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A review of literature on the relationship between legibility standards for printed and projected type

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Abstract

Print legibility is of concern to all seeing, reading individuals. For over 100 years educators, printers, psychologists and ophthalmologists, among others, have investigated a wide number of interrelated factors in print legibility. This research reached its zenith in the 1920's through 1940's, particularly in the voluminous work of M.A. Tinker and D. G. Paterson. There is a large and growing body of knowledge available on what affects the quality of our perceptions of printed typography.

A REVIEW OF LITERATURE ON THE RELATIONSHIP

BETWEEN LEGIBILITY STANDARDS FOR

PRINTED AND PROJECTED TYPE

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Chapter 1

THE PROBLEM, PURPOSE, AND DEFINITIONS OF TERMS

Introduction to the Problem

Print legibility is of concern to all seeing, reading individuals. For over 100 years educators, printers, psychologists and ophthalmologists, among others, have investigated a wide number of interrelated factors in print legibility. This research reached its zenith in the 1920's through 1940's, particularly in the voluminous work of M. A. Tinker and D. G. Paterson. There is a large and growing body of knowledge available on what affects the quality of our perceptions of printed typography.

However, the last several decades have brought dramatic and drastic changes to the field of communications and the methods of making visible typographic images have expanded beyond the printed alone. Television, film, microfilm, videotape, computers, as well as the more traditionally thought-of projected forms of slides, filmstrips, opaque and overhead transparencies, are all used extensively in education and other areas of our society.

> The mass-produced word is no longer merely a "colored letter at the bottom of a ditch" but a sign which may be printed, reproduced or projected in a wide variety of ways, and read under many different conditions, . . . (Spencer, p. 10)

Because of this, the value of much research has become dated. It is in relation not only to today's printing techniques but also to these additional alternative methods of visual communication that research must be carried out.

> The rapidly increasing use of television, film, and microfilm soon to be joined by electronic video-recording requires that legibility research should concern itself not merely with the printed word but with the visible word in all media, and with the growing need for messages to be designed so that they may be freely converted from one medium to another. (Spencer, p. 9)

Statement of the Problem

Future print legibility studies, to be valid and significant, must be concerned with such new and diverse communication systems as the cathode ray tube composer, electrostatic printer, television and electronic digital signs and their display methods, as well as the needs of the human reader using such processes as well as conventional printing processes.

How are these new systems effective in terms of legibility of printed and projected images? Are there limitations? May there be guidelines in their imaging as there are in traditionally printed formats? How do existing research findings relate to newer methods of type imaging?

Specifically, is traditionally printed text, viewed under optimal conditions, as legible as the same text projected in any of the projected formats? Is such printed text more easily legible or less legible, assuming optimal conditions for both communication systems?

What are the optimal viewing conditions for traditional printed typographic images? What are the best conditions for projected typographic images? If there are differences, how do they vary?

Investigations into the legibility values of the various new communication systems is of great importance in all areas of use.

This is particularly true in education where knowledge and its transmission is its prime "raison d'etre," and any body of knowledge is of questionable value if incomprehensible or confusing. Further, how can these new forms of communication be utilized to their utmost if there is not a solid understanding of what is acceptable in typography for good legibility. What works on the printed page may not work in the projected image, nor on an electronic screen in countless varied sizes, and under conditions that the designer may not have foreseen, nor be able to control.

Definition of Terms

Ascender. "That part of a lower case letter which rises above the x-height, as in b, d, f, h, k, and l" (Watts & Nisbet, p. 91).

Descender. "That part of a lower case letter which descends below the base line, as in j, p, y, g, and q" (Watts & Nisbet, p. 91).

Em. "The square of the body of any size of type. Derived from the letter 'M', whose capital, the widest of the font, occupies the whole body width" (Watts & Nisbet, p. 91).

Font. Also Family and Face. "Complete set of a particular size and design of type comprising lower case, capitals, small capitals, figures and punctuation marks" (Watts & Nisbet, p. 91).

Leading. "Extra space between lines of type" (Watts & Nisbet, p. 91).

Legibility. "The ease with which running text matter can be understood under normal reading conditions" (Foster, p. 279).

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Lower Case. "Small letters in a font, as opposed to capitals, a, b, c, d, etc." (Watts & Nisbet, p. 91).

Point. A unit of size in printing. There are 72 points to an inch.

Readability. ". . . in the sense of 'comprehension due to the style of writing' (as in readability formula)" (Foster, p. 279).

San Serif. Also Gothic. "A style of type which has no serifs" (Watts & Nisbet, p. 91).

Serif. Also Roman. "The finishing strokes at the top and bottom of a letter" (Watts & Nisbet, p. 91).

Solid Setting. Type set without extra spacing or leading.

Tachistoscope. An instrument which permits perception of a visual stimulus under controlled conditions of exposure" (Watts & Nisbet, p. 91).

Type Face. "The style or design of a particular type font" (Watts & Nisbet, p. 91).

Upper Case. "Capital letters, i.e., A, B, C, D, etc." (Watts & Nisbet, p. 91).

Visibility. "Identifiability of a printed character . . ." (Foster, p. 279).

Weight. Also Boldness. "The degree of heaviness of a type face, e.g.--light, medium (normal), or bold" (Watts & Nisbet, p. 91).

x-height. "The height of lower case letters without ascenders and descenders, as measured from the base line to the top of the face of the lower case 'x'" (Spencer, p. 83).

Chapter 2

REVIEW OF THE LITERATURE

Introduction to the Literature Review

We are all affected daily by the visible word. Until recently communication of information has been through the use of printed symbols, primarily typeforms. The bulk of research into how we recognize and comprehend this information has been limited, therefore, to the traditional printed formats.

