7 to 8-point type found in newspapers: 25 to 35 foot-candles.

4. Illumination for casual (short time) reading of (a) good book-sized type: 10 to 15 foot-candles; (b) smaller type sizes: 15 to 20 foot-candles.

5. Illumination for reading print of medium low visibility (brightness contrast of .40 to .55): 35 to 50 foot-candles.

6. Illumination for reading print of very low visibility: 75 to 100 foot-candles. It is difficult to find any reading in the home, in school, or in libraries that would require more than 50 foot-candles.

7. Illumination for eyes with less than normal visual acuity: casual reading, 25 to 30 foot-candles; sustained reading, 35 to 40 foot-candles.

8. Illumination in sight-saving classes: 50 to 60 foot-candles.

The intensity of light values suggested above are higher than those listed by Weston (237) but lower than those recommended in the various pamphlets on American recommended practice (200, 201, 212, 237). There is nothing final or absolutely exact in any list of recommended practices. However, it is desirable to have some suggestions of light intensities which will provide levels of illumination that will be adequate for efficient and easy reading for the majority of people.

Distribution of Illumination

The control of light distribution or diffusion of illumination throughout the work or reading room is of prime importance. Hygienic vision is achieved only when intensity and distribution of light are properly coordinated. It has been shown (124) that to increase the intensity of light without maintaining good distribution only makes a bad situation worse. Glare effects are increased. Failure to maintain satisfactory diffusion of light produces lessened visual efficiency, discomfort, and eyestrain. These result from glare due to poor arrangement and type of lighting fixtures, from surface reflection, and from alternation of bright areas and shadows in the visual field. The materials on this subject have been summarized by Luckiesh (206) and by Tinker (224). Good suggestions on distribution of light are found in recommended practice listings for library (201) and office (212) lighting.

The Visual Field and Glare. The uncomfortable effect of bright spots of light above or off to the side of the line of vision, while one is reading, doing other visual tasks, or even when no visual discrimination is involved, is common experience. When these side lights become brighter or are moved closer to the line of direct vision, i.e., the immediate working surface, the effect becomes greater. Visual discrimination becomes poorer, speed of reading is reduced and discomfort increases. Furthermore, the greater the number of such peripheral light sources, the more detrimental is the effect upon vision. Elimination of this disturbing peripheral illumination by reorganizing the lighting arrangement, employing more satisfactory fixtures, or shielding the eyes, is necessary if comfortable and efficient vision is to be maintained. Modern lamps, lighting fixtures, and installation practices make it possible to control or eliminate this type of glare.

The Brightness Ratio. Visual fatigue and lessened efficiency are produced by brightness contrast within that portion of the visual field where critical vision is required and also within the immediate surroundings. When the eyes must shift back and forth from bright to dark areas or when there is a sharp division between dark and bright portions of the working area, the eyes must constantly re-adapt to the different degrees of brightness. Experiments show that eyestrain, discomfort, and reduced efficiency of visual discrimination result from these conditions. Examples are: (a) White paper on a dark desk, (b) a dark undersurface of an opaque eyeshade used in a brightly illuminated room, and (c) use of a desk lamp which brightly illuminates a small portion of the working surface and leaves the rest dimly illuminated or in shadow.

The critical area, within which brightness differences are most harmful, subtends a visual angle of about 60 degrees, i.e., 30 degrees in all directions from the visual axis or fixation point at the center of the visual task such as the page of a book. The term *brightness ratio* is commonly used to denote the relation of the brightness in adjoining areas such as on a book and on the surroundings. When the surrounding area is one-third as bright as that of the immediate task (a 1 to 3 ratio), there is no noticeable discomfort or loss of efficiency. In general, brightness ratios of less than 1 to 5 are desirable, while 1 to 3 is ideal. For example, if the brightness on the page of a book is 30 foot-lamberts and that on the surrounding area 10 foot-lamberts, the ratio is 1 to 3, etc. Efficiency decreases markedly when the brightness ratio becomes much greater than 1 to 10. It is desirable to keep this ratio less than 1 to 5 if possible.

Specular Glare. Specular glare originates from specular reflection, as from a mirror. A variety of surfaces reflect light in some degree like a mirror. Striking examples are glossy, hard surface printing paper, polished chrome, or nickel steel parts of a typewriter or other objects, highly polished desk and table tops, and, worst of all, a glass-covered desk top. The reflected highlights from polished metallic objects can be very distracting. Ordinarily, specularly reflected images tend to reduce ease of seeing and visibility of critical details. Direct, poorly diffused light or a shiny printed page can produce a situation in which it is difficult to distinguish enough details to read the words. It is like a haze spread over the surface of the page.

Coordination of Decoration With Lighting. The color and brightness of painted or papered walls, of furnishings and floors should be coordinated with lighting in planning the illumination of a room or working area. A sizeable portion of the well-distributed illumination in a room should come from light reflected off the walls and furnishings. In addition, to maintain proper brightness ratios within the field of vision, the reflectances of adjoining areas must be controlled. This holds for the walls, ceilings, furnishings, and even the floor. For instance, to maintain satisfactory brightness ratios, the reflectances of surfaces and objects in schoolrooms, offices, and libraries should be in the following ranges: (a) ceilings and upper part of walls, 80 to 90 per cent; (b) walls, 45 to 60 per cent; (c) desk tops, table tops, file cabinets, business machines, 25 to 40 per cent; (d) floors, 15 to 25 per cent. In the case of chalkboards, the adjoining wall areas should be intermediate in brightness between the chalkboard and the walls; that is, the reflectances should shade off by steps to avoid a sharp demarcation between adjoining areas.

One cannot overemphasize the view that brightness contrast is about the most important factor in the hygiene of vision. Adequate visibility in reading depends upon a high brightness contrast between print and paper, and comfortable and efficient seeing depends upon maintaining satisfactory brightness ratios between adjoining areas in the field of vision.

Color harmony is a desirable psychological aspect that must be considered to provide a pleasing living environment. This is concerned with the decoration of the walls and ceiling as well as of the furnishings. Fortunately, harmonizing color combinations can be achieved while maintaining proper brightness ratios.

Avoiding Glare Effects. The following will aid in maintaining well-distributed illumination and in eliminating glare effects.

1. Avoid peripheral light sources such as wall brackets and low hanging fixtures which reach down into the field of vision and are not shielded.

2. Use lighting fixtures which are properly shielded and which diffuse the emitted light as much as possible.

3. Avoid strictly local lighting like that produced by most desk lamps with opaque shades. To obtain light of proper intensity upon the work surface, employ a general illumination of moderate brightness (about 5 to 10 foot-candles) plus local lighting on the working surface. This is more practical than trying to maintain a general illumination of high intensity throughout a room. Single lighting units which yield both general and diffused local illumination are now available.

4. Avoid as far as possible the use of glazed paper and highly polished metal objects.

5. Maintain brightness ratios of areas within the field

of vision that are not greater than 1 to 5, preferably not over 1 to 3.

6. In general, maintain as equal a distribution of light as possible over the working surface and within the immediate surrounding area.

Summary

1. Illumination should be of proper quality, intensity, and distribution to provide comfortable vision and efficient and easy reading.

2. Any illuminant in general use is as good as any other for efficiency of vision in the reading situation. Certain illuminants are preferred over others because of the unfortunate effects of some on the color of human complexions, clothing, and room decorations. Thus, light from some fluorescent tubes and mercury arc lamps destroy "soft" and "warm" appearing colors, reducing them to a harsh colorless or grayish appearance.

3. The intensity of illumination should be sufficient for efficient and easy reading. But excessive intensities are costly and serve no useful purpose. Moderate intensities of 20 to 30 foot-candles are adequate for most reading. For reading nonoptimal typographical arrangements such as small print, or material with low brightness contrast between print and paper, a brighter light is needed. The same rule holds for elderly people and for any others with less than normal visual acuity. There are few reading situations that require intensities of over 50 foot-candles of light.

4. Lighting specifications based upon visual acuity or visibility data overestimate the requirements for reading. On the other hand, specifications should not be at the critical levels discovered in speed-of-reading measurements. The specifications should be enough above the critical levels to

provide a margin of safety. Otherwise, there may be a cumulative effect of marginal conditions which seriously reduces visual efficiency.

5. To achieve effective and comfortable vision in reading, intensity and distribution of light should be coordinated. To increase intensity without maintaining well-diffused illumination only makes the situation worse.

6. Glare effects which have a deleterious action on vision occur in a number of situations: (a) peripheral light sources such as wall brackets, low hanging fixtures, and unshielded fixtures of various kinds; (b) strictly local lighting such as from many kinds of desk lamps; (c) glazed paper and highly polished metal objects; and (d) alternating bright and dark areas within the field of vision.

7. The following will aid in eliminating glare effects: (a) avoid peripheral, unshielded light sources; (b) avoid use of glazed paper and polished metal objects; (c) maintain a brightness ratio of not over 1 to 5 (preferably 1 to 3) for areas in the field of vision; (d) employ general plus local lighting for tasks which require higher intensities of illumination; and (e) maintain as even a distribution of light as possible over the working surface and in the surrounding area.

16. The Hygienic Reading Situation

THE HYGIENIC READING SITUATION involves a number of factors. Typographical arrangements of the printed material must have optimal legibility. Illumination must be of proper color, intensity, and distribution. These factors have been considered in preceding chapters. In addition, there are several other factors to be dealt with: (a) location of the light source in relation to the reader; (b) position of the reading copy in relation to the visual axis of the reader; (c) flatness of the printed copy; (d) angular alignment of the printed material; (e) vibration of the printed material; and (f) length of reading period permissible without undue fatigue.

Light Source and the Reader

The notion is commonly believed that light should come over the left shoulder when one is reading. Apparently this view originated out of consideration for the right-handed person. When writing, his hand does not cast an annoying shadow on the working surface if the light comes from the left. But when reading it is just as satisfactory to have the light at the right as at the left. The only requirement is that the light be so placed that it does not shine into the reader's eyes and so that there are no shadows on the reading material. Light sources behind the spectacled reader may cause annoying reflections in one or the other lens of his glasses. This may be avoided by properly shielding the light source and by moving the lamp more to one side.

For reading or writing at a desk, the illumination should be distributed evenly over the working surface which is ordinarily the size of a large blotter pad, i.e., 18 by 24 inches. If local lighting is used, there also should be general illumination of 5 to 10 foot-candles. The desk lamp for local lighting should be placed at the side, should be without flicker (such as occurs with some of the single-tube fluorescent lamps), and the lower edge of the shielding shade should not be over 15 inches from the desk top. Fairly satisfactory desk illumination can be obtained from a pin-to-the-wall lamp which has an opaque shade and a porcelain bowl below the bulb to diffuse the light shining through it onto the desk. The lower edge of the shade should be about 42 inches from the floor to shield the eyes from the light. In addition, there should be general illumination of about 5 to 10 foot-candles.

For reading in bed, the recommended posture (237) locates the eyes at 20 inches above the mattress. This allows the desirable 45-degree tilt (see below) of reading matter. With lamps fastened to the wall, the lower edge of the shielding is about 30 inches above the mattress. For table lamps of approved design (a single lighting unit which yields both general and local illumination), the lower edge of the shade should be at eye level, i.e., 20 inches above the mattress. The lamp should be about 22 inches out from the center of the printed page and slightly back of the plane of the reader's eyes. Additional arrangements are described in *Recommended Practice for Residence Lighting* (236).

The use of a spotlight type of illumination alone is considered unsatisfactory. The surroundings are too dark for comfortable seeing.

Illumination of reading rooms in libraries (201) has changed with the advent of new and more efficient light sources and improved installation arrangements. Modern libraries no longer depend on a low level of general illumination plus local lighting at the reading tables. The trend is towards general illumination suitable for reading. The usual practice is to employ fluorescent luminaires (hanging fixtures) or troffers (fixtures flush with the ceiling). However, tungsten filament lamps in hanging fixtures are still used in many libraries, particularly old-fashioned reading rooms with very high ceilings.

Proper Slope for the Reading Page

When printed copy is held flat, with the plane of the copy at right angles to the line of sight, the printed symbols are seen in their exact form. Through experience, some people have sensed that printed material seems easier to read when maintained in a position that does not deviate markedly from this angle. As the copy is tipped downward and away from the right-angle alignment, the geometric forms of letters become distorted in vision. The greater the slope, the greater becomes the distortion. For instance, if the reader is sitting up straight, the normal and comfortable line of vision is perpendicular to the plane of the copy when the latter is sloped about 45 degrees from the vertical. But when the copy is lying flat on the table, i.e., 90 degrees from the vertical, there is some distortion of letter forms. Many people, both children and adults, read and study with the text lying flat on a table or desk. Occasionally some people, in reading a newspaper, slope it below the horizontal, or more than 90 degrees from the vertical.

When printed symbols are distorted by sloping the text downward away from the plane that is perpendicular to the line of vision, it is probable that the legibility of print is less than optimal. Tinker (140) measured the influence of sloped text on the legibility of print in terms of speed of reading and visibility of words. The Tinker Speed-of-Reading Test was set in 10-point Excelsior type in a 20-pica line width with 2-point leading on eggshell paper stock, and also in 8-point Excelsior type in a 12-pica line width with 2-point leading on eggshell paper stock. There were 300 readers. For the visibility measurements, 16 five-letter words were cut from the test and mounted on white cards, one word per card. Visibility was measured by the Luckiesh-Moss Visibility Meter. Copy for both the speed of reading and the visibility measurements was held in the following positions by an adjustable reading stand: 45 degrees from the vertical, 90 degrees from the vertical or horizontal, —10 degrees below the horizontal, and —30 degrees below the horizontal. All reading was done under 25 foot-candles of light. Speed of reading and visibility at the 45-degree position served as the standard.

The trend of the results is as follows: (a) For 10-point type, speed of reading was retarded 5.7 per cent at the 90-degree position in comparison with the 45-degree position, 8.8 per cent at the —10-degree position, and 17.1 per cent at the —30-degree position. (b) For the 8-point type, the losses in speed of reading were similar: 8.1, 7.6, and 14.8 per cent respectively. (c) Losses in visibility were similar to losses in speed of reading. For 10-point type, they ranged from 3.4 to 31.7 per cent and for the 8-point type, 8.0 to 25.8 per cent, respectively. (d) The conclusion is that, both in terms of speed of reading and visibility, material lying flat on the table is significantly less legible than when held at 45 degrees to the visual axis.