Visual communicators in the new technologies have been forced to rely on past research and practices in using type and planning for its legibility. These guidelines have not been appropriate in all instances.

Legibility standards were originally developed through the process of printing and evaluating the success or failure of the printed piece. These rule-of-thumb standards have, in many cases, been legitimized by scientific research under controlled conditions. However, this research has contradicted some long-held beliefs as well.

Print studies have investigated a multitude of interrelated elements, such as size, boldness, style and spacing of type, and have found a great deal concerning optimum standards of legibility under various conditions and for different situations.

While individual studies have attempted to control for all but one or two elements, many of these factors are so interdependent that caution must be exercised in trying to evaluate them singly. Paterson

and Tinker (Lucas & Britt, 1950) admitted their amazement to the neutralizing effect on one factor resulting from changes in another.

The vast majority of literature reviewed has dealt with research on the legibility of printed type. The factors controlled for and investigated generally are:

Type styles--fonts (or families)--serif vs. san serif
capitals vs. lower case
boldface vs. medium vs. light weight
positive vs. reverse
expanded vs. normal vs. condensed
Type sizes--text size
display size
Length of line
Leading
Spacing--between letters
between words
between paragraphs
margins
Contrast and color

It is important to distinguish between "legibility" and "readability." While legibility refers to how easily type can be identified and understood, readability refers to a comprehension level that is found in the individual viewer and is uncontrolled by the visible image or image designer.

A number of different methodologies have been developed over the years for testing different printed factors. Depending upon the elements involved there have always been questions of validity and reliability about the testing instruments.

The literature review will begin with a brief review of the process of human perception and early studies of visual perception which provided the basic groundwork for traditional legibility research. Then an investigation of the various research methodologies will show

similarities and differences in approach to the study of type legibility factors. Finally, the finding of the research studies will be presented and related.

Literature Review

Perception

In order to understand the intent and direction of most legibility studies it is necessary to understand how the human eye perceives in reading. Most adults read at the rate of about 250 to 300 words per minute. While reading the eye moves along in "saccadic jumps" from fixation to fixation. It is during these brief pauses, lasting on the average of 1/4 of a second, that 92% to 94% of reading time is taken (Tinker, 1944). No reading is done during the jumps.

Perception is by whole words, and peripheral vision allows for a previewing of upcoming information. It is not even accurate to say that a person reads words, actually he perceives only a few letters in the word and fills in the rest from the context. If presented with mutilated words in a tachistoscope (if certain letters are omitted or incorrect) the subject may read them as there, filling in gaps from the context, reading by the general shape of the word (Burtt, 1938).

It is necessary to realize that the internal patterns as well as the outlines provide cues which are essential to accurate perception. Tinker (1963) has stressed the distinction between "total word shape," the bare outline of a word, and "total word structure."

Occasionally while reading, the eye will move backwards on the line of type in what is called a "regression." These regressions are to correct inadequate perceptions.

Effective reading is based on a combination of factors: familiarity of subject matter, its simplicity or complexity, the motivation of the reader, his posture, his visual acuity, and the illumination of the type. Good reading depends on large spaces between fixations, short pauses, and a good rhythm of eye movement with a minimum of regressions.

Some of the earliest legibility research dealt with how humans perceive. Javal, in the late 19th century, demonstrated that the upper half of a line of words is more easily read than the lower half (Spencer, 1969). Lucas and Britt (1950) later qualified this as being words printed in lower case letters. Messmer, in 1903, supported these findings and attributed this to the dominant nature of letters with ascenders, which carry the main role in word recognition. He described words containing an equal amount of vertical letters (l, k, h, f) and curved letters (c, s, e, o) as being "the most favorable total form" (Spencer, 1969, p. 14).

Cattell, in 1885, showed that the eye grasps whole words as quickly as letters. Erdmann and Dodge, in 1898, strongly supported Cattell's findings. Subjects found words recognizable when printed in sizes of type at which individual letters were too small to be identified (Spencer, 1969). Erdmann and Neal (1968) qualified this by

finding that words are more legible than individual lower case letters "only for familiar words at high levels of legibility" (p. 408).

Pillsbury's tachistoscopic experiments showed that an error in the first part of a word is more easily recognized than one in the latter part (Pillsbury, 1897). Vernon's claim that the importance depends more upon the particular word is based on the idea that the most significant part of a word, its root, is different in English words derived from Latin than from those of Anglo-Saxon origin (Vernon, 1931).

Research Methodologies

A number of different methodologies have been developed over the years for testing different factors. Depending upon the element involved there has always been a question of validity and reliability about the testing instruments. This is especially true in using these basically print type research methods with projected type in studies.

The most often used methodologies and their usage are:

Visibility Measurement
Maximum Distance
Speed of Perception
Focal Variator
Speed of Reading

Visibility measurement. Primarily associated with Luckiesh and Moss, it utilizes the visibility meter. The meter has filters with circular gradients of varying densities, which are rotated during testing until the subject can recognize a printed word through them. Visibility testing has been used in the testing of relative visibilities

of different type faces and sizes and to measure the effects of variation in brightness contrast between paper and printed image (Luckiesh & Moss, 1940).

No studies have been found that used this method with projected type, but the applicability is obvious, since brightness contrast is a primary factor in projected legibility.

Maximum distance method. This has been used to test legibility, perceptability at a distance, and peripheral vision. The instrument employed is similar to that used in eye tests, with a head rest on one end and a rail marked with a centimeter scale. The stimulus material is placed in a small, well-lit carrier which can be moved to any distance along the rail. The maximum distance at which the specimen can be read is taken as an inverse measure of legibility (Burtt, 1938).

This method has been used by researchers from Anisson in the 18th century, to Javal in the 19th, to Rothlein and Dearborn in the early 20th century. It is most valid when assessing the legibility of individual symbols or letters intended to be seen at a distance, such as poster or road signs. The results can be misleading if applied to lengths of words designed to be read under normal conditions, according to Tinker (1963).

The application of maximum distance as a testing method for projected type legibility has validity. The overhead and opaque projectors, as well as film and filmstrip and slide projectors, display an image seen at different distances from the members of the viewing

audience. The angle of vision is another related factor to be considered. However, the same limitations apply to test results.

Speed of perception method. This method determines legibility based on the speed of accurately perceiving printed symbols. The instrument used is the tachistoscope. There are many varities of tachistoscopes used, but generally they expose the subject to the stimulus (the printed symbol, word, or words) for a set amount of time, usually 1/10th of a second. The subject or researcher controls the activation of the stimulus and the perception is written down or reported. Speed of perception testing is most useful in investigating individual letter legibility, alternative design legibility for particular letters or signs (Tinker, 1963; Rehe, 1974), and it is used in the field of word-perception research (Rehe, 1974).

The similarity of the tachistoscope to the face of a television or computer display screen should not be overlooked. This may be a means of adapting this form of research methodology to the study of projected type. Again, the limitations of the existing research findings would be the same. These limitations are the difficulty relating a single tachistoscopic fixation to normal reading fixations (Spencer, 1969; Tinker, 1963).

Focal variator method. This approach relies on sharpness of focus as the means of measuring the legibility of the printed image. The focal variator has a series of lenses which project the stimulus upon a ground glass screen in any degree of focus. When operated by the subject a crank allows the image to appear and gradually come into

focus. The subject reports as soon as he/she perceives a legible form, and the scale value is recorded. A zero scale is maximum sharpness.

The use of the ground glass screen upon which the image is to be focused shows the adaptability of this research method to projected type. Film, filmstrip, slide, opaque, and overhead projectors all may be employed to control the variation of focus to test projected print legibility.

As with visibility measurement, maximum distance measurement, and speed of perception, the focal variator method is somewhat limited in that it measures in unnatural reading situations. Its greatest advantage is the precise measurements it does provide, which should allow for a high degree of validity (Tinker, 1963).

Speed of reading. The speed of perception method is based upon the principle that more legible material can be read more rapidly. There are several ways to measure speed of reading. In its simplest form, one would let the subject read a certain amount of material at his normal rate and time with a stop watch. The other generally applied method is imposing a time limit and measuring the amount of text read.

This instrument in one form or another has been used by Pyke and Ovink (Spencer, 1969), Burtt (1938), and Paterson and Tinker (1929, 1932, 1936, 1941). Paterson and Tinker developed tests in which they claimed, "comprehension was constant and speed of reading was measured as a single variable" (Spencer, 1969, p. 23). They used the Chapman-Cook Speed of Reading Test. This has two equivalent forms, each

containing 30 items of 30 words each. They later used a longer, modified version developed by Tinker. Each series of brief paragraphs has one incorrect word, spoiling the meaning. To check comprehension the subject must mark out this word. The number of paragraphs correctly marked in a given amount of time is an indication of how rapidly the subject reads (Burtt, 1938; Spencer, 1969).

Tinker (1963, 1965) sees speed of reading as the best method of measurement of legibility available. It is probably the most widely used at the present time in print legibility testing. Some disagreement with its validity is based on the fact that it puts the rapid skim reader at a disadvantage (Zachrisson, 1965) and that it demands only a minimum level of comprehension (Poulton, 1960). Poulton advocates a "rate of comprehension" approach wherein the score of comprehension is divided by the time of reading as a more reliable criterion of legibility.

The speed of reading method of testing in any form or version is adaptable to projected type studies. Rather than marking out incorrect words, the subject may write it down or identify it verbally or point to it, depending on the media employed. Distance from the subject to the screen must be carefully controlled for so it does not become a determining variable.

There are a number of other techniques used in legibility research. These are either of doubtful validity or highly specialized in their area of study. Motion was used by Moede to compare the legibility of san serif and serif typefaces, but it has been rejected as unsuitable

by Luckiesh, among others (Luckiesh & Moss, 1940; Spencer, 1969). Burtt (1938) has put forth subject preference as a measurement technique, but most researchers have found little correlation between the aesthetic preferences of readers and objective measurements of legibility. Eye movement is a technique using a camera or human observer to measure reading speed and fixation pauses, their duration, and regressions. This method could provide valuable clues to legibility factors in typography, relating positive or negative perceptions of typefaces to eye fixations and their duration, as well as eye regressions (Rehe, 1974). One drawback is that present testing models interfere with normal reading conditions (Lucas & Britt, 1950). Visual fatigue in reading has been extensively studied but has not provided any significant clues to legibility. Anderson and Meredith (1948) have found that readers can sustain several hours of uninterrupted reading, both of projected and printed type without significant signs of fatigue. This is the only major research found to include projected type images as an integral part of the study. A projector used to display microfilmed book pages onto the ceiling developed for bed-ridden patients was employed. The reflex-blink rate has been presented by Luckiesh and Moss (1940) as a means of measuring legibility. It is assumed that poor legibility of type will result in increased blinking. This would be counted manually or photographically. However, the validity and reliability of this method has been frequently questioned (Tinker, 1963). Minimum illumination was used along with maximum distance measuring in the early years of print legibility research and appears to

have fulfilled its limited capabilities (Rehe, 1974; Spencer, 1969; Tinker, 1963). Whether it can add valuable research results to projected type studies remains to be seen. The method seems to be applicable based on its use of illumination or brightness, an important factor in projected image visibility if not legibility.