It is now desirable to determine how far below the 45-degree position the printed page can be tipped before speed of reading is affected. Skordahl (96) completed an experiment to check this. He had his subjects read copy held at 45, 60, 75, and 90 degrees from the vertical. Otherwise, the

TABLE 16.1—Effect of Sloping Text Upon Speed of Reading 10-Point Print
(*The standard was speed of reading at the 45-degree position*)

Slant of Print in Degrees	Differences From Standard in Paragraphs*	Differences From Standard in Per Cent	Diff. / S.E. Diff.
45 (control)	0.00	0.00	0.00
60	—0.67	—1.5	1.45†
75	—2.39	—5.3	3.60‡
90	—4.42	—9.8	5.17‡

* Minus signifies less legible than the standard at 45 degrees.
† Significant at the 7 per cent level.
‡ Significant at the 1 per cent level.

procedure was the same as above, except that only material in 10 point was used. The results are presented in Table 16.1. Speed of reading at each position by 40 subjects was compared with the standard which was speed of reading at the 45-degree position.

The results show a definite trend. As the text is sloped by successive steps of 15 degrees each away from the 45-degree position toward the horizontal, the deleterious effects become greater and greater. The visibility scores showed the same trend.

The trends in these two studies are consistent with each other. Printed copy held at about 45 degrees from the vertical promotes fastest reading and is most visible. As the copy is sloped more and more toward the 90-degree position, which would be flat on a desk, both speed of reading and visibility of print decrease. These results have significant implications for schools, libraries, and other situations where reading activities take place. Provision should be made by means of sloping tables, desks, or other means for maintaining reading copy at about 45 degrees from the vertical. A few schools have sloping desk tops but ordinarily the slope is not nearly as much as 45 degrees. In any case, students should be encouraged when reading to hold their books up from the desk at an angle of approximately 45 degrees. Inexpensive book racks are available for this purpose and are being used in a few schools.

Angular Alignment and Reading Ease

When printed copy is set so that the lines run horizontally left to right, and so that they are perpendicular to the median plane of the body, eye movements in reading are relatively uncomplicated. The eyes merely move horizontally from one fixation pause to the next along a line of print. These saccadic eye movements are the most practiced oculomotor adjustments made by any person who does much reading. The interior (toward the nose) and exterior (toward the temples) eye muscles attached to the eyeball do most of the work during such movements. When the printed copy is rotated to the right or to the left away from the horizontal position, the oculomotor adjustments in reading become more complicated. The eyes have to move obliquely from one fixation pause to another along the line of print. This involves to a greater degree all of the six eye muscles attached to the eyeball, and is a more intricate and difficult type of oculomotor adjustment than merely moving right and left horizontally. Also, with the oblique alignment of printed lines, the word forms are in an unfamiliar orientation. If the printed lines run vertically, either up or down, the eye movements are not as difficult to execute as in the oblique alignment, but more difficult than in the horizontal. In addition, the unfamiliar orientation of the word forms in the vertical alignment may well hinder rapid reading.

In many reading situations, the alignment of printed lines frequently departs from the horizontal position. This occurs with both children and adults, particularly when a book or magazine is lying flat on a table or desk and the reader is taking notes. And many backbone titles of books and magazines are printed in a vertical alignment. Some of the latter have to be read upward, others downward. Any complication which interferes with smooth eye movements or visibility and hence with rapid perception is likely to retard speed of reading. To investigate these problems, Tinker (141) measured speed of reading and visibility of printed words in various angular alignments. The reading stand was sloped 45 degrees up from the horizontal. This stand, holding the reading copy, could be rotated to any angular alignment desired. The standard with which the other arrangements were compared was speed of reading and visibility of words in the horizontal alignment. There were 300 readers. Time in seconds was recorded for reading 18 paragraphs (540 words) in each arrangement. Visibility scores for five-letter words were obtained with the Luckiesh-Moss Visibility Meter. The various positions studied and the results are given in Table 16.2.

The following trends are found in the table: (a) Any considerable deviation, 45 to 90 degrees, from the horizontal arrangement of printed lines retards speed of reading and

TABLE 16.2—Effect of Angular Alignment on Speed of Reading and Visibility of Words
(Scores in each arrangement were compared with the Standard)

Alignment of Print	Per Cent Difference* From Standard in Speed	Diff. / S.E. Diff.	Per Cent Difference From Standard in Visibility	Diff. / S.E. Diff.
Horizontal (control) ...	0.0	0.00	0.0	0.00
45° Clockwise	− 51.4	15.81	−11.1	7.99
90° Read down	−203.4	13.70	−20.9	9.07
45° Counter-clockwise ..	− 53.1	13.79	−12.2	8.28
90° Read up	−206.7	17.35	−20.7	12.05

* Minus signifies less efficient than the standard arrangement. All differences are significant at the 1 per cent level.

lowers visibility of words by significantly large amounts. (b) Reading in the vertical alignment has a much greater deleterious effect than in the oblique 45-degree position. (c) In terms of both speed and visibility, it is just as easy (or just as difficult) to read upward as downward. (d) Reading obliquely from upper left to lower right, or lower left to upper right, is equally difficult.

It is likely that, in addition to reduced visibility, the retardation in speed of reading when the alignment deviates from the horizontal is due partly to the unfamiliar orientation of word forms, inability to use peripheral vision effectively, and increased complexity of the oculomotor adjustments required.

Obviously, further investigation is needed to determine precisely how much printed lines may be rotated away from the horizontal alignment before ease and speed of reading is adversely affected to a significant degree. But the results in this experiment are striking enough to make it advisable for readers, including school children, to maintain the alignment of print approximately in the horizontal position while reading.

Flat Versus Curved Print

When a printed page is lying flat, the accommodation changes required for clear seeing, as the eyes shift from fixation pause to fixation pause along a line of print, are relatively slight and do not appear to interfere with the mechanics of reading. In addition, on flat copy the word forms are clearly visible. In some books, such as thick texts, dictionaries, and bound volumes of journals, the printed material does not lie flat. There tends to be considerable curvature of the page near the inner or gutter margin. Also, some people may tilt a newspaper or book sideways while reading so that parts of the printed line are at varying distances from the eyes. Any such situations may seriously interfere with visibility and hence with clear and rapid perception.

In an initial experiment, Tinker (136) determined the effect on visibility and speed of reading when printed copy is slanted so that parts of a line are at varying distances from the eyes. The standard condition was the flat copy sloped at 45 degrees from the vertical. Performance in reading copy slanted at 45 and 60 degrees away from the flat copy was compared with the standard.

Material at the 45-degree slant was read 5.7 per cent more slowly and at the 60-degree slant 16.4 per cent more slowly than the standard flat material. The visibility scores revealed a similar trend. Visibility of words at the 45-degree slant was 31.3 per cent less than on the flat copy, and at the 60-degree slant 48.4 per cent less. Scores at the 60-degree slant were 24.9 per cent poorer than at the 45-degree slant. It is clear that reading print slanted so that various parts of a line are at different distances from the eyes reduces visibility and slows rate of reading.

Before these results can be applied to curvature of print in books, it is necessary to devise an experiment that approximates the book-reading situation. This was done in the next study (142). Brief mention of this experiment was made in Chapter 8. As before, speed of reading and visibility were measured. There were 104 subjects. A cylindrical reading stand, eight inches in diameter, was constructed so that it could be set at any position from the vertical to the horizontal. The reading material was printed in 10-point Scotch Roman type in a 19-pica line width with a 2-point leading on eggshell paper stock. For visibility measurements, 20 five-letter words were cut from the test material and mounted on 3 by 5-inch cards, one word per card. The standard situation was a flat surface sloped 45 degrees above the table top. All

TABLE 16.3—Effect of Curved Text on Speed of Reading and Visibility of Print
(The scores are for the standard situation minus those for each position shown in the table)

Position of Copy Compared With Flat, 45° (Control)	Per Cent Difference* From Standard in Speed	Diff. / S.E. Diff.	Per Cent Difference From Standard in Visibility	Diff. / S.E. Diff.
Flat, 45° (control)	0.0	0.00	0.0	0.00
Curved, 45°	– 7.2	3.35	– 9.7	5.95
Curved vertical	–11.4	3.86	–39.1	16.58
Curved Horizontal	–36.5	7.68	–20.0	8.63

* Minus indicates slower reading and poorer visibility than for the standard flat copy. All differences are significant at the 1 per cent level.

scores were compared with the standard as shown in the table. The arrangements and results are given in Table 16.3.

The results indicate that: (a) Curved printed matter was read significantly more slowly than flat text in all comparisons. The most serious retardation was from curved copy in a horizontal position. (b) Visibility was significantly less for curved text than for flat in all comparisons; the largest loss was in the vertical position. (c) The retardation in speed of reading curved text seems to be due largely to reduced visibility of word forms.

The curved text employed in this experiment is a close approximation to the practical situation found in many large books and bound journals. The results obtained indicate that the marked curvature of line of print near the inner, or gutter, margin of such volumes without doubt adversely affects speed of reading and visibility of printed words. If much wider inner margins were used, the situation would be much improved because most of the printed line would then be relatively flat. In general, the reader should try to maintain the printed page as flat as possible and at right angles to the line of vision, as well as sloping the page at about 45 degrees above the horizontal.

Effect of Vibration on Reading

All who attempt to read while riding on airplanes, trains, and buses are aware of the frequently annoying vibration of the reading material. Subjectively, it seems that the blurring caused by the vibration introduces a severe visual task which is apt to be fatiguing. In the first experiment (128), the effect of vibration on speed of reading material printed in 10-point type was determined. The vibration movement was 1/16 inch and there were five movement cycles per second. This vibration approximates that of one's book while riding on a fast train. There were 138 subjects. Each subject read without vibration for two successive 5-minute periods and then with vibration for two successive 5-minute periods. The vibration retarded speed of reading significantly, about 5 to 5.5 per cent, for each 5-minute period and for the total 10 minutes. The retardation was slightly greater during the second 5 minues. In his second experiment, Tinker (135) compared speed of reading material printed in 10-point type without vibration to speed of reading material printed in 6-point Roman type and 6-point italics without and with vibration. Each type size was printed in an optimal typographical arrangement for that size of type (see Chapter 7). Without vibration, the text in 6-point type was read 8.49 per cent more slowly than the 10-point type. With the 6-point Roman type and vibration, the retardation was 10.99 per cent; with the 6-point italics and vibration, the retardation was 14.21 per cent. The effect of the combined nonoptimal conditions, i.e., small type, italics, and vibration, appears to be cumulative in reducing speed of reading. That is, the combined effect is much greater than the effect of any one nonoptimal condition alone. In general, vibrating text is difficult to read. This difficulty is increased greatly when trying to read text in nonoptimal typography.

Length of the Reading Period

Carmichael and Dearborn (20) report an extensive investigation of reading in relation to visual fatigue. Subjects read easy and difficult material in regular book type and in projected microfilm for a continuous period of six hours. The reading was done under 16 foot-candles of light. Records of eye movements, number of pages read, and blink frequency were kept for each 30-minute period. They found no significant decrements appearing consistently in any of the recorded scores for the six hours of continuous reading of any of the materials. Except for some subjective reports of mild discomfort on the part of a few, there was no evidence that continuous reading for six hours was done at any "cost" to the subjects. As noted earlier in this report, the authors state that there seems to be no basis for the belief that requiring long periods of reading on the part of high school and college students may be injurious to the eyes, provided such students have reasonably satisfactory eyes to begin with.

It seems safe to conclude that if the typography has good legibility, adequate illumination is used, and one has approximately normal vision, long periods of reading may be done without undue fatigue or loss of efficiency.

Summary

1. The source of illumination should be so located that the light is shielded from the reader's eyes. Illumination from the light source should be spread uniformly over the immediate working surface, that is, the area in which a book, papers, or other reading materials lie. On a desk, this would include an area of about 18 by 24 inches.

2. For reading, it is optional whether light comes from the left or the right provided there are no shadows on the printed material.

3. The lower edge of the shade of a desk reading lamp should be no more than 15 inches above the desk surface.

4. When reading in bed, one's posture should be such that the eyes are about 20 inches above the mattress. For diffuse illumination coming from a table lamp or wall fixture, the lamp or fixture should be so arranged that no light shines directly into the reader's eyes. The use of a spotlight is undesirable since the dark surroundings produce a fatiguing contrast.

5. With improvement in lighting, the trend is to employ general illumination of satisfactory intensity and diffusion from ceiling fixtures (usually fluorescent) in library reading rooms and offices.

6. Printed material should be sloped at about 45 degrees from a flat table or desk top for most effective reading. Lowering the slope of the page by only 15 degrees from the 45 degree position reduces reading efficiency. When a book is flat on the table, the loss of efficiency is severe.

7. For most efficient reading, lines of print should run horizontally so that they are perpendicular to the median plane of the body. Rotating the printed page clockwise or counter-clockwise by any appreciable amount reduces reading efficiency.

8. Speed of reading is significantly slower on a curved page, like that found near the inner margin of large books and bound journals. Narrow inner margins should be abandoned.

9. Vibration of a page of print, such as occurs on a fast-moving train, slows reading by a significant amount. If typography is nonoptimal, such as small print, the retardation is even greater.

10. If one's eyes are normal, the print is legible, and the light adequate, a person can read at least six hours in a stretch without measurable signs of fatigue or loss of efficiency.

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2. Anderson, I. H., and Meredith, C. W. "The Reading of Projected Books With Special Reference to Rate and Visual Fatigue," *Journal of Educational Research,* **41** (February, 1948), pp. 453–60.

   The effects of reading microfilmed versus printed material, and of surrounding light on visual fatigue, and rate of reading were studied. The average rate of reading projected microfilm was 12% slower than that for printed material. No evidence of fatigue was found for either type of material. Microfilm was read more rapidly without surrounding light.

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   The legibility of four typographical arrangements of a telephone directory was determined. A 4-column page with 1-point leading was the most legible.

4. Bell, H. M. "The Comparative Legibility of Typewriting, Manuscript and Cursive Script: I. Easy Prose, Letters and Syllables," *Journal of Psychology,* **8** (October, 1939), pp. 295–309.

Legibility of typewriting, manuscript, and cursive script was determined. Typewriting was read significantly faster than manuscript and cursive script except for 1 and 3-syllable nonsense words in manuscript. Manuscript was read faster than cursive script, except for alphabet letters when cursive was read faster.

5. Bell, H. M. "The Comparative Legibility of Typewriting, Manuscript, and Cursive Script: II. Difficult Prose and Eye-Movement Photography," *Journal of Psychology,* **8** (October, 1939), pp. 311–20.