Research Findings

What have all these methods of research given us concerning optimums in type legibility? The results of research as it relates to the listed factors found on page six will be briefly summarized.

Type styles. Basically it is agreed that the easiest type styles to read are those we have seen most often. This is true in both printed and projected forms. The majority of text printing is in a Roman style with serifs. Paterson and Tinker (1932) found in a test of type styles, using speed of reading, that the maximum variation in five Roman type styles was statistically not significant, less than 3%. Personal and interrelated factors are involved. In referring to this study, Burtt has suggested "that the speed of reading technique is not so sensitive to small differences as the other methods . . ." (Burtt, 1938, p. 314). The focal variator method was used by Burtt and Basch (1923) in a study comparing specific alphabet letters in three different type faces: Bodoni, Baskerville Roman, and Cheltenham. The average legibility of 18 individual letters in upper and lower case were measured using seven subjects. Cheltenham was superior. This may be attributed to the boldness and consistency of the fairly heavy strokes in Cheltenham, and heavy, triangular serifs, as opposed to Bodoni which has some hairline

strokes and light, straight serif lines at right angles to the main strokes (Burtt & Basch, 1923).

Familiarity seems to have a great deal to do with the recognition of any particular type. Serif-taught adults read traditional (Roman) typefaces better while san serif-educated young people did as well in san serif reading (Burt, 1959).

The value of serifs in visual perception was raised by Robinson, Abbamonte and Evans (1971). Based upon the psychological structure of the eye's photoreceptors, which consist of different "feature detectors" for spots, lines, edges and corners, for example, they utilized a computer digital model for line detection. When applied to serif and san serif letterforms of the same height, width and thickness of line, the results showed that serifs preserve the original image of small letters. Upper case san serif were considerably degraded. It is evidently not disastrous in the context of sentences because of the influence of the text.

Bass (1967) stated, in regard to typeface design for television, "Much of the character of serif faces lies in the pronounced contrast of weights. An insufficient compromise fails to avoid decay. Additional compromise tends to destroy the original characteristics" (p. 361).

Paterson and Tinker (1941) concluded that, "type faces in common use are equally legible under conditions of ordinary reading" (p. 114).

It has been found that in printed text areas it is more legible to use lower case Roman type and avoid large blocks of capitals (Bahr,

1969). Studies by Burtt (1938) using the tachistoscope with constant exposure, found 30% more words in lower case than in upper case were perceived. When reading at a normal rate of speed, 10% more text was read in lower case. "Even though the lower case letters were comparatively smaller on the average, the words were read more rapidly" (Burtt, 1938, p. 316).

Focal variator tests by Rothlein (Burtt, 1938) presented contradictory results: upper case was 20% superior to lower case in Bodoni, 25% in Baskerville, and 29% in Cheltenham. The relative size difference and the fact that identification was made of individual symbols using the focal variator, and that normal reading was not tested, presumably account for the results.

It has been shown that all-capitals in running printed text retards speed of reading by 12% over lower case of the same face (Lucas & Britt, 1950). However, if distance of perception, attention value or general appearance are more important, as in billboards, road signs or posters, upper case is more effective.

> The value of upper case or lower case typography . . . thus depends on the conditions under which it is read. If the main consideration is perceptibility at the greatest possible distance and the speed of reading is of minor importance, . . . then upper case is indicated. (Burtt, 1938, p. 316)

Recent testing involving drug labels conducted by Poulton (1965) and Hailstone and Foster (1967) has come up with another condition when upper case is preferable to lower case. Where very small type sizes approaching the threshold of legibility are used, upper case letters are more easily discriminated.

The findings hold true in regard to upper and lower case letters projected onto screens, although Kodak does list typewritten pica and elite capitals as more legible at somewhat greater distances in 35mm slides (TerLouw, 1955). TerLouw also recommends a medium weight san serif over a serif (such as Roman), although certain serif faces above a minimum size are satisfactory. Phillips (1977) found serif style letters significantly more legible in projected 35mm slides.

Type styles were specifically designed for television in order to eliminate problems found on the screen such as type decay, distortion, and halation-blooming or bleeding of light at all corners (Rehe, 1974). Type tends to fill-in easily, sharp corners become rounded and fine serifs disappear (Bass, 1967). San serif faces of medium weight were most appropriate for television screens. Serif faces with strengthened strokes improved reproduction at larger sizes, but deterioration still happened in smaller sizes (Bass, 1967).

Concerning boldface type versus normal weight in printed text, boldface can be read just as rapidly as normal weight lower case letters, but the latter are considered more legible by readers (Tinker, 1963). Tests by Burtt (1938) using the maximum distance method found, averaging all available results on bold versus medium weight type together, boldface legible at a 16% greater distance. Results were of the same magnitude in a test of bold against light weight type of the same style. Burtt also found bold condensed type was discerned at the same distance as medium and that normal width bold was superior, indicating that the condensation of the type counteracted previous gain.

Such findings remain consistent in projected type, where it is also found wise to avoid extra bold and condensed faces (TerLouw, 1955; Phillips, 1977).

Preference usually goes to dark figures against light backgrounds. Print research discussed later deals with this. In non-print McKittrick (1976) hypothesizes that insufficient or excessive contrast between typefaces and backgrounds in negative images may be uncomfortable. Superimposed type in television usually is white on black, which is technically necessary but causes problems. The letters themselves are light-emitting, which causes a bleeding of light at the corners (Bass, 1967). The value of reverse type for legibility by the elderly and those suffering from eye problems has been raised, but not studied in any controlled manner.