The comparative legibility of typewriting, manuscript, and cursive script was investigated by means of eye-movement photography. Typewriting was read more rapidly than cursive script, manuscript was read as rapidly as typewriting, and manuscript was read more rapidly than cursive script.

6. Bentley, M. "Leading and Legibility," *Psychological Monographs,* **30** (1921), pp. 48–61.

The effect of 10 different amounts of leading upon legibility of 3 type sizes at various distances was determined. Facility and rate of reading depended, at least partially, on leading. Unleaded material was read relatively slowly. Reading rate increased with additional leading up to 7 point, and then rapidly declined.

7. Berger, C. "Stroke-width, Form and Horizontal Spacing of Numerals as Determinants of the Threshold of Recognition," *Journal of Applied Psychology,* **28** (June and August, 1944), pp. 208–31, 336–46.

The effect of certain typographical variations upon the threshold of recognition of numerals as applied to vehicle license plates was determined. For white numerals on black, 6 millimeters was the optimal stroke width, and for black on white, 10 millimeters was optimal. Single white numerals were 8.2% more recognizable than optimally constructed black numerals of the same area.

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The influence of width of numbers 0 and 5 on visibility was determined. Legibility generally increased with increases in width.

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The influence of height in relation to various widths of certain symbols upon legibility was investigated. The threshold of legibility increased slightly less than proportionally as a function of height. Effects of width varied with height and the symbol used.

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The visibility of print on 16 different papers was compared. A new experimental paper, Facilex, would appear, for practical purposes, to produce as much type visibility as the "white" paper now used in basal readers.

11. Bitterman, M. E. "Electromyographic Recording of Eyelid Movements," *American Journal of Psychology,* **58** (January, 1945), pp. 112–13.

Weaknesses of photographic and direct observation methods of recording eye movements were discussed. A new electromyographic method of recording eye movements which amplifies and records muscle potentials arising from the *orbicularis oculi* was described. The new method allows freedom of movement and may prove to be a useful technique for the conditioned eyelid response.

12. Bitterman, M. E. "Heart Rate and Frequency of Blinking as Indices of Visual Efficiency," *Journal of Experimental Psychology,* **35** (August, 1945), pp. 279–92.

The effects of type size and illumination on heart and blink rates were determined. Both criteria failed to show any reliable and expected differences and thus failed to support Luckiesh and Moss's conclusions on the value of these criteria as indices of the ease of visual work.

13. Bitterman, M. E. "A Reply to Dr. Luckiesh," *Journal of Experimental Psychology,* **36** (April, 1946), pp. 182–84.

Bitterman justifies techniques used by him and statements made in previous studies that were criticized by Luckiesh. The author concludes that Luckiesh should re-examine his experimental procedures and re-evaluate his experimental conditions.

14. Bitterman, M. E., and Soloway, E. "The Relation Between Frequency of Blinking and Effort Expended in Mental Work," *Journal of Experimental Psychology,* **36** (April, 1946), pp. 134–36.

Blink rates under quiet and distracting conditions were compared. Blink frequency bore no relation to task difficulty, and no tendency for muscular tension to influence frequency of blinking was indicated.

15. Bitterman, M. E., and Soloway, E. "Minor Studies from the Psychological Laboratory of Cornell University, XCIII. Frequency of Blinking as a Measure of Visual Efficiency: Some Methodological Considerations," *American Journal of Psychology,* **59** (October, 1946), pp. 676–81.

This study attempts to duplicate conditions in the Luckiesh study of glare using the blink technique. The results did not agree with those obtained by Luckiesh, and the authors concluded that the value of blink rate as an index of visual efficiency must be denied at present.

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A short-exposure technique was used to compare the legibility of single-column headlines printed in all capitals and lower case. The all capitals retarded reading by 18.9%.

17. Bryan, A. I. "Legibility of Library of Congress Cards and Their Reproductions," *College and Research Libraries,* **6** (September, 1945), pp. 447–64.

Speed and accuracy of transcribing foreign and English materials from Library of Congress cards and reproductions of the cards in bound volume form were compared. Only 85% as much material was transcribed in the same amount of time from reproductions as from cards, and more errors were also made when working from reproductions. English materials were easier to transcribe than foreign, and readers' opinions favored L. C. cards.

18. Burtt, H. E., and Basch, C. "Legibility of Bodoni, Baskerville Roman, and Cheltenham Type Faces," *Journal of Applied Psychology,* **7** (September, 1923), pp. 237–45.

The comparative legibility of upper case and lower case individual letters of the three type faces was studied. The letters were scored in terms of the distance they could be thrown out of focus and still be recognized. In general, the order of legibility for both upper and lower case was, first, Cheltenham, then Baskerville, and Bodoni.

19. Burtt, H. E., Beck, H. C., and Campbell, E. "Legibility of Backbone Titles," *Journal of Applied Psychology,* **12** (April, 1928), pp. 217–27.

Three styles of printing backbone titles were compared. Printing upward was inferior to printing downward or printing downward with letters in an upright position. Printing downward provided for quick recognition or selection of a single title, and printing downward with upright letters should receive more consideration.

20. Carmichael, L., and Dearborn, W. F. *Reading and Visual Fatigue.* Boston: Houghton Mifflin Co., 1947, pp. 206–451.

Visual fatigue during long periods of reading book print and microfilm was studied using blink frequency and eye-movement measures. No significant decrements or changes occurred with prolonged reading. For normal adults and high school students with adequate vision, no harm to the eyes will result from long periods of reading. This book also contains a fine survey of studies dealing with legibility of print.

21. Crosland, H. H., and Johnson, G. "The Range of Apprehension as Affected by Inter-Letter Hair-Spacing and by the Characteristics of Individual Letters," *Journal of Applied Psychology,* **12** (February, 1928), pp. 82–124.

The effect of ½-point inter-letter spacing and of position in the group and characteristic form on legibility of letters was studied. Inter-letter spacing did not appreciably affect legibility. Legibility of individual letters in a group of 10, decreased consistently as position in the group progressed from left to right. Serifed letters were significantly more legible than unserifed letters.

22. Dearborn, W. F. "The Psychology of Reading: Chapter XII. The Length of Text-lines and Motor Habits," *Archives of Philosophy, Psychology and Scientific Methods,* 4 (March, 1906), pp. 8, 13–14, 99–115.

The effects of variations in line width on eye movements in reading were determined. In short lines more fixations were required to read the same amount of material, the attention span was smaller and pause duration was less. Line length was a major determinant of the distribution of time spent on parts of a sentence. Regular, uniform motor habits were more readily formed in short lines, and the field of attention could be expanded more frequently and easily.

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The extent of the visual field for alphabetical letters and the relative legibility of the letters were determined. The question of whether or not part of a line of print must be filled in by context when all of the line is perceived was also studied. The span of distinct vision for 10-point letters was between 20 and 22 millimeters on either side of the fixation point. The broad alphabet letters tended to be most legible.

24. English, E. "A Study of the Readability of Four Newspaper Headline Types," *Journalism Quarterly,* **21** (September, 1944), pp. 217–29.

Three-line headlines in Bodoni Bold, Karnak Bold, and Tempo Medium type faces were compared by the short-exposure method. Condensed and regular versions of Cheltenham Bold were also compared. Bodoni and Tempo were read significantly faster and with half as many errors as Karnak. Cheltenham (regular) and Cheltenham Condensed were both easier to read than all capitals.

25. Gilliland, A. R. "The Effect on Reading of Changes in the Size of Type," *Elementary School Journal,* **24** (October, 1923), pp. 138–46.

Changes in reading with variation in type size were investigated. Reading of average adults was not greatly affected by changes in type size between 6 and 36 point, and individual variations in the effects of type size were numerous. Type size is not as important a factor in the reading of children as has sometimes been supposed.

26. Glanville, A. D., Kreezer, G. L., and Dallenbach, K. M. "The Effect of Type-Size on Accuracy of Apprehension and Speed of Localizing Words," *American Journal of Psychology,* **59** (April, 1946), pp. 220–35.

This study determined accuracy of apprehension and speed of location for dictionary words printed in 6 and 12-point types. Setting vocabulary words in 12-point boldface is better than 6-point boldface as words may be more quickly and easily located. Adults and children both preferred the larger type size.

27. Gould, P. N., Raines, L. C., and Ruckmick, C. A. "The Printing of Backbone Titles on Thin Books and Magazines, *Psychological Monographs,* **30** (1921), pp. 62–76.

Relative rates of reading printed titles from top to bottom and from bottom to top were determined. Slight and inconsistent results yielded comparatively little evidence in favor of printing backbone titles uniformly from top to bottom or from bottom to top.

28. Greene, E. B. "The Legibility of Typewritten Material," *Journal of Applied Psychology,"* **17** (December, 1933), pp. 713–28.

Speed of reading 7, 10, 12, and 14-point typewriter types with variations in line width and leading was determined. For different type sizes no differences in speed and accuracy of reading were obtained. Leaded samples were read 3.3% faster than set solid samples, and a 21-pica line was read 1.1% faster than a 41-pica line.

29. Greene, E. B. "The Relative Legibility of Linotyped and Typewritten Material," *Journal of Applied Psychology,* **18** (October, 1934), pp. 697–704.

The speeds of reading 7 and 10-point Ionic Linotype, and American Typewriter type were compared. The differences were small and unreliable. Seven-point Linotype was slightly more legible and 10-point type slightly less legible than American Typewriter in the same type sizes.

30. Griffing, H., and Franz, S. I. "On the Condition of Fatigue in Reading," *Psychological Review,* **3** (September, 1896), pp. 513–30.

A comprehensive study was made of the physical conditions causing visual fatigue. Type size was the all-important factor, and legibility increased with increases in type size. The lowest limit to size of type in common use should be 1.5 millimeters in height. Low illumination levels caused great fatigue and 100 candle-meters was considered a safe limit. The use of leading and white paper in contrast to colored papers was recommended.

31. Hackman, R. B., and Tinker, M. A. "Effect of Variations in Color of Print and Background Upon Eye Movements in Reading," *American Journal of Optometry and Archives of the American Academy of Optometry,* **34** (July, 1957), pp. 354–59.

Eye movements were photographed during the reading of various color combinations of print and background. Black on yellow, red on white, green on red, and black on white provided best legibility. Brightness contrast was the important determinant of legibility.

32. Hoffman, A. C. "Eye-Movements During Prolonged Reading," *Journal of Experimental Psychology*, **36** (April, 1946), pp. 95–118.

A study was made of the effect of prolonged reading on eye movements. The number of fixations made and number of lines read decreased during the 4-hour period, whereas the number of blinking movements increased.

33. Hoffman, A. C., Wellman, B., and Carmichael, L. "A Quantitative Comparison of the Electrical and Photographic Techniques of Eye-Movement Recording," *Journal of Experimental Psychology*, **24** (January, 1939), pp. 40–53.

A comparison of the corneal reflection photographic technique and an electrical method involving changes in the corneo-retinal potential for recording eye movements was made. Constancy of changes in the corneo-retinal potential, and correlation with absolute degree of ocular excursion, make this method a reliable and satisfactory technique for various psychological studies.

34. Hollingworth, H. L. *Advertising and Selling*. New York: D. Appleton & Co., 1920, pp. 76–78.

Contrast was discussed as a mechanical attention-attracting device and the greater attention value of black on white explained. Black on white and white on black show no differences in legibility or acuity. The greater attention value of black on white is probably due to the association of *dark spaces* with objects, and *light spaces* with background and the special notice usually given to objects.

35. Holmes, G. "The Relative Legibility of Black Print and White Print," *Journal of Applied Psychology*, **15** (June, 1931), pp. 248–51.

The distance method was used to determine the legibility of 10-point type in black on white and in white on black. The legibility of the black on white was 14.7% greater than that of white on black.

36. Hovde, H. T. "The Relative Effect of Size of Type, Leading and Context, Part I," *Journal of Applied Psychology,* **13** (December, 1929), pp. 600–629.

The relative effects of type size, leading, and context on the legibility of Intertype Ideal News Face Type were studied. Context was a more important factor in its effect on reading rate than sensory materials. (See 37.)

37. Hovde, H. T. "The Relative Effect of Size of Type, Leading and Context, Part II," *Journal of Applied Psychology,* **14** (February, 1930), pp. 63–73.

Reader preferences for different type settings and reasons for their preferences are given. Readers tend to prefer larger type faces and more leading, but their preferences and legibility opinions differ from amount of reading as measured by the reading rate. (See 36.)

38. Huey, E. B. "Preliminary Experiments in the Physiology and Psychology of Reading," *American Journal of Psychology,* **9** (July, 1898), pp. 575–86.

Physiological and psychological occurrences during reading were studied. Horizontal sense material was read more rapidly than vertical. First parts of words were more important in word recognition than last parts. Eye movements can be measured mechanically and objectively, and the eyes do not travel the entire length of the line while reading.

39. Kirschmann, A. "Über die Erkennbarkeit geometrischer Figuren und Schriftzeichen im indirekten Sehen," *Archiv für die Gesamte Psychologie,* **13** (December, 1908), pp. 352–88.

The relative perceptibility (legibility) of black symbols on white versus white symbols on black was determined by the method of campimetry. White symbols on black were uniformly perceived more readily than black on white.

40. Kuntz, J. E., and Sleight, R. B. "Effect of Target Brightness on 'Normal' and 'Subnormal' Visual Acuity," *Journal of Applied Psychology,* **33** (February, 1949), pp. 83–91.

This study attempted to determine whether the amount of increase in visual acuity with increase of target brightness differs for persons with "normal" and "subnormal" visual acuity. "Subnormal" subjects gained significantly more in terms of visual acuity with increases in target brightness than did "normal" subjects. Adequate light for seeing details would be between 10 and 30 foot-lamberts for persons with normal vision and somewhere between 30 and 40 foot-lamberts for those with subnormal vision.

41. Lansdell, H. "Effect of Form on the Legibility of Numbers," *Canadian Journal of Psychology,* **8** (June, 1954), pp. 77–79.

The legibility of a newly devised angular form of numerals was compared with that of Mackworth numbers and the Mound revision of Mackworth numbers. With some practice, the new numerals proved to be better than the accepted standard.

42. Luckiesh, M. *Light and Color in Advertising and Merchandising.* Chapter XIV. Electrical Advertising. New York: D. Van Nostrand Co., 1923, pp. 246–51.

Important factors in the preparation of poster boards and signs and studies on the legibility of color combinations of print and background were discussed. Condensation of ideas, type size, and simplicity, color contrast and brightness contrast are of special importance in poster boards and signs. Most legible combinations of print and background at a distance were: Black on yellow, green on white, red on white, and blue on white.