Type size. Different type sizes are not photographic enlargements or reductions of a single size. Carefully designed faces are proportionally wider in the small sizes. The weight of lines is usually lightened slightly as the sizes increase. Eight-point type cannot be enlarged three times and appear identical to a natural 24-point type, for example (Bahr, 1969). Research into the most legible size of type has found that "type size is not as important a factor in legibility as previously claimed" (Lucas & Britt, 1950, p. 338). Burtt (1938) claims that up to a certain point increases in type size increase the attention evoked.

Tinker and Paterson (1929) found in speed of reading tests that in lines of type 80 millimeters long, 10-point type was most satisfactory.

Another test using speed of reading with Granjon, a serif typeface, showed maximum reading accomplished with 11-point type in 3 1/16 inch (80mm) lengths. It was noted that sizes below 8-point and above 12-point were not recommended for running texts.

Bahr (1969) writing from a printer's viewpoint lists 9-, 10-, 11-, 12-, and maybe 14-point type as suitable for texts. Also from a printer's standpoint Wales, Gentry and Wales (1958) give 12-point type set 21 pica wide, with all other factors being equal, as having maximum readability.

In a recent study of Univers typeface, Poulton (1972) found the previously stated minimum lower case size of 6.6-point generalizes to other fonts and to their capitals. He asserts that lower case minimum sizes should be determined by an x-height, and an x-height of 1.2mm is minimum for Univers and other related serif faces. Perpetua was found to need a minimum body size of 8.5-points. It is important to note that Poulton is dealing with minimum x-height sizes for these typefaces, not average sizes.

In type projected onto reflected screens, practical usage has provided means of determining optimum type size. These sizes are dependent on screen-to-subject distance and height of projected image, not printed point size. Young (1980) has a formula for determining letter size which has the viewing distance divided by a ratio number providing the letter height: $\frac{V.D.}{R.N.} = L.H.$ To determine the optimum viewing distance for a particular letter height the formula: $R.N. \times L.H. = V.D.$ is used. To find a ratio number from existing

visuals the following formula is used: $\frac{V.D.}{L.H.} = R.N.$ "As long as the viewer distance to letter height ratio remains constant, the letter will appear the same size to the observer" (p. 43). A rule-of-thumb given by Young is one inch of letter height for each 120 inches (10 feet) of viewing distance.

TerLouw (1955) gives a table with symbol sizes ranging from 4 inch letter sizes for a viewing distance of 128 feet, to 1/4 inch letters viewed at 8 feet distance. For thermal transparencies a minimum of 1/4 inch has been suggested by Braman & Rudnick (1980). Kodak recommends an absolute minimum of 1/8 inch. In motion pictures the smallest letters in titles should be at least 1/25 of the projected x-height (Kodak, 1971).

In television type size is determined two ways. For electronically created type it is measured vertically by the number of scan lines and horizontally by the stroke width. Optimal size has been determined to 30 scan lines with a minimum of 11 to 15 lines (Bass, 1971; Elias, Snadowsky & Rizy, 1965). In printed type used in television a proportion of 1/17 of the TV size for the smallest type, with a recommended limit of 25 words in the 6 3/4 inch by 9 3/4 inch essential area is utilized (Wurtzel, 1979).

<ins>Line length.</ins> In dealing with line length, leading between lines, spaces and margins, interrelations are found and are difficult to untangle. One problem is that the most reliable test instrument for use in normal reading situations, the speed of reading method, does not appear to be sensitive enough to measure these individual elements (Tinker & Paterson, 1936).

Paterson and Tinker (1929) found 6-point type, set solid, read with equal speed in lengths from 1 1/2 to 4 2/3 inches. An 8 inch length read slightly less successfully. Ten-point read the same as 6-point, and 12-point was as legible up to a length of 6 inches.

Using eye movements as the test instrument, Burtt (1938) found a comparatively satisfactory arrangement with lines about 3 1/2 inches long. Using 10-point Scotch Roman typeface, and the speed of reading method, Tinker and Paterson (1932) found an optimal length of 59 to 97mm and suggest a length between 75 and 90mm (3 and 3 1/2 inches). Another test showed 80mm with 10-point superior to 80mm at 6-, 8-, 12-, or 14-point type size (Paterson & Tinker, 1932). A study by Starch (1923) using speed of reading showed 10- to 12-point at 70mm lengths superior.

Bahr (1969), again from his printer's viewpoint, presents the optimum as 40 characters and spaces or 7 to 9 words per line. He gives as explanation that the longer line will result in the eye resisting and moving prematurely to the next line. If set too narrowly it destroys the continuity.

No studies in projected type have dealt with line length. Its variation from printed type is minimal, although its means of measurement differs. Texts typewritten in templates for slide reproduction must fit within character limits. The same holds true for television type, it also is counted by characters per line. Consideration must be given to line length in type displayed on television screens because of the loss of a percentage of the image from source to screen.

Leading. Speed of reading was not seen as a sensitive tool for measuring, so nothing significant was found testing leading alone. Ordinary text type can run to at least five inches in length with no more than two points of leading. Readers prefer leading, feeling they make faster progress. Short lengths and some leading make easier transfers from line to line possible (Lucas & Britt, 1950). Wales, Gentry and Wales (1958) also contend that spacing between lines adds to readability and give three points as "ideal." Basing their results on viewer appeal, Becker, Heinrich, Sichowsky and Wendt claim that different type families need different amounts of leading, with san serif and italicized type needing one more point than Roman (serif) typefaces (1970).

While no research results in projected type were found on this, practical application provides some standards. Braman and Rudnick (1980) give a leading equal to the letter height as optimal for thermal transparencies. Kodak, in a pamphlet on slide production (1972), lists at least the height of a capital letter between lines of words. TerLouw (1955) recommends greater leading in projected type, 1 1/2 times the height of the letters in texts. It seems apparent that leading, though not researched to any degree, is a greater factor in projected images than in printed images.

Spacing. Since the eye sees several words at each fixation, it is important that words not be spaced so closely that it is difficult to tell where one ends and another begins. Bahr (1969) suggests spacing between words that is not less than 4-to-an-Em, and not more than 3-to-an-Em.

Tinker and Paterson found that "the practice of separating thought units by regular indentation justifies itself in terms of legibility" (1940, p. 131). They determined that a moderate indentation (about 2 or 3 Ems) at the beginning of a paragraph improves reading speed by about 7%. If there is no indentation between paragraphs extra paragraph spacing, in addition to normal leading, is needed. Lucas and Britt (1950) have found that paragraph spacing produces faster reading speed of printed texts.

In a related area, studies by Lees and Farman (1970) on traffic control devices show that maximum legibility was achieved when place names had 40% larger than normal spacing, and legibility can be improved by increasing margin space between the message and the edge of the sign.

In regard to margins, it is common to print books with 50% of the page as white space around the text. However, books with no margins are read with the same speed as those with normal margins--prompting Paterson and Tinker to recommend double columns of text (1932). The inner margin in bound publications should be wide enough to avoid curving type, which Tinker found to significantly reduce reading rates and word visibility (1957). Margins are a definite factor in type projected onto television screens. This is controlled by the number of characters used. Their size determines how many can be fit into the essential area. In projected images, Kodak (1972) recommends 1/2 inch margins in 35mm slides.

<u>Contrast and color</u>. Black and white provides maximum contrast, and black type on a white background is superior to reverse printing in

legibility. Using maximum distance as the testing method, Burtt (1938) found black on white legible at 160 centimeters and white on black at 140 centimeters, 15% closer. Using speed of reading, passages were read at a normal rate, and black letters were read at an average of 6.06 compared to 4.26 for white letters (Burtt, 1938). Tinker has concluded that with text printed in black ink, all paper surfaces with a reflective surface of 70% or more are equally legible (Spencer, 1969).

Contrast is the more important of the two factors in projected images. TerLouw (1955) states that:

> The legibility of anything viewed in a classroom is based on the design of large enough materials, with good contrast, and the conditions under which these are displayed. These conditions are the brightness of the task area, surface glare and general illumination of the screen. (p. 1)

These three factors are all elements of contrast. Considering the inconsistencies of contrast and the lack of control in viewing situations, projected type images should aim for maximum brightness contrasts within limits of color combinations.

The exception is in television where, for production purposes, the brightest "white" is actually a #1 gray with 70% reflectivity and the darkest value is "TV black," which is #10 gray, with 3 1/2% reflectivity (Wurtzel, 1979).

Color is not seen to be as crucial in working with color type as is brightness difference between the letters and background. Luckiesh (1940) found greatest legibility for black print on yellow surfaces. Preston (1932), using maximum distance and isolated words, lists legibility in the following order: blue on white; black on yellow; green

on white; and black on white. Sumner (1932) using a subject walking toward the card found black on gray, black on yellow, and blue on gray as most legible. Paterson and Tinker with speed of reading tests show black on white, green on white, and blue on white with a rank order correlation to .86. Miyaki, using a tachistoscope and single numbers, found that from an attention-getting standpoint it is the amount of color, not how it is employed, that is important (Burtt, 1938).

It seems evident that the value in the results where an off-white background was highly ranked is due to the reduced surface glare. Practical usage with overhead projected images point to the fact that black on yellow is highly legible and has a less contrasty appearance, so glare does not reduce the ability to distinguish fine detail.

Another consideration relating to contrast and color for projected images is the brightness ratio. For text type an acceptable ratio is 1:5 between non-image screen brightness (from incidental light) and the focused, projected image (TerLouw, 1955). Factors in this brightness ratio include the size of the room, the type of projector and bulb used, the distance from projector to screen and the room darkening capabilities.

Summary

The research methods cited and examined were developed to test printed type. Almost all results are based on the utilization of printed type. All of the techniques are adaptable to some degree to testing non-print type of one form or another.

Similarities among the techniques show that the visibility measurement, maximum distance, speed of perception and focal variator techniques all measure individual letter, symbol or word perception. They do not give valid information about normal text reading. The legibility of any group of words, whether in a phrase, sentence, paragraph or page is not being tested. Generalization of results is difficult using such instruments as the tachistoscope, visibility meter or focal variator. They have provided a great deal of data on such elements as effective color and contrast combinations between the type and its background, between identical letters in two different type styles or type sizes, and the effectiveness of particular signs or symbols. They have not brought forth results that provide guidelines or recommendations concerning arrangements of these elements for optimum reading in normal situations.

The speed of reading technique does just that. It tests subjects reading printed text normally. It has a built-in means of testing comprehension. Although there are arguments about the type of reader that this research would most accurately reflect, it is the most reliable method of its kind. The eye movement technique may provide valid, reliable results when proper testing procedures can be achieved.

As far as the test results are concerned, the following recommendations and generalizations may be made.

For both printed and projected text type a lower case letterform except for necessary capitalization is more legible. When printed, a serif face is more legible. When projected both forms have been

recommended, with greater usability shown for san serif. Display type would work better in upper case type if brief, particularly in situations where there is ample time to observe and identify letter/word shapes.

Type weight tests show normal width boldface is legible at greater distances than medium weight letters. Type size has been found to be less important a factor as previously thought. Relationships seem to be the critical factor, relationships between length of line and size of type, or between weight of letter and viewing distance to screen. Type faces in the range from 8-point to 14-point are most often mentioned for texts, with line lengths from 70mm to 90mm (2 3/4 inches to 3 1/2 inches).