43. Luckiesh, M. "Discussion: Comments on Criteria of Ease of Reading," *Journal of Experimental Psychology,* **36** (April, 1946), pp. 180–82.

Luckiesh discussed factors in the readability studies of Bitterman and McNally which may have resulted in conclusions different from his own. The choice of subjects, experimental task, techniques of measurement, and surrounding conditions were discussed. Attempts to reproduce Luckiesh's results must involve the careful reproduction of his techniques and procedures.

44. Luckiesh, M. "Reading and the Rate of Blinking," *Journal of Experimental Psychology,* **37** (June, 1947), pp. 266–68.

By a comparison of methods and procedures used by Luckiesh and other investigators in determining rate of reflex blinking, the author attempted to prove validity of the technique. As comparable investigations showed somewhat similar trends, the author concluded that blink rate is a valid criterion of ease of seeing when procedures similar to his are used.

45. Luckiesh, M., and Moss, F. K. "The Effect of Visual Effort Upon the Heart-Rate," *Journal of General Psychology,* **13** (July, 1935), pp. 131–39.

Heart-rate was determined under conditions varying in duration and severity. Heart-rate decreased as duration and severity of the visual task increased. Heart-rate and muscular tension were so related as to suggest common origin.

46. Luckiesh, M., and Moss, F. K. "Visibility: Its Measurement and Significance in Seeing," *Journal of the Franklin Institute,* **220** (October, 1935), pp. 431–66

The rationale behind the development of the Luckiesh-Moss Visibility Meter and its visibility and recommended foot-candle scales were presented. The basic research, the calibration, and use of the meter were discussed.

47. Luckiesh, M., and Moss, F. K. "The Relative Visibility of Print in Terms of Illumination Intensity," *Sight-Saving Review,* **5** (December, 1935), pp. 272–80.

The Luckiesh-Moss Visibility Meter and a study on the relation of illumination intensity to type size were discussed. About 3½ times as much illumination was required to make 6-point Bodoni type as visible as 12 point. Deficiencies in type sizes between 6 and 12 point can be compensated for by increases in illumination.

48. Luckiesh, M., and Moss, F. K. "The Visibility of Various Type Faces," *Journal of the Franklin Institute,* **223** (January, 1937), pp. 77–82.

The relative visibility of 20 type faces and the effect of changes in illumination on visibility were determined. Garamond Bold was the most visible and Caslon Light Italic the least visible. Increases in illumination could compensate for deficiencies in visibility in type sizes between 6 and 12 point, and for various type faces.

49. Luckiesh, M., and Moss, F. K. "The Eyelid Reflex as a Criterion of Ocular Fatigue," *Journal of Experimental Psychology,* **20** (June, 1937), pp. 589–96.

Blink rate was determined under varying conditions to test the hypothesis that it may be correlated with factors pertaining to the expenditure of energy in seeing. Blink rate appeared to be dependent on the duration and severity of visual tasks and increased with the severity of the task.

50. Luckiesh, M., and Moss, F. K. "Effects of Leading on Readability," *Journal of Applied Psychology,* **22** (April, 1938), pp. 140–60.

The legibility of 10-point Linotype Textype with 0, 1, 2, 3, and 6-point leading was determined by several speed-of-reading criteria and eye-blink frequency. All speed-of-reading criteria failed to show any significant differences with variations in leading. The eye-blink technique indicated that the practical optimum in readability was with 3-point leading.

51. Luckiesh, M., and Moss, F. K. "Visibility and Readability of Print on White and Tinted Papers," *Sight-Saving Review,* **8** (June, 1938), pp. 123–34.

The visibility of print on 10 papers was compared and speed of reading, rate of blinking; and reader preferences compared for 4 papers. All criteria showed red to be inferior to other papers; readers preferred white and disliked yellow and red.

52. Luckiesh, M., and Moss, F. K. "The Quantitative Relationship between Visibility and Type Size," *Journal of the Franklin Institute,* **227** (January, 1939), pp. 87–98.

Certain quantitative relationships between type size and visibility were determined by precise laboratory measurements. The Luckiesh-Moss Visibility Meter scale can be used to determine to what degree a certain type provides visibility.

53. Luckiesh, M., and Moss, F. K. "Frequency of Blinking as a Clinical Criterion of Ease of Seeing," *American Journal of Ophthalmology,* **22** (June, 1939), pp. 616–21.

Rate of reflex blinking was studied under various experimental conditions. The authors concluded that blink rate is an extremely sensitive criterion of ease of seeing, and may also serve as a valuable ophthalmological clinical criterion.

54. Luckiesh, M., and Moss, F. K. "The Readability of Stencil-Duplicated Materials," *Sight-Saving Review,* **9** (December, 1939), pp. 3–12.

Visibility and readability of average and superior grades of stencil-duplicated materials were compared. Visibility of the average specimens was approximately 70% of that which might be achieved by the best stencil-duplicating processes. Both readability (blink rate) and speed of reading showed an advantage for superior material.

55. Luckiesh, M., and Moss, F. K. "The Visibility and Readability of Printed Matter," *Journal of Applied Psychology,* **23** (December, 1939), pp. 645–59.

Visibility was determined for 7 modern 10-point types and blink rate and speed of reading determined for 3 types. Blink frequency decreased as visibility increased. Speed-of-reading differences were less decisive than those for blink rate, and the authors concluded that involuntary blinking was a more valid criterion of readability than speed of reading.

56. Luckiesh, M., and Moss, F. K. "Boldness as a Factor in Type-Design and Typography," *Journal of Applied Psychology,* **24** (April, 1940), pp. 170–83.

Visibility, blink rate, and speed-of-reading measurements were obtained for 10-point Memphis Light, Medium, Bold, and Extra Bold types. Visibility and blink-rate measurements indicated that Memphis Medium was the optimum degree of boldness. Results for speed of reading were quite small and confirmed the authors' opinions that reading speed is an insensitive and inadequate criterion for appraising readability.

57. Luckiesh, M., and Moss, F. K. "Criteria of Readability," *Journal of Experimental Psychology,* **27** (September, 1940), pp. 256–70.

The rate of involuntary blinking and the speed of reading were appraised as measures of readability. Due to conflicting results, the authors concluded that the normal rate of reading was a less sensitive indication of readability than blink rate.

58. Luckiesh, M., and Moss, F. K. "The Effect of Line Length on Readability," *Journal of Applied Psychology,* **25** (February, 1941), pp. 67–75.

Blink rate, eye movements, and speed-of-reading measurements were compared for 10-point Textype in 13, 17, 21, 25, and 29-pica line widths. According to blink-rate results, readability increased as line width was increased from 13 to about 21 picas. Eye movements and speed of normal reading are considered inadequate criteria of readability as they do not show perfectly correlated or as large differences as the rate of reflex blinking.

59. Luckiesh, M., and Moss, F. K. "The Visibility of Print on Various Qualities of Paper," *Journal of Applied Psychology,* **25** (April, 1941), pp. 152–58.

Visibility of print on 9 grades of so-called "white" paper was determined. The degrees of visibility obtained with various grades and finishes of white papers were not radically different when an optimum quality of printing was used. It appeared that a possible advantage of extreme "whiteness" of paper is unimportant from the viewpoint of visibility.

60. Luckiesh, M., and Moss, F. K. "The Extent of the Perceptual Span in Reading," *Journal of General Psychology,* **25** (October, 1941), pp. 267–72.

The effects of variation in type size and line width on the perceptual span in reading were studied. The numbers of characters per fixation decreased from 8.50 to 7.84 as type size was increased from 4 to 10 points, and the span increased from 8.14 to 9.31 characters as line width was increased from 13 to 29 picas. The number of characters recognized in a "typical" fixation appeared to be substantially independent of type size and line width.

61. Luckiesh, M., and Moss, F. K. "Visual Tasks in Comic Books," *Sight-Saving Review,* **12** (March, 1942), pp. 19–24.

Visibility of average and superior grades of comic books was compared. In general, average specimens were far more severe visual tasks than superior grades, although both fell short of being suitable printed material for children. Dark-colored backgrounds and small type sizes should be abandoned.

62. Lyon, O. C. "The Telephone Directory," *The Bell Telephone Quarterly,* **3** (July, 1924), pp. 175–85.

The legibility of existing telephone directories with special reference to alphabetical sections was studied. The 6-point type in 4-column directories was satisfactory but the 7-point type used in 2 and 3-column directories needs redesigning.

63. McFarland, R. A., Holway, A. H., and Hurvich, L. M. *Studies of Visual Fatigue.* Part V. Ordinary Blinking and Visual Fatigue. Boston: Graduate School of Business Administration, Harvard University, April, 1942, pp. 71–86.

The authors checked the claim of Luckiesh and Moss that blink frequency is a good measure of visual fatigue and ease of seeing. Blink rate did not necessarily increase with task duration, and hence blink rate was not established as a measure of fatigue or ease of seeing.

64. Miyake, R., Dunlap, J. W., and Cureton, E. E. "The Comparative Legibility of Black and Colored Numbers on Colored and Black Backgrounds," *Journal of General Psychology,* **3** (April, 1930), pp. 340–43.

A study to determine the relative legibility of numerals 1 to 9 typewritten in black on red, yellow, or white backgrounds, and traced in red, green, yellow, or white ink on a black background. Brightness difference between symbol and background appeared to be an important determinant of legibility. Poorest legibility occurred with black numbers on a red background and red numbers on a black background.

65. Nelson, L. P. *Employee Handbook Printing Practices.* Minneapolis: Industrial Relations Center, University of Minnesota, January, 1949, pp. 27.

Employee handbooks were evaluated by means of typographical criteria for promoting maximum readability. A considerable number of nonoptimal practices were found, and it would appear that editors of handbooks have attempted to prepare attractive and effective manuals without an awareness of optimal printing arrangements.

66. Newland, T. E. "A Study of the Specific Illegibilities Found in the Writing of Arabic Numerals," *Journal of Educational Research,* **21** (March, 1930), pp. 177–85.

Frequency and types of illegibilities occurring in the writing of Arabic numerals were determined. Adults wrote arabic numerals illegibly about twice as often as elementary or high school students. Certain numerals were frequently written illegibly.

67. Newland, T. E. "An Analytical Study of the Development of Illegibilities in Handwriting from the Lower Grades to Adulthood," *Journal of Educational Research,* **26** (December, 1932), pp. 249–58.

Forms and frequencies of various handwriting illegibilities were analyzed for different age levels. Four types of letter malformation caused over 50% of the illegibilities. Illegibility frequency tended to increase with age.

68. North, A. J., and Jenkins, L. B. "Reading Speed and Comprehension as a Function of Typography," *Journal of Applied Psychology,* **35** (August, 1951), pp. 225–28.

This study compares speed of reading and comprehension of material in three styles of typography: (a) standard arrangement, (b) spaced into thought units, and (c) a square-block arrangement employing the principles of "square span and spaced unit."

69. Ovink, G. W. *Legibility, Atmosphere-Value and Forms of Printing Types.* Leiden: A. W. Sitjthoff's Uitgeversmaatschappij N. V., 1938, pp. 1–106.

A short-exposure technique was used to study the legibility of lower-case letters of uniform stroke, and of upper and lower-case display types. Detailed results for each character and suggestions for maintaining or improving legibility of single letters and numbers were given. This book also contains a fairly extensive survey and evaluation of experimental studies on the legibility of print.

70. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: II. Size of Type," *Journal of Applied Psychology,* 13 (April, 1929), pp. 120–30.

Speed of reading 6, 8, 10, 12, and 14-point types in a constant 19-pica line was determined. Six, 8, 12, and 14-point types were read more slowly than the 10-point standard. For a 19-pica line set solid, 10-point type is thus the optimum size of type for efficient reading.

71. Paterson, D. G., and Tinker, M. A. "Time-Limit vs. Work-Limit Methods," *American Journal of Psychology,* 42 (January, 1930), pp. 101–4.

The question of whether the time-limit and work-limit methods of administering speed tests are equivalent and interchangeable was studied. The two methods agreed with each other as closely as each method agreed with itself, thus demonstrating equivalence of the methods.

72. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: IV. Effect of Practice on Equivalence of Test Forms," *Journal of Applied Psychology,* 14 (June, 1930), pp. 211–17.

The effect of practice on the equivalence of Forms A and B of the Chapman-Cook Speed-of-Reading Tests was studied. Equivalence between the two forms can only be assumed when the tests are administered to subjects who have had no previous experience with them.

73. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: VI. Black Type versus White Type," *Journal of Applied Psychology,* **15** (June, 1931), pp. 241–47.

Speed of reading black print on a white background and white print on a black background was compared. White on black retarded reading speed by 10.5%, indicating that when white on black is used to attract attention, the amount of reading text should be minimal.

74. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: VIII. Space Between Lines or Leading," *Journal of Applied Psychology,* **16** (August, 1932), pp. 388–97.

Speed of reading 10-point type with 0, 1, 2, or 4-point leading was determined. In comparison with solid setting, 1-point leading did not facilitate reading speed, 2-point leading was read 7.5% faster, and 4-point leading 5.0% faster.

75. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: X. Style of Type Face," *Journal of Applied Psychology,* **16** (December, 1932), pp. 605–13.

The relative legibility of the following type faces was determined: Scotch Roman, Garamond, Antique, Bodoni, Old Style, Caslon Old Style, Kabel Light, Cheltenham, American Typewriter, and Cloister Black. American Typewriter and Cloister Black significantly retarded speed of reading, but the other type faces in common use were equally legible.

76. Paterson, D. G., and Tinker, M. A. "Studies of Typographical Factors Influencing Speed of Reading: XII. Printing Surface," *Journal of Applied Psychology,* **20** (February, 1936), pp. 128–31.

Speed of reading materials on 3 different papers was determined. All 3 paper surfaces produced equally legible material. Slight differences in color of printing surface and striking differences in degree of gloss do not influence reading speed.

77. Paterson, D. G., and Tinker, M. A. "The Part-Whole Proportion Illusion in Printing," *Journal of Applied Psychology,* **22** (August, 1938), pp. 421–25.

Readers estimated the percentage of total page space devoted to print in typical book printing, and the percentage of cards covered by various amounts of black and white. Readers believed that, on the average, 75% of the page is devoted to print whereas a 50% rule is followed in actual practice. This discrepancy is due to the part-whole illusion.

78. Paterson, D. G., and Tinker, M. A. "Influence of Line Width on Eye Movements," *Journal of Experimental Psychology,* **27** (November, 1940), pp. 572–77.