Leading (the spacing between lines) appears more important in projected type than printed and varies from one to one and one-half times the height of the letters. Spacing between letters and words appears to be consistent between printed and non-printed type. Not as much white space is needed around text type as previously believed.

In terms of color and contrast, black and white provides maximum contrast, but evidence seems to indicate surface glare may reduce its legibility. Black on yellow, black on gray, and blue on gray were seen as highly legible in different tests. Color is not as important as the brightness difference between figure and background. This is especially true in projected type. Reverse type (white print on black) is not highly legible, except in certain specific conditions.

Chapter 3

SUMMARY

Introduction to the Summary

Studies into letter forms and their legibility have been going on since the 19th century, first by scholarly printers and psychologists, but increasingly involving researchers in such varied and diverse areas as education, engineering, linguistics, highway safety, electronics, graphic design, mass communication and advertising, and journalism.

One thing can be stated about all this research: the various fields, grouped into the three categories of type design, typographic research and communications technology, do not communicate with one another. There are misunderstandings between those who design type, those who work with letterforms and those who are interested in studying the effects and history of letterforms. Typographers and graphic designers hold research at arm's length in equal measures suspicious of it and intimidated by it. Miles Tinker exemplifies one arm of research and its attitudes. He has made clear that typographic designers only confuse things and are "introspective aesthetes deserving, on the whole, of contempt" (Baudin, 1967, p. 205).

The electronic communication revolution has added problems. For example, in the mid-1960's the Standards Institute of the U.S. directed a 25-man committee to develop the U.S. standard optical character recognition typeface. Not one of the committee had any connection with typography or type design (Wrolstad, 1969).

Just as Gutenberg attempted to faithfully reproduce handwriting in three-dimentional wooden blocks, electronic phototypesetters are going through an initial period of reproducing metal type faces in CRT (Character Recognition Typeface). For their part type designers approach computers and electronics with a good deal of mistrust. There is the constant fear of the "perfectly designed" geometric letterforms being created by a machine.

All of this completely ignores the problems of projecting such typeforms in a number of different visual formats, each containing its own unique set of intrinsic limitations. The new technologies are working in visual communication with past research techniques, with printed typographic legibility requirements as their only standards. While they coincide in some cases, they are not appropriate in all instances. What is needed is an interaction between designers, users and researchers in <u>all</u> visual communication forms.

Summary

The research leading to the present legibility standards has originated from many disciplines, for many reasons. There have remained gaps between what studies find and what is actually practiced. In many cases there are still conflicting results where experimental methods and procedures differ.

What legibility standards there are, are primarily concerned with printed typography. Within this area many requirements are not even fully applicable to the newer printing techniques.

Legibility standards were originally produced from studies into how humans view and perceive written information. Psychology has continued to have an important part in legibility research. Perception studies reveal that the human eye perceives in many short fixations. These pauses allow for grasping whole words, or shapes of words, at a time with some previewing help. Humans read and comprehend in context, being able to fill-in gaps and pass over parts of words and still perceive and understand.

Some perceptual findings are that the total word form, its length and characteristic shape are important in reading. The first half of a word is more easily recognized than the second half, the upper half of a line of type is more easily read than the lower half. Certain letters of the alphabet are dominant in providing word recognition.

A number of research methodologies have been developed and utilized in legibility research depending on the area of study or emphasis of investigation. Maximum distance has been used to test legibility of individual symbols, distance perceptability and study aspects of peripheral vision. It does not give optimals in areas such as type size or face, line width or length or leading. Visibility measurement is used to test relative visibilities of different type faces and sizes and measure the variations in brightness contrast in papers and printed marks. It has basically the same limits in application as maximum distance. Speed of perception investigates individual letter legibility, alternatives to the design of letters and symbols and word perception in general. As with the previous two methods, it

has little value in studying legibility in continuous, contextual reading situations. Focal variator is a method which has studied the legibility differences between typefaces. Its greatest asset is its accuracy in measuring differences. Its applicability has been limited to comparing single characters. Speed of reading has tested type legibility in situations most like those encountered in normal reading. It has studied nearly all different factors in typography, including size and style of type, line width, margins, and letterform boldness. Other research techniques mentioned include motion, subject preference, eye movement, visual fatigue, reflex-blink rate, and minimum illumination.

Research results relate almost exclusively to print typography. Due to the related nature of typography it has been difficult to single out and study type elements one at a time. Further problems in comparing results are due to the differences in methodologies employed.

What has been shown is that differences in typefaces have to be radical to appreciably affect legibility under normal reading conditions. Typefaces in common use and most familiar to readers are equally legible. Most text type is in a Roman style with serifs. All upper case text retards the speed of reading more than any other single factor. Where distance of reading or attention value is most important or where very small type size is necessary, capitals are more effective. In television, display size of characters and screen size limitations have prompted designers to use all upper case san serif letterforms with little research data to show its legibility value or limitations.

Boldface type can be read at a greater distance than normal weight letterforms, although no real differences in legibility have been found. It is favored by some researchers for its greater visibility. Moderate boldness of type is seen as advantageous in projected type, and "video alphabets" require a greater overall boldness than printed type.

In terms of type size, printed text type is recommended to run from 8-point to 12-point depending on such variables as the type style and length of the line. Where projected media is concerned the type size is dependent on distance from projector to screen and viewer to screen. Some recommended distance/size ratios given are one inch letters to ten foot viewer distance, and 1/4 inch size to eight foot viewing distance. For television scan lines are counted rather than points. Optimum size has been determined to be 30 scan lines, with a minimum between 11 and 15.