Oculomotor patters employed in reading an excessively short 9-pica line and an excessively long 43-pica line were compared to those for an optimum 19-pica line. Less efficient reading occurred with the very long and very short lines. The primary difficulty in reading the short line appeared to be due to inability to make maximum use of horizontal perceptual cues, and in the long line to inaccuracy in relocating the beginning of each new line.

79. Paterson, D. G., and Tinker, M. A. *How to Make Type Readable.* Harpers, 1940, pp. xix–209.

Results of 12 years of research on legibility of print as measured by speed-of-reading tests are summarized. Legibility factors studied included kinds of type — different type styles, italics versus lower case, all capitals versus lower case, boldface versus ordinary lower case; size of type, width of line and leading, and the relationships between two or more of these factors; spatial arrangements of the printed page, including size of full page, size of printed page, margins, single versus double column composition, intercolumnar spaces and rules, and paragraph arrangement; black versus white print; color of print and background, and color combinations; printing surfaces; and optimal versus nonoptimal printing arrangements for three type sizes.

80. Paterson, D. G., and Tinker, M. A. "Influence of Size of Type on Eye Movements," *Journal of Applied Psychology,* **26** (April, 1942), pp. 227–30.

Oculomotor patterns when reading excessively small 6-point type and unusually large 14-point type were compared to patterns for medium 10-point type. Ten-point type was read more efficiently than 6 or 14 point. The reduced efficiency with 6-point type appeared to be due to reduced visibility. For 14-point type, reduced efficiency was primarily due to the increased amount of printing area that had to be covered in reading a given amount of text.

81. Paterson, D. G., and Tinker, M. A. "Influence of Line Width on Eye Movements for Six Point Type," *Journal of Educational Psychology,* **33** (October, 1942), pp. 552–55.

Eye movements were photographed for 6-point type in 5, 36, and 13-pica line widths. The reading of excessively short or long lines was less efficient than the reading of moderate 13-pica lines. Difficulty in reading short lines was attributed to the inability to make maximum use of horizontal peripheral cues, and difficulty in long lines to inability of the eyes to locate accurately the beginning of successive lines of print.

82. Paterson, D. G., and Tinker, M. A. "Eye Movements in Reading Type Sizes in Optimal Line Widths," *Journal of Educational Psychology,* **34** (December, 1943), pp. 547–51.

Eye-movement records of 6, 8, and 11-point types in optimal line widths were compared. For 8 versus 11-point type there were significant increases in fixation frequence, pause duration, and perception time, and a decrease in words per fixation. For 6 versus 11-point type there were significant increases in pause duration and perception time.

83. Paterson, D. G., and Tinker, M. A. "Eye Movements in Reading Optimal and Non-Optimal Typography," *Journal of Experimental Psychology,* **34** (February, 1944), pp. 80–83.

Eye movements in reading optimally arranged 10-point type were compared with eye movements for nonoptimal 6-point type. The nonoptimal arrangement resulted in highly significant differences in all eye-movement measures except pause duration, and these were larger than those obtained with any single variable. It appears that when several undesirable typographical factors are combined, they operate together to produce inefficient oculomotor patterns

84. Paterson, D. G., and Tinker, M. A. "Readability of Newspaper Headlines Printed in Capitals and Lower Case," *Journal of Applied Psychology*, **30** (April, 1946), pp. 161–68.

The authors summarized three studies done by their students dealing with the relative legibility of newspaper headlines set in lower case and in all capitals. All three studies indicated that lower-case headlines were more legible than all-capital headlines.

85. Paterson, D. G., and Tinker, M. A. "The Relative Readability of Newsprint and Book Print," *Journal of Applied Psychology*, **30** (October, 1946), pp. 454–59.

The speed of reading 10-point Cheltenham book print was compared with the speed of reading 7-point Ionic No. 5, and 8-point Opticon newsprint. Book print was read significantly faster than both types of newsprint and also was judged to be more pleasing.

86. Paterson, D. G., and Tinker, M. A. "Influence of Leading Upon the Readability of Newspaper Type," *Journal of Applied Psychology*, **31** (April, 1947), pp. 160–63.

The speed of reading and readers' opinions of legibility were obtained for 7-point Ionic No. 5 newsprint with 0, 1, 2, 3, 4, 5, 7, and 9-point leading. Type with 4 or 5-point leading was most legible, and 1-point leading most practical. Readers considered the material read the fastest to be most legible.

87. Paterson, D. G., and Tinker, M. A. "The Effect of Typography Upon the Perceptual Span in Reading," *American Journal of Psychology*, **60** (July, 1947), pp. 388–96.

Eight studies were conducted to determine the effect of various typographical factors on the perceptual span in reading. Eye-movement patterns were compared for variations in type size, type form, line width, etc. Typographical variation was shown to be an important determinant of the perceptual span.

88. Perry, D. K. "Speed and Accuracy of Reading Arabic and Roman Numerals," *Journal of Applied Psychology,* **36** (October, 1952), pp. 346–47.

Speed and accuracy of reading various sizes of Arabic and Roman numerals were compared. In all cases Arabic numerals were read significantly faster and more accurately than Roman numerals, and absolute and relative differences increased as the numbers got larger. For most purposes the use of Arabic rather than Roman numerals would seem desirable.

89. Pratt, C. C. "A Note on the Legibility of Items in a Bibliography," *Journal of Applied Psychology,* **8** (April, 1924), pp. 362–64.

The optimal position for a suffix to dates in bibliographical references for quick legibility was found to be the one in which the letter suffix was above the line and separated from the date by a space.

90. Pressey, L. C., and Pressey, S. L. "Analysis of Three Thousand Illegibilities in the Handwriting of Children and of Adults," *Educational Research Bulletin,* **6** (September, 1927), pp. 270–73, 285.

Type and frequency of malformations of handwriting and particular letters involved which adversely affect legibility were studied. Twenty characteristics interfering with legibility were found. Five specific malformations accounted for a quarter of the difficulties.

91. Preston, K., Schwankl, H. P., and Tinker, M. A. "The Effect of Variations in Color of Print and Background on Legibility," *Journal of General Psychology,* **6** (April, 1932), pp. 459–61.

The distance method was used to investigate the effect of 10 variations in color of print and background on the perceptibility of isolated words. In general, the greater the luminosity or brightness contrast between symbol and background, the greater was the legibility of the print.

92. Pyke, R. K. *Report on the Legibility of Print.* London: H. M. Stationery Office, September, 1926, pp. 123.

Relative legibility of 8 type faces was determined. The least legible types (Modern Condensed No. 39 and Caslon Modern Series No. 23) were 70% poorer than the best (Old Style No. 2). There must be marked differences in type faces to produce significant differences in legibility in ordinary reading. This book also contains an excellent summary of literature on the legibility of print appearing prior to 1926.

93. Roethlein, B. E. "The Relative Legibility of Different Faces of Printing Types," *American Journal of Psychology,* **23** (January, 1912), pp. 1–36.

The distance method was used to determine the legibility of isolated and grouped alphabet letters in 26 different type faces. Certain type faces were more legible than others and certain letters more legible than others. Legibility was attributed to letter form (least important), letter size, heaviness of type face, width of white margin surrounding letter, position of letter in letter group, and shape and size of adjacent letters.

94. Sanford, E. C. "The Relative Legibility of the Small Letters," *American Journal of Psychology,* **1** (May, 1888), pp. 402–35.

The effect of word form on legibility and the relative legibility of small alphabet letters were determined. Orders of legibility differed with method used. Legibility could be improved by increase in size, increase in differences between letters, simplicity of outline, concentration of differences on one particular characteristic, and short-triangular serifs.

95. Scott, W. D. *The Theory of Advertising.* Chapter VIII. Psychological Experiment. (Legibility of a Time Table.) Boston: Small, Maynard & Co., 1903, pp. 119–29.

The relative legibility of 2 styles of type used in railroad timetables (light face and heavy face) was determined. Large-face type was easier and more pleasant to read and not so subject to error as small-face type.

96. Skordahl, D. M. "Effect of Sloping Text Upon the Speed of Reading and Upon Visibility," Unpublished paper, University of Minnesota, 1958.

Speed of reading and visibility measurements were determined for copy slanted at 4 angles: 45, 60, 75, and 90 degrees (flat). Although visibility results were somewhat inconsistent, clear-cut results were obtained in the speed-of-reading tests, and these indicated that copy placed at right angles to the line of vision was read faster.

97. Soar, R. S. "Readability of Typography in Psychological Journals," *Journal of Applied Psychology,* **35** (February, 1951), pp. 64–67.

Eighteen journals were examined for comformity with optimal printing practices. Some nonoptimal practices have been widespread or even increased. There was little evidence that available research findings were being applied, although this would result in more legible printing.

98. Soar, R. S. "Height-Width Proportion and Stroke Width in Numerical Visibility," *Journal of Applied Psychology,* **39** (February, 1955), pp. 43–46.

The effect of different combinations of height and width, with area constant, on the visibility of numerals was studied. Stroke width and height-width proportion showed no interaction. A height-width ratio of 10:7.5 and a stroke width to height ratio of 1:10 were the most visible combinations of height, width, and stroke width for all numerals.

99. Stanton, F. N., and Burtt, H. E. "The Influence of Surface and Tint of Paper on Speed of Reading," *Journal of Applied Psychology,* **19** (December, 1935), pp. 683–93.

This study determined the effects of paper surface and color on reading speed. None of the differences in reading was significant. Kind of surface and yellowish tint of paper do not influence speed of reading to a significant degree.

100. Starch, D. *Principles of Advertising*. Chapter XXV. Layout and Typography. Chicago: A. W. Shaw Co., 1923, pp. 657–69.

Speed-of-reading tests were used to compare type styles, line widths, and effect of backgrounds. In tests of italic versus Roman and all-capital versus lower-case printing, Roman was read more rapidly than italic, and lower case 10% more rapidly than all-capital text. Text in 2¾-inch lines was read more rapidly than that in 1½ or 5-inch lines, and black print on white background was read 42% more rapidly than white print on dark gray background.

101. Stern, B. "Upper versus Lower Case Copy as a Factor in Typesetting Speed for Linotype Trainees," *Journal of Applied Psychology,* **34** (October, 1950), pp. 351–54.

No significant differences in speed or errors occurred in a study to determine whether linotype operators can set more material from all-capital or lower-case copy. This was probably partly attributable to the stress on accuracy in the linotyping operation.

102. Sumner, F. C. "Influence of Color on Legibility of Copy," *Journal of Applied Psychology,* **16** (April, 1932), pp. 201–4.

The legibility and preferences for 42 color combinations of print and background were obtained. Gray formed the most legible background for colored lettering. Legibility and affective preference correlated .54.

103. Taylor, C. D. The Relative Legibility of Black and White Print," *Journal of Educational Psychology,* **25** (November, 1934), pp. 561–78.

Several studies were undertaken to compare the legibility of black print on white with white on black. All measures indicated that black on white was more legible.

104. Taylor, C. D., and Tinker, M. A. "The Effect of Luminosity on the Apprehension of Achromatic Stimuli," *Journal of General Psychology,* **6** (April, 1932), pp. 456–58.

The effects of luminosity (brightness) on apprehension of black, dark gray, and light gray stimuli were investigated. For homogeneous letters the light gray apprehension score was smaller than those for black and dark gray letters, and for heterogeneous letters the apprehension score was largest for black. The amount of luminosity contrast between stimulus and background is an important determinant of visual apprehension.

105. Taylor, N. W. "On the Improvement of the Dictionary," *Science,* **74** (October 9, 1931), pp. 367–68.

Difficulties in locating words in a German-English dictionary were discussed and a new typographical arrangement suggested. In the new arrangement common syllables and letters were omitted once they had been located, and distinguishing letters were printed in boldface or capitals.

106. Terry, P. W. "The Reading Problem in Arithmetic," *Journal of Educational Psychology,* **12** (October, 1921), pp. 365–77.

Techniques used in reading arithmetic problems and numerals not set in problems were studied. There were 2 phases in reading arithmetic problems: first reading and rereading. Isolated numerals were read by grouping, and the number of eye pauses and reading time were proportional to the length of the numeral.

107. Tinker, M. A. "Reading Reactions for Mathematical Formulae," *Journal of Experimental Psychology,* **9** (December, 1926), pp. 444–67.

A short-exposure apparatus was used to compare the relative legibility of symbols when used as exponents and subscripts, or in the body of mathematical formulae, and to compare the legibility of certain parts of formulae. Letters lost more in legibility than did digits when used as exponents and subscripts. Position and size were factors in determining legibility of exponents and subscripts. Four-letter words were read considerably faster than mathematical formulae, indicating that reading involving no selection from material presented is easier.

108. Tinker, M. A. "Numerals Versus Words for Efficiency in Reading," *Journal of Applied Psychology,* **12** (April, 1928), pp. 190–99.

Eye-movement measures and reading speed for arithmetical problems with numbers in the form of words or Arabic numerals were obtained. The problems with numbers in the form of Arabic numerals were read with fewer fixations and faster than those with numbers in word form. Thus printing in the form of Arabic numerals not only promotes compactness but favors reading speed.

109. Tinker, M. A. "A Photographic Study of Eye Movements in Reading Formulae," *Genetic Psychology Monographs,* **3** (February, 1928), pp. 95–136.

A study of eye movements in reading algebraic and chemical formulae in context was made. Both types of formulae made much greater demands on the eye than did material without formulae. For chemical formulae it made no difference whether a formula or a name of a compound came first.

110. Tinker, M. A. "How Formulae are Read," *American Journal of Psychology,* **40** (July, 1928), pp. 476–83.

A study was undertaken to determine the perception span in reading mathematical formulae and groups of letters and to discover any tendency toward configuration in reading formulae. Mathematical signs were much easier to read than digits or letters, and the perception span for formulae was nearly twice as great as that for groups of unrelated letters. The larger perception span was due to a tendency towards configuration.

111. Tinker, M. A. "The Relative Legibility of the Letters, the Digits, and of Certain Mathematical Signs," *Journal of General Psychology,* **1** (July-October, 1928), pp. 472–96.

A thorough summary was made of previous literature and a study of the relative legibility of the letters, digits, and certain mathematical signs was made, using a short-exposure technique. The following factors apparently influenced the legibility of isolated characters: size, simplicity or complexity of outline, stroke width and heaviness of type face, shading and hairlines.

area or white space included within the outline, and emphasis or lack of emphasis on differentiating parts (most important).

112. Tinker, M. A. "The Relative Legibility of Modern and Old Style Numerals," *Journal of Experimental Psychology,* **13** (October, 1930), pp. 453–61.

The relative legibility and speed and accuracy of reading modern and Old Style digits in groups and isolation were determined. Old Style digits were somewhat more legible than modern digits in isolation, and Old Style were considerably more legible in groups. Under ordinary reading conditions the two styles of digits were read equally fast and accurately.

113. Tinker, M. A. "Apparatus for Recording Eye-Movements," *American Journal of Psychology,* **43** (January, 1931), pp. 115–18.

The Minnesota Apparatus for Recording Eye-Movements by the corneal reflection method was described.

114. Tinker, M. A. "The Effect of Color on Visual Apprehension and Perception," *Genetic Psychology Monographs,* **11** (February, 1932), pp. 61–136.

The relation of color and brightness contrast to visual apprehension and perception in reading was determined. Apprehension of homogeneous (all one color) colored letters was somewhat related to brightness contrast, and apprehension of heterogeneous (each letter was a different color) letters was fairly closely related to brightness contrast.

115. Tinker, M. A. "The Influence of Form of Type on the Perception of Words," *Journal of Applied Psychology,* **16** (April, 1932), pp. 167–74.

The distance method was used to compare the perceptibility of words and letters in lower-case and all-capital printing. Word form appeared to be more important in reading lower-case type. Lower-case type should be used for smooth, rapid reading, whereas all capitals would be preferred for perceptibility at a distance.

116. Tinker, M. A. "Cautions Concerning Illumination Intensities Used for Reading," *American Journal of Optometry and Archives of the American Academy of Optometry,* **12** (February, 1935), pp. 43–51.

Current procedures used in recommending desirable illumination intensities were discussed and criticized. Readers prefer low intensities, and the intensity permissible is directly dependent upon the uniformity of diffusion present. Ten to 15 foot-candles are adequate for all but abnormal eyes and illegible print. With poor light distribution, lower intensities are more hygienic.

117. Tinker, M. A. "Reliability and Validity of Eye-Movement Measures of Reading," *Journal of Experimental Psychology,* **19** (December, 1936), pp. 732–46.

Realiability and validity of the eye-movement technique was studied for reading materials varying in length and difficulty. For group comparisons, adequate reliability was achieved with 5 to 6 lines of print, but for individual diagnosis 20 or more lines must be read. With material strictly comparable to that in performance tests, the validity of fixation frequency and perception time was very high.

118. Tinker, M. A. "The Effect of Illumination Intensities Upon Speed of Perception and Upon Fatigue in Reading," *Journal of Educational Psychology,* **30** (November, 1939), pp. 561–71.

The effect of illumination, with 2 or 15 minutes of adaptation, upon speed of reading and upon clearness of seeing as measured by the "li" test was determined. With 2-minute adaptation, illuminations below 10.3 foot-candles retarded speed of reading and with 15-minute adaptation, intensities below 3.1 foot-candles retarded reading speed. With adequate adaptation, the critical level of illumination for 10-point type was approximately 3 foot-candles and, allowing a margin of safety, the desirable level would be 10 to 15 foot-candles.

119. Tinker, M. A. "Effect of Visual Adaptation Upon Intensity of Light Preferred for Reading," *American Journal of Psychology,* **54** (October, 1941), pp. 559–63.

The effect of visual adaptation upon light intensity preferred for reading was determined. The status of adaptation determined to a large degree the intensities preferred for reading. The levels to which subjects were adapted were chosen most frequently. It would appear that preference for illumination intensity is not a satisfactory method of determining illumination intensity for efficient work.

120. Tinker, M. A. "Readability of Comic Books," *American Journal of Optometry and Archives of the American Academy of Optometry,* **20** (March, 1943), pp. 89–93.

Factors determining readability of comic books were discussed and possible improvements suggested. Visibility can be improved by use of an optimal type size and light-colored backgrounds. Readability and hygienic vision could be improved by employing lower-case type.

121. Tinker, M. A. "Illumination Intensities for Reading Newspaper Type," *Journal of Educational Psychology,* **34** (April, 1943), pp. 247–50.

The critical level of illumination intensity for reading 7-point Ionic No. 5 newspaper type was determined. The critical level was approximately 7 foot-candles. To provide a margin of safety, at least 15 to 20 foot-candles should be employed for reading newspapers.

122. Tinker, M. A. "Criteria for Determining the Readability of Type Faces," *Journal of Educational Psychology,* **35** (October, 1944), pp. 385–96.

Visibility, perceptibility at a distance, and speed of reading were compared as measures of readability for 10 type faces. Considering the normal reading situation and perceptual habits, speed of reading appeared to be the most valid measure of readability.

123. Tinker, M. A. "Reliability of Blinking Frequency Employed as a Measure of Readability," *Journal of Experimental Psychology,* **35** (October, 1945), pp. 418–24.

Two studies were undertaken to determine the reliability of response for the blink-rate technique. For adjacent 5-minute periods, reliability was high, but it dropped for 10-minute periods and fell to .50 with 20-minute intervening periods. Considerable individual variation was evident.

124. Tinker, M. A. "Effect of Visual Adaptation Upon Intensity of Illumination Preferred for Reading with Direct Lighting," *Journal of Applied Psychology,* **29** (December, 1945), pp. 471–76.

The effect of visual adaptation upon illumination intensities preferred for reading under strictly local direct lighting was determined. Adaptation influenced choice only moderately, and there was frequent choice of high intensities. As high intensities in direct lighting systems make a bad situation worse, reader preferences for illumination intensities would yield unsatisfactory data for prescribing lighting for the individual.

125. Tinker, M. A. "Validity of Frequency of Blinking as a Criterion of Readability," *Journal of Experimental Psychology,* **36** (October, 1946), pp. 453–60.

Blink rate and speed of reading were compared as criteria for determining the readability of lower case versus all-capital material. Blink rates showed no significant differences, whereas the speed-of-reading technique indicated decrements in reading all capitals ranging from 9.53 to 19.01%. Apparently frequency of blinking is an unsatisfactory criterion of readability.

126. Tinker, M. A. "Time Relations for Eye-Movement Measures in Reading," *Journal of Educational Psychology,* **38** (January, 1947), pp. 1–10.

A study was undertaken to determine the relation of eye-movement time to pause-duration time in reading. Proportion of time taken by eye movements varied with comprehension demands of the reading situation. Pause or perception time involved 92 to 94% of reading time; consequently, the eyes were motionless a large part of the time.

127. Tinker, M. A. "Readability of Book Print and Newsprint in Terms of Blink-Rate," *Journal of Educational Psychology,* **39** (January, 1948), pp. 35–39.

Newsprint and book print were compared to test the validity of blink frequency as a criterion of readability. Contrary to other evidence indicating that newsprint is less readable than book print, significantly fewer eye blinks were recorded for newsprint in this study. Therefore, the blink technique does not appear to be a valid measure of ease of seeing.

128. Tinker, M. A. "Effect of Vibration upon Reading," *American Journal of Psychology,* **61** (July, 1948), pp. 386–90.

Speed of reading stationary and vibrating copy was compared. Vibration reduced speed of reading by about 5%, significant beyond the 1% level.

129. Tinker, M. A. "Cumulative Effect of Marginal Conditions Upon Rate of Perception in Reading," *Journal of Applied Psychology,* **32** (October, 1948), pp. 537–40.

The effect of 3 marginal conditions of illumination intensity, type form, and type size when operating together on speed of reading was determined. Eight-point italic print under 3 foot-candles of light retarded reading speed by 10.4%. Thus the 3 marginal conditions when operating together produced a markedly nonoptimal task. An adequate margin of safety above the critical illumination level should be used.

130. Tinker, M. A. "Involuntary Blink Rate and Illumination Intensity in Visual Work," *Journal of Experimental Psychology,* **39** (August, 1949), pp. 558–60.

Blink rate during normal reading was determined under a relatively high (100 foot-candles) and very low (2 foot-candles) illumination intensity. The increase in blink rate from initial to final times was almost identical for the 2 illumination levels. Consequently, under such conditions, blink rate does not reflect differences in the ease of seeing.

131. Tinker, M. A. "Reliability and Validity of Involuntary Blinking as a Measure of Ease of Seeing," *Journal of Educational Psychology,* **41** (November, 1950), pp. 417–27.

Studies concerned with the reliability and validity of the blink technique were discussed. Reliability appears adequate but should be determined in each new investigation using the technique. Reflex blinking is not considered a valid measure of readability and ease of seeing.

132. Tinker, M. A. "Derived Illumination Specifications," *Journal of Applied Psychology,* **35** (December, 1951), pp. 377–80.

Illumination intensities computed by the Weston-Crouch method and experimentally derived intensities were compared. For newsprint and book print, the specifications derived through computation were excessively high in comparison with experimental findings. It appears that the Weston-Crouch method is not a valid technique for determining illumination specifications.

133. Tinker, M. A. "Interpretation of Illumination Data," *American Journal of Optometry and Archives of the American Academy of Optometry,* **29** (June, 1952), pp. 293–300.

Validity of current practices in interpreting illumination data was examined. Statistical evaluation showed that the small gains obtained at higher intensities on logarithmic curves are not significant. Significant gains in performance should be established in illumination data prior to employing such data as bases for recommendations in practical seeing situations.

134. Tinker, M. A. "The Effect of Intensity of Illumination Upon Speed of Reading Six-Point Italic Print," *American Journal of Psychology,* **65** (October, 1952), pp. 600–602.

The relation between illumination level and speed of reading 6-point italic type was studied. Speed of reading increased significantly as illumination was increased from 1 to 25 foot-candles. Allowing for a margin of safety, the desirable intensity for adequate perception of 6-point italic type would be between 30 and 40 foot-candles.

135. Tinker, M. A. "Effect of Vibration upon Speed of Perception While Reading Six Point Print," *Journal of Educational Research,* **46** (February, 1953), pp. 459–64.

Speed of perception of 6-point type, Roman and italic, when stationary and vibrating, was determined. Stationary 6-point Roman was read 8.49% slower, vibrating 6-point Roman 10.99% slower, and vibrating 6-point italic 14.21% slower than stationary 10-point Roman. Small type, vibration, and italics cumulatively produce a relatively large drop in speed of perception.

136. Tinker, M. A. "Effect of Slanted Text Upon the Readability of Print," *Journal of Educational Psychology,* **45** (May, 1954), pp. 287–91.

Visibility and readability of copy held flat and at a 45 and a 60-degree slant were compared. Both visibility and readability were adversely affected to a marked degree when copy was held so that parts of lines were at different distances from the eyes. Reduced visibility of word forms was the dominant factor in retardation of reading speed.

137. Tinker, M. A. "Readability of Mathematical Tables," *Journal of Applied Psychology,* **38** (December, 1954), pp. 436–42.

The influence of certain typographical variations upon readability of mathematical tables was studied. The following typographical arrangements favor good readability: A reasonable number of columns; one set of columns with about 50 entries per column used per page; use of at least 8-point type in Old Style or modern face; generous leading to group items in fives down the columns; boldface printing in the number column; thick paper to eliminate shadows from reverse side, and assurance of maximum brightness contrast by the use of mat white paper and jet black ink.

138. Tinker, M. A. "Perceptual and Oculomotor Efficiency in Reading Materials in Vertical and Horizontal Arrangements," *American Journal of Psychology,* **68** (September, 1955), pp. 444–49.

The effect of a limited practice period in reading materials in vertical columns on speed of reading and eye-movement patterns while reading vertical and horizontal materials was studied. After practice, there was a 17.8% gain in reading vertical material, although it was still read more slowly than horizontal material. Eye movements in reading vertical material became more efficient after practice. The results suggest that with extensive practice vertical arrangements could become as efficient, or more efficient, than horizontal.

139. Tinker, M. A. "Prolonged Reading Tasks in Visual Research," *Journal of Applied Psychology,* **39** (December, 1955), pp. 444–46.

A study was undertaken to demonstrate the usefulness of longer periods of reading in studying the effects of typographical variation on speed of perception. With periods of 10 minutes or more, italics significantly retarded speed of reading in comparison with Roman. All capitals retarded reading speed regardless of length of work period between 4 and 16 minutes.

140. Tinker, M. A. "Effect of Sloped Text Upon the Readability of Print," *American Journal of Optometry and Archives of the American Academy of Optometry,* **33** (April, 1956), pp. 189–95.

Visibility and speed of reading sloped text were determined. In comparison to the 45-degree angle, materials at other slopes were read more slowly, and the greater the degree of slope downward from 45, the greater the retarding effect. Visibility results were similar to speed-of-reading measurements, and both indicated that for clear perception and fastest reading it is best to hold printed copy perpendicular to the line of sight.

141. Tinker, M. A. "Effect of Angular Alignment Upon Readability of Print," *Journal of Educational Psychology,* **47** (October, 1956), pp. 358–63.

Changes in reading speed and visibility were determined for 5 angular alignments of printed copy. Readability of print was adversely affected when alignment departed markedly from the horizontal. Reduction of reading rate at nonhorizontal alignment was due to reduced visibility, unfamiliar orientation of word forms, inability to use peripheral vision effectively, and increased complexity of oculomotor requirements.

142. Tinker, M. A. "Effect of Curved Text Upon Readability of Print," *Journal of Applied Psychology,* **41** (April, 1957), pp. 218–21.

The effects of curved text on speed of reading and visibility were determined. Rate of reading was significantly slower and visibility significantly reduced for curved text. Retardation in reading rate was due largely to reduced visibility of word forms. Wider inner margins should be employed in large books and magazines to avoid marked curvature and thereby improve readability of print.

143. Tinker, M. A. "Length of Work Periods in Visual Research," *Journal of Applied Psychology,* **42** (October, 1958), pp. 343–45.

Speed of perception in reading under varying levels of illumination was investigated using work periods of 1½, 5, and 10 minutes to determine the effects of differing lengths of work periods. The results led the author to conclude that work periods as short as 1½ minutes may be safely used in studying the relation between illumination and visual efficiency.

144. Tinker, M. A. "Brightness Contrast, Illumination and Visual Efficiency," *American Journal of Optometry and Archives of the American Academy of Optometry,* **36** (May, 1959), pp. 221–36.

A study was undertaken to determine the effects of illumination intensity upon visual efficiency with variations in brightness contrast between print and paper. With constant 25 foot-candle illumination, reading speed was gradually reduced as brightness contrast was reduced. Excessively high illumination intensities were not necessary for quick perception of connected materials, except for very poor brightness contrasts. For all brightness contrasts, visibility increased consistently with increases in illumination, and the increases were directly proportional to the amount of brightness contrast. Visibility measurements involve threshold discrimination and should not be used as a basis for specifying illumination satisfactory for reading.