Line length can vary within limits without diminishing legibility. The optimal line length seems to be about 10 to 12 words in length or 60 to 70 characters. Six and 10-point lettering have both been found to read the same up to 4 2/3 inches, set solid. A line of 8-, 9-, and 10-point type was found to be satisfactory at 3 1/2 inches. In millimeters, another test showed an optimum of from 75mm to 90mm for 10-point type.

Line length as such has not been studied in projected type.

Leading of printed type has not been easily, nor accurately, tested as an individual variable. In relation to line length it has

been found that 2-point leading allowed 8- and 10-point type to be extended without a loss of legibility. However, leading does not make small type more legible than larger size type. Short lines with some leading facilitate eye movement from line to line. In projected type, leading seems to be more critical, with leading between lines recommended from one to one and one-half the capital letter size.

For spacing, a printer suggests no less than 4-to-an-Em and no more than 3-to-an-Em between words. Paragraph indentation has been shown to aid readability, and extra paragraph spacing may be adequate in its place. It is common to print books with 50% of the page white, with one researcher recommending the printing be in two columns. In television the essential area determines margins.

Different color and contrast combinations have been studied. Black and white provides maximum contrast, while black on yellow gives the best legibility results. Black ink on white or light backgrounds is generally superior to the reverse. If there is at least 70% reflectance from the paper surface and black ink is used, one research finding is that there is no appreciable difference in legibility. Contrast is critical in projected type. A brightness ratio of 1:5 between non-image screen brightness and projected image brightness is acceptable for viewing text type.

Discussion and Conclusions

Are there consistencies to legibility standards and recommendations in print and non-print communication systems? What legible images may be expected in printed text areas on paper or television

or projected onto reflective screens by overhead projectors? Has an increasingly technological society outstripped its ability to plan, research and apply information in all its diverse modes of communications?

These open-ended questions reveal the magnitude of the problems facing typographic research at this time. This investigation has been wide-ranging and one immediate conclusion can be stated. There is no common ground for study of the new and different conditions facing researchers in legibility. There are so many professionals approaching from so many different directions without an awareness of one another that gaps and redundancies are apparent. There needs to be a clearinghouse of some sort where those studying the legibility of printed words for their perceptual implications, for example, may have access to the information of those who are studying or have studied the same elements for typographic design or its technological applications.

Until such a time as this happens it will be necessary to evaluate legibility studies in terms of narrowly-structured criteria, developed and presented in a variety of different professional journals.

Some things can be stated about the legibility of both printed and projected words. Research findings on how humans perceive remains constant, regardless of what medium is utilized. Whether displayed on a TV screen, computer printout or overhead projection, the eye still moves quickly from area to area, taking in entire word structures, comprehending from context. Peripheral vision aids in previewing. How

efficiently and effectively the viewer reads a particular body of words is based on such factors as how familiar she/he is with it, the simplicity or complexity of its arrangement, how motivated she/he is, his/her visual acuity, and how well illuminated it is in terms of the contrast ratio between the figure and ground.

When concerned with the research findings in regard to the different elements of typography, wide agreement disappears. Serif (Roman) typefaces appear to be more legible in printed text and display situations. This is primarily due to the fact that most people have seen this face while learning to read. Roman faces have been predominant since movable metalcast type was developed. The serifs have been accepted as an integral part of the letterform for aesthetic reasons. Current design attitudes hold that form should follow function and some technological requirements demand simplicity and economy of line and shape, leading researchers to the san serif face. However, viewers are not as familiar with san serif typefaces, therefore these faces are read slower and found to be less legible, particularly where used most often, in computer and digital displays and on television. This will change with time and exposure just as viewer preference changed from hand-lettered script and pseudo-script printed type to machine cast serif faces.

In terms of upper and lower case letterforms, it has generally been proven that display lettering--headlines, posters and road signs--can be most effective in all upper case. There is some evidence that they can also be legible at very small sizes, in limited amounts.

However, in text printing lower case lettering is needed in all forms of visual communications. This is due to the nature of human perception and the forms of familiar phonetic arrangements, individual letters and total word forms.

Boldness is valuable in projected type images and is potentially more effective in printed type, although medium type is also legible. Where boldness is not an aid in legibility, in the televised image, it is because of added distortion problems. It is also in television that reverse type appears to be more legible than positive type, yet this is only in the superimposed headlines. A good deal of research is needed into reverse type in projected text communication, particularly in regard to its legibility for the visually impaired.

The problem of relating legibility standards is nowhere more difficult than when it comes to optimum type sizes. Printed type is measured in points, and it has generally been determined that text types of from 9- to 12-point, with extremes of 8- and 14-point, are best. It is also necessary to realize that type size and line length go together closely. Line leading, spacing between letters, words, lines and blocks of type all seem to be closely related. Currently utilized research methods are not sensitive or accurate enough to distinguish individual optimums for these elements, if, in fact, they can be separated.

Projected type is measured not by its produced size, but by the dimensions it has when on the screen in relation to the viewing distance of the audience. Various formulas exist to determine letter

sizes, all have been determined by practical use, not through scholarly research. Length of line has been standardized for typewritten letters, but no others. Greater space is needed between lines with fewer lines of type overall. Margins are determined by the size of the material to be projected.

Television has its own unique measurement problems. What is produced in the television studio is translated into horizontal lines and transferred to receivers with different sets of controls. Minimum and optimal line sizes have been determined at 11 to 12 lines for a minimum and 30 lines as an optimum. This could vary depending on the quality of television equipment. Research information in this area is new and difficult to obtain. The bulk seems to have been produced by technical concerns such as MITRE corporation, the Society of Motion Picture and Television Engineers (SMPTE), and the United States Air Force. The length of lines is counted and limited by the number of individual characters. And, as with all other forms of type display, the line length is related to the type style and its spacing.

In regard to color and contrast, the determining factor in print type is the degree of brightness