145. Tinker, M. A. "Legibility of Mathematical Tables," *Journal of Applied Psychology,* 44 (April, 1960), pp. 83–87.

The effects of type size, arrangements of numerals in columns, and space versus space plus rules between columns on speed of locating numbers in mathematical tables were studied. Six and 8-point type were equally effective when numerals were grouped by fives. Grouping numerals in fives or tens in columns promoted rapid location. A 1-pica space or a 1-pica space plus a rule were equally effective for separating columns of numerals.

146. Tinker, M. A., and Frandsen, A. "Evaluation of Photographic Measures of Reading," *Journal of Educational Psychology,* **25** (February, 1934), pp. 96–100.

The significance of 4 photographic measures of eye movements in reading was determined. Fixation frequency and perception time were closely related to each other and consequently were considered highly satisfactory measures of reading ability. Regression frequency was a fair measure and pause duration a poor measure of reading ability.

147. Tinker, M. A., and Paterson, D. G. "Influence of Type Form on Speed of Reading," *Journal of Applied Psychology,* **12** (August, 1928), pp. 359–68.

The speed of reading lower case versus all capitals and italics was compared. Lower-case type was read 13.4% faster than all capitals and 2.8% faster than italics.

148. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: III. Length of Line," *Journal of Applied Psychology,* **13** (June, 1929), pp. 205–19.

Speed of reading 10-point type in line widths varying from 59 to 186 millimeters was determined. As the 80-millimeter line width was read most rapidly, it would be the optimum line length for 10-point type.

149. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: V. Simultaneous Variation of Type Size and Line Length," *Journal of Applied Psychology,* **15** (February, 1931), pp. 72–78.

The speed of reading Scotch Roman type in various line widths and type sizes was determined. Line for line arrangements varying from a standard text printed in 10-point type with an optimal 19-pica line width yielded equally efficient reading performance for 8 and 10-point types and possibly for larger sizes. Six-point type with reduced line width reduced reading rate significantly.

150. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: VII. Variations in Color of Print and Background," *Journal of Applied Psychology,* **15** (October, 1931), pp. 471–79.

Speed of reading 10 color combinations of print and background and of black on white was determined. Black on white, grass green on white, lustre blue on white, and black on yellow provide good legibility. A printed page should show maximum *brightness contrast* between print and background.

151. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: IX. Reduction in Size of Newspaper Print," *Journal of Applied Psychology,* **16** (October, 1932), pp. 525–31.

The legibility of 7-point Mergenthaler's Ionic linotype and reproductions of it at 80, 50, and 30% original size were compared. Reductions to 80% did not significantly retard speed of reading, and reductions to 50% did not reduce reading speed enough to make it impractical to use. Reductions to 30% came close to the lower limits of legibility and significantly retarded rate of reading.

152. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: XI. Role of Set in Typographical Studies," *Journal of Applied Psychology,* **19** (December, 1935), pp. 647–51.

The effect of "set" on the readability of printed matter was studied and verification was sought for the 16.5% retarding effect of Cloister Black type. The use of Cloister Black rather than Scotch Roman as the standard did not upset equivalence and resulted in approximately the same retarding effect (15.98%). This would eliminate the factor of "set" as an influence in producing differences obtained by authors when variations in typography are introduced.

153. Tinker, M. A., and Paterson, D. G. "Studies of Typographical Factors Influencing Speed of Reading: XIII. Methodological Considerations," *Journal of Applied Psychology,* **20** (February, 1936), pp. 132–45.

Methodological problems in the use of the Chapman-Cook Speed of Reading Test in legibility studies were discussed. It is possible to introduce typographical change in Form B and obtain a direct measure of the effect of such change on reading speed insofar as sampling errors are concerned. Reliability of the test ranged from +.75 to +.90. The use of control groups is essential for correction of extraneous variables in test groups.

154. Tinker, M. A., and Paterson, D. G. "Influence of Type Form on Eye Movements," *Journal of Experimental Psychology,* **25** (November, 1939), pp. 528–31.

Eye movements were photographed to determine the specific patterns responsible for the disclosed 13.4% retardation in reading all capitals in comparison with lower case. The slower reading of all capitals was mainly due to an increase in the number of fixations and a corresponding decrease in the number of words per fixation and increase in total perception time.

155. Tinker, M. A., and Paterson, D. G. "Eye Movements in Reading a Modern Type Face and Old English, "*American Journal of Psychology,* **54** (January, 1941), pp. 113–14.

Eye movements in reading Cloister Black and Scotch Roman type faces were compared. Although the eye-movement patterns were not as efficient in reading Cloister Black type, the differences were not as striking as the differences in rate of reading between the two types. Apparently eye-movment photography alone is not entirely adequate for measuring the effiiciency of different typographical arrangements.

156. Tinker, M. A., and Paterson, D. G. "Reader Preferences and Typography," *Journal of Applied Psychology,* **26** (February, 1942), pp. 38–40.

To determine the extent of agreement between judged legibility and judged pleasingness, ordinary lower case versus boldface lower case, and lower case versus all-capital printing were compared. The reader placed high esthetic value on the printing arrangements which appeared most legible, and consequently there was close agreement between judged legibility and judged pleasingness.

157. Tinker, M. A., and Paterson, D. G. "Differences Among Newspaper Body Types in Readability," *Journalism Quarterly,* **20** (June, 1943), pp. 152–55.

Speed of reading 9 newspaper type faces was determined. The order from most to least readable was Opticon, Regal No. 1, Century Expanded, Paragon, Excelsior, Ideal, Ionic No. 2, Textype, and Ionic No. 5.

158. Tinker, M. A., and Paterson, D. G. "Eye Movements in Reading Black Print on White Background and Red Print on Dark Green Background," *American Journal of Psychology,* **57** (January, 1944), pp. 93–94.

A study was made to determine specific differences in eye-movement patterns underlying the 39.5% retardation in rate of reading red print on green background. Red on green greatly reduced perception span and increased markedly number of fixations, pause duration, total perception time, and number of regressions. Difficulty encountered in reading red on green appeared to be primarily due to reduced visibility.

159. Tinker, M. A., and Paterson, D. G. "Wartime Changes in Newspaper Body Type," *Journalism Quarterly,* **21** (March, 1944), pp. 7–11.

Changes occuring in newspaper printing from 1935 to 1942 and possible space-saving arrangements were discussed. In 1942 Ionic and Ideal types were used less, there was a trend toward larger type sizes, editorial line widths were more commonly 15 and 15½ picas, and only slight changes in leading occurred. To save space, 7 point on 8-point slug in an 11½ to 12½-pica line, as narrow a margin as desired, and a rule without a space instead of greater intercolumnar space may be used.

160. Tinker, M. A., and Paterson, D. G. "Influence of Simultaneous Variation in Size of Type, Width of Line, and Leading for Newspaper Type," *Journal of Applied Psychology,* (in press).

The effects of simultaneous variations in type size, line width, and leading on speed of reading Excelsior newspaper type were studied. The most favorable typographical conditions for promoting rapid reading were 7, 8, and 9-point type with 2-point leading (or 1-point leading for 7-point type) in a 12-pica line. In addition, 9-point type with 2-point leading in an 18-pica line width was read equally fast.

161. Tinker, M. A., and Paterson, D. G. "Effect of Line Width and Leading on Readability of Newspaper Type," *Journalism Quarterly,* **23** (September, 1946), pp. 307–9.

Speed of reading and reader opinions of judged legibility were obtained for 8-point Excelsior type set solid or leaded ½, 1, or 2 points in a 6, 12, 18, 24, 30, or 36-pica line width. The most readable text was obtained with an 18-pica line width with 1 or 2-point leading. Readers judged the larger amounts of leading more legible and pleasing.

162. Tinker, M. A., and Paterson, D. G. "Readability of Mixed Type Forms," *Journal of Applied Psychology,* **30** (December, 1946), pp. 631–37.

Reader preferences and speed-of-reading measurements were obtained for two medley typographical arrangements versus straightforward lower-case Roman type. The medley arrangements retarded reading speed 8.35 and 11.39%. Judged legibility agreed with the readability measurements but judged pleasingness disagreed with both judged legibility and speed-of-reading measurements.

163. Tinker, M. A., and Paterson, D. G. "Speed of Reading Nine Point Type in Relation to Line Width and Leading," *Journal of Applied Psychology,* **33** (February, 1949), pp. 81–82.

The speed of reading 9-point Scotch Roman type set solid, or leaded 1, 2, or 4 points and in 8, 14, 18, 30, or 40-pica line widths was determined. The optimal arrangement was a 14 to 30-pica line width with 1 to 4-point leading.

164. Tinker, M. A., and Paterson, D. G. "The Effect of Typographical Variations Upon Eye Movement in Reading," *Journal of Educational Research,* **49** (November, 1955), pp. 171–84.

Eye-movement patterns in reading optimal and nonoptimal typographical arrangements were discussed. Some significant increases in eye-movement measures occurred with each nonoptimal arrangement. Qualitative analysis of difficulties presented by typographical arrangements are necessary in addition to performance measures.

165. Turner, O. G. "The Comparative Legibility and Speed of Manuscript and Cursive Handwriting," *Elementary School Journal,* **30** (June, 1930), pp. 780–86.

Legibility and rate of production of manuscript and cursive handwriting were compared. Manuscript was significantly superior to cursive script in legibility. Production rate for manuscript increased constantly up to Grade VI.

166. Uhlaner, J. E. "The Effect of Thickness of Stroke on the Legibility of Letters," *Proceedings of the Iowa Academy of Science,* **48** (1941), pp. 319–24.

Two studies were conducted to determine the optimal stroke for 3-inch block letters. The optimal stroke was closest to 18% of the width or height of the letter.

167. Vernon, M. D. *III. Studies in the Psychology of Reading.* A. The Errors Made in Reading. London: H. M. Stationery Office, 1929, pp. 5–36.

A study was made to determine how far typographical errors enter into reading of various types of material. Confusion of similar appearing letters occurred mainly in material with little context meaning and was a very minor factor in ordinary reading of meaningful materials.

168. Webster, H. A., and Tinker, M. A. "The Influence of Type Face on the Legibility of Print," *Journal of Applied Psychology,* **19** (February, 1935), pp. 43–52.

The legibility of the following type faces was determined by the distance method: Scotch Roman, American typewriter, Cheltenham, Antique, Old Style, Caslon Old Style, Garamond, Bodoni, Kabel Lite and Cloister Black. American Typewriter was the most legible type face and Cloister Black the least legible. The results were considerably different from those obtained by speed-of-reading measurements and suggested that certain factors which increase *perceptibility* of words at a distance reduce *speed* of reading.

169. Webster, H. A., and Tinker, M. A. "The Influence of Paper Surface on the Perceptibility of Print," *Journal of Applied Psychology,* **19** (April, 1935), pp. 145–47.

The distance method was used to compare the perceptibility of print on 3 paper surfaces with varying degrees of glaze. No differential effect of the 3 paper surfaces was found. Eyestrain resulting from reading material on glazed papers must be due to continuous reading in a nonuniformly dispersed light.

170. Weiss, A. P. "The Focal Variator," *Journal of Experimental Psychology,* **2** (April, 1917), pp. 106–13.

The construction, operation, and uses of the Focal Variator were discussed. With the Focal Variator, the degree to which characters and letters, etc., may be thrown out of focus and still remain distinguishable may be determined. The apparatus is useful in determination of the relative legibility of various typographical factors.

171. Weston, H. C. *The Relation Between Illumination and Industrial Efficiency.* 1. The Effect of Size of Work. London. H. M. Stationery Office, 1935, pp. 14.

The relation between task size and illumination was studied. Size affected performance at all illumination levels to a greater extent than did illumination at any size. It is impossible by any practicable increase in illumination to compensate for a considerable decrease in size so as to bring performance up to that for the largest size.

172. Weston, H. C. *The Relation between Illumination and Visual Efficiency—The Effect of Brightness Contrast.* London. H. M. Stationery Office, 1945, pp. 35.

A study was made to determine how performance of simple visual tasks, differing only in contrast, varies with illumination and absolute brightness contrast between the components of contrast. With small-sized tasks the relation between performance and illumination depended on contrast presented by the task. Equal *relative* performance (but not absolute) will be possible with similar tasks varying only in contrast, if the illumination provided is such as to give the same brightness difference for each contrast.

173. Weston, H. C., and Taylor, A. K. *The Relation between Illumination and Efficiency in Fine Work (Typesetting by Hand)*. London: H. M. Stationery Office, 1927, pp. 18.

The relation between illumination intensity and fine work was determined. Rate of output increased with increase in illumination and, at 24.5 foot-candles, rate and ratio of errors to output reached the values obtained with standard daylight conditions. The optimum illumination for hand composing was on the order of 20 foot-candles.

174. Weston, H. C., and Taylor, A. K. *The Effect of Different Systems of Lighting on Output and Accuracy in Fine Work (Typesetting by Hand)*. London: H. M. Stationery Office, 1928, pp. 12.

The effects of 4 systems of general lighting on accuracy and output in fine work were studied. With sufficient illumination, direct or semi-indirect general lighting alone was satisfactory. Semi-indirect plus local and indirect with partial daylight correction reduced output.

175. Wood, C. L., and Bitterman, M. E. "Blinking as a Measure of Effort in Visual Work," *American Journal of Psychology,* **63** (October, 1950), pp. 584–88.

The correlations between blink rate and performance and effort were determined. Blink rate decreased with decrease in effort. Blink rate was shown to be an inverse correlate of performance. Probably blink rate is also inversely correlated with effort.

Bibliography of Supplementary and Relevant Survey Materials

176. Andrews, R. B. "Reading Power Unlimited," *Texas Outlook,* **33** (1949), pp. 20–21.

The author proposes a typographical arrangement called "square span" in which material is printed in double-line blocks.

177. Anthony, M. J. *Just the Type: A Manual on Improved Typography for Newspaper Advertising*. Danville, Ill.: Newspaper Advertising Executives Association, 1949, pp. 52.

Typography and legibility of print are surveyed with special emphasis on newspaper type.

178. Banister, H. "Block Capital Letters as Tests of Visual Acuity," *British Journal of Ophthamology,* **11** (February, 1927), pp. 49–61.

The relative legibility of capital letters employed as test objects was considered. See 111.

179. Banister, H., Hartridge, H., and Lythgoe, R. J. "The Influence of Illumination on Visual Acuity," *British Journal of Ophthalmology,* **11** (July, 1927), pp. 321–30.

The influence of illumination on visual acuity was discussed. See 111.

180. Blackhurst, J. H. *Investigations in the Hygiene of Reading*. Baltimore: Warwick & York, 1927, pp. 63.

Several of the author's experiments on the legibility of print in children's books are surveyed.

181. Bowerman, C. W., *et al. Report of the Committee Appointed to Select the Best Faces of Type and Modes of Display for Government Printing*. London: H. M. Stationery Office, 1922, pp. 18.

This report deals with the best type faces to be used in government printing as revealed by various discussions and experimental reports.

182. Brown, W. C., *et al.* (Committee on Industrial Lighting of the Illuminating Engineering Society.) *American Standard Practice for Industrial Lighting*. New York: Illuminating Engineering Society, August, 1952, pp. 40.

This pamphlet presents recommendations for practice in industrial lighting.

183. Burt, C. "The Psychological Study of Typography," *British Journal of Statistical Psychology,* **8** (May, 1955), pp. 29–55.

The author reports on typography and related literature. See 184.

184. Burt, C. *A Psychological Study of Typography.* Cambridge (England): Cambridge University Press, 1959, pp. 68.

Typographical factors influencing legibility of print are discussed. For the most part, consideration is given to discussions and experimental reports written by Englishmen. Only part of the available literature is covered.

185. Burtt, H. E. *Psychology of Advertising.* Chapter XVII. Typography. Boston: Houghton Mifflin Co., 1938, pp. 310–30.

Legibility of print was surveyed with special reference to use of printing in advertising.

186. Burtt, H. E. "Typography and Readability," *Elementary English,* **26** (April, 1949), pp. 212–21.

The author presents a critical survey of legibility of print with special emphasis upon the University of Minnesota studies.

187. Cattell, J. McK. "The Inertia of the Eye and Brain," *Brain,* **8** (October, 1885), pp. 295–313.

A study on the relative legibility of alphabet letters is reported. See 111.

188. Cohn, H. L. *Hygiene of the Eye in Schools.* London: Simpkin & Marshall, 1886, pp. 236.

This book contains an early discussion of factors involved in the legibility of print in children's books.

189. Cohn, H. L., and Rübencamp, R. *Wie sollen Bücher und Zeitungen gedruckt werden.* Brunswick: Vieweg & Son, 1903, pp. 112.

This is an early discussion of legibility of print for books and other printed materials.

190. Committee of the British Association. *Report of the Committee of the British Association on the Influence of Schoolbooks on Eyesight.* Dundee meeting, 1912, pp. 295.

This is a relatively early discussion of the factors influencing legibility of print in children's books.

191. Ewing, A. E. "The Value of Letters and Characters as Visual Tests," *An International Congress of Ophthalmology* (1922), pp. 604–6.

The relative legibility of alphabetical letters employed in visual tests was reported. For summary see 111.

192. Finzi, J. "Zur Untersuchung der Auffassungsfähigkeit und Merkfähigkeit," *Psychologische Arbeiten,* **3** (1900), pp. 289–384.

The relative legibility of letters of the alphabet was discussed. For summary see 111.

193. Gage, H. L. "Research in Readability: I. The Program for Research," *Linotype News,* **16** (1937), p. 2.

This article deals with suggestions for research on the legibility of print.

194. Gage, H. L. "Research in Readability: II. Effects of Leading," *Linotype News,* **16** (1938), pp. 2.

The author surveys some of the factors involved in the effects of leading on the legibility of print.

195. Gray, W. S. "Summary of Investigations Relating to Reading," *Supplementary Educational Monographs,* **82** (1925), pp. 275.

The author summarizes reading investigations written in English and published up to 1925. The summary includes a section on the legibility of print or hygiene of reading.

196. Gray, W. S. "Summary of Reading Investigations, July 1, 1957, to June 30, 1958," *Journal of Educational Research,* **52** (February, 1959), pp. 203–21.

Annual summaries of reading investigations written in English, including a section on legibility of print or hygiene of reading, are presented. These summaries extend from 1926 through 1960 in *The Elementary School Journal* and *The Journal of Educational Research.* Beginning in 1961, the reviews are done by Dr. Helen M. Robinson.

197. Hartridge, H., and Owen, H. B. "Test Types," *British Journal of Ophthalmology,* 6 (December, 1922), pp. 543–49.

This article reports on the relative legibility of alphabet letters employed as test objects. For summary, see 111.

198. Huey, E. B. *The Psychology and Pedagogy of Reading.* New York: The MacMillan Co., 1908, pp. 469.

This book contains a chapter in which Huey surveys and evaluates the legibility of print as reported in studies prior to 1908.

199. Javal, E. *Physiologie de la lecture et de l'écriture.* Paris: Felix Alcan, 1905, pp. 296.

This book contains an important early discussion on the legibility of print.

200. Kahler, W. H., *et al.* (Subcommittee on Supplementary Lighting Study Projects in Industry of the Illuminating Engineering Society.) *Recommended Practice for Supplementary Lighting.* New York: Illuminating Engineering Society, May, 1953, pp. 16.

This pamphlet contains recommended standards for supplementary lighting.

201. Ketch, J. M., *et al.* (Committee on Library Lighting of the Illuminating Engineering Society.) *Recommended Practice of Library Lighting.* New York: Illuminating Engineering Society, May, 1950, pp. 16.

This phamphlet contains standards recommended for library lighting practice.

202. Kirsch, R. "Sehschärfenuntersuchungen mit Hilfe des Visometers von Zeiss (Zugleich ein Breitrag zur frage der Lesbarkeit von Druck schriften)," *Graefe's Archiv fur Ophthalmologie,* **103** (December, 1920), pp. 253–79.

This is a report on the legibility of print. For summary, see 111.

203. Kirschmann, A. *Antiqua oder Fraktur* (3rd Ed.). Leipzig: Deutscher Buchgewerbeverein.

Studies comparing Roman and German print are surveyed. For summary, see 69.

204. Legros, L. A. *A Note on the Legibility of Printed Matter.* London: H. M. Stationery Office, 1922, pp. 17.

The author presents a brief statement on the legibility of print for use in British governmental publications.

205. Legros, L. A., and Grant, J. C. *Typographical Printing Surfaces.* London: Longmans, Green & Co., 1916, pp. 732.

An extensive evaluation of printing paper surfaces as related to legibility of print is made.

206. Luckiesh, M. *Light, Vision and Seeing,* New York: D. Van Nostrand Co., 1944, pp. 323.

This book contains certain materials on the relationship of visual acuity, visibility, and print to legibility.

207. Luckiesh, M., and Moss, F. K. *The Science of Seeing.* Chapter XII. Reading as a Task. (Typography.) New York: D. Van Nostrand Co., 1937, pp. 455–67.

This book contains a chapter in which early studies on the legibility of print are discussed and evaluated.

208. Luckiesh, M., and Moss, F. K. *Reading as a Visual Task.* New York: D. Van Nostrand Co., 1942, pp. 428.

This is an extensive report of studies completed by the authors and colleagues on various factors affecting the legibility of print and visual fatigue.

209. Lythgoe, R. J. *I. Illumination and Visual Capacities.* London: H. M. Stationery Office, 1926, pp. 80.

The literature on illumination in relation to visual capacities is surveyed extensively.

210. Mergenthaler Linotype Company. *The Legibility of Type.* Brooklyn: Mergenthaler Linotype Co., 1935, pp. 67.

A small treatise on legibility of type from the viewpoint of the printer is presented.

211. Milne, J. R. "The Arrangement of Mathematical Tables," *Napier Tercentenary Memorial Volume.* London: Longmans, Green & Co., 1915, pp. 293–316.

This is a discussion (not experimental) of factors to be considered in printing legible mathematical tables.

212. Neidhart, J. J., *et al.* (Committee on Office Lighting of the Illuminating Engineering Society.) *Recommended Practice for Office Lighting.* New York: Illuminating Engineering Society, 1960, pp. 36.

This pamphlet contains standards recommended for practice in office lighting.

213. Poulton, E. C. *Effects of Printing Types and Formats on the Comprehension of Scientific Journals.* Cambridge (England): Cambridge University Press, 1959, pp. 22.

A few studies of legibility are surveyed, and a report of an experiment is given. A test of the relative comprehensibility in scientific papers of the four different styles of printing used showed one arrangement (11 point with 2-point leading in a 30-pica line width) superior to the others.

214. Radojevic, S. "Die Erkennbarkeit von Antiqua- und Frakturbuckstaben im indirecten Sehen," *Archiv fur Augenheilkunde,* **88** (1921), pp. 192–97.

A study on the relative legibility (recognizability) of Roman and German type is reported. For summary, see 111.

215. *Report of the Committee Appointed to Select the Best Faces of Type and Modes of Display for Government Printing*. London: H. M. Stationery Office, July, 1922, pp. 18.

This report makes a series of recommendations for different kinds of printing.

216. Starch, D. *Advertising*. New York: Scott, Foresman and Co., 1914, pp. 182–90.

Material on the effects of capitals, italics, Roman type, length of line, and effect of background on speed of reading is presented.

217. Taylor, C. D. "The Legibility of Black and White Print." Ph.D. thesis, University of Minnesota, 1933, pp. 177.

This thesis contains an exhaustive survey of the literature on the relative legibility of black and white print.

218. Tinker, M. A. "Legibility and Eye-Movement in Reading," *Psychological Bulletin,* **24** (November, 1927), pp. 621–39.

This is a survey of studies published prior to 1927 on the legibility of print.

219. Tinker, M. A. "Visual Apprehension and Perception in Reading," *Psychological Bulletin,* **26** (April, 1929), pp. 223–40.

This is a critical review of visual apprehension and perception in reading, including certain materials related to the legibility of print.

220. Tinker, M. A. "Physiological Psychology of Reading," *Psychological Bulletin,* **28** (February, 1931), pp. 81–97.

Certain factors involved in the production of legible printing are surveyed.

221. Tinker, M. A. "Experimental Study of Reading," *Psychological Bulletin,* **31** (February, 1934), pp. 98–110.

This is a critical review of eye movements, perception, etc., in the field of reading. Certain studies reviewed have a bearing on the legibility of print.

222. Tinker, M. A. "Illumination and the Hygiene of Reading," *Journal of Educational Psychology,* **25** (December, 1934), pp. 669–80.

The author presents a critical survey of certain reports bearing on the hygiene of reading.

223. Tinker, M. A. "Eye-Movement, Perception, and Legibility in Reading," *Psychological Bulletin,* **33** (April, 1936), pp. 279–90.

This is a critical review of legibility of print and certain related materials.

224. Tinker, M. A. "Illumination Standards for Effective and Comfortable Vision," *Journal of Consulting Psychology,* **3** (January and February, 1939), pp. 11–20.

Published illumination standards which pertain to visual efficiency are discussed.

225. Tinker, M. A. "The Effect of Adaptation upon Visual Efficiency in Illumination Studies," *American Journal of Optometry and Archives of the American Academy of Optometry,* **19** (April, 1942), pp. 143–51.

The author presents an experimental report on the relation of visual adaptation to visual efficiency in illumination studies. Also included is a critical survey of other experiments concerned with this subject.

226. Tinker, M. A. "The Study of Eye Movements in Reading," *Psychological Bulletin,* **43** (March, 1946), pp. 93–120.

This is a critical review of eye movements in reading, including certain studies bearing on the legibility of print.

227. Tinker, M. A. "Illumination Standards," *American Journal of Public Health,* **36** (September, 1946), pp. 963–73.

Published illumination standards related to the reading situation are reviewed.

228. Tinker, M. A. "Illumination Standards for Effective and Easy Seeing," *Psychological Bulletin,* **44** (September, 1947), pp. 435–50.

Illumination requirements for efficient vision are discussed. See also 227.

229. Tinker, M. A. "Fixation Pause Duration in Reading," *Journal of Educational Research,* **44** (February, 1951), pp. 471–79.

This is an experimental report concerning certain materials related to the legibility of print.

230. Tinker, M. A. "Recent Studies of Eye Movements in Reading," *Psychological Bulletin,* **54** (July, 1958), pp. 215–31.

The author presents a critical review of studies on eye movements in reading, including eye-movement measures as related to legible printing.

231. Tinker, M. A., and Paterson, D. G. "Typography and Legibility in Reading," *Handbook of Applied Psychology.* New York: Rinehart & Co., 1950, pp. 55–60.

A brief statement of techniques of measurement and legibility factors in typography is made.

232. Traxler, A. E. *Ten Years of Research in Reading.* New York: Educational Records Bureau, March, 1941, pp. 195.

Reading investigations, with a section on legibility or hygiene of reading, are summarized.

233. Traxler, A. E., and Townsend, A. *Another Five Years of Research in Reading.* New York: Educational Records Bureau, October, 1946, pp. 192.

Reading investigations, including a section on legibility or hygiene of reading, are summarized.

234. Traxler, A. E., and Townsend, A. *Eight More Years of Research in Reading.* New York: Educational Records Bureau, January, 1955, pp. 283.

This is a summary of reading investigations with a section on hygiene or legibility of reading.

234a. Traxler, A. E., and Jungeblut, A. *Research in Reading During Another Four Years.* New York: Educational Records Bureau, May, 1960, pp. 226.

This is a summary of reading investigations with a section on the legibility of print.

235. Vernon, M. D. *The Experimental Study of Reading.* London: Cambridge University Press, 1931, pp. 190.

The author presents a systematic treatise on reading, including a section on the legibility of print.

236. Webber, M. E., *et al.* (Committee on Residence Lighting of the Illuminating Engineering Society.) *Recommended Practice for Residence Lighting.* New York: Illuminating Engineering Society, November, 1953, pp. 44.

This pamphlet contains illumination standards recommended for practice in residence lighting.

237. Weston, H. C. *Sight, Light and Efficiency.* London: H. K. Lewis & Co., Ltd., 1949, pp. 308.

This book contains a considerable amount of material bearing on visual efficiency and the hygiene of reading. Particular emphasis is placed upon adequate illumination for effective vision. These standards agree fairly well with the results of numerous studies completed at the University of Minnesota.

238. Wick, W. "Die vergleichende Bewertung der deutschen und Lateinischen Schrift vom Standpunkt der Augenärzte," *Klin. Monatsbl. f. Augenheilkunde.* **66** (January and June, 1921), pp. 758–59.

Legibility of German versus Roman print is reported from the viewpoint of medical men. For summary, see 111.

For other supplementary and survey materials see 20, 69, 79, 92, and 111.

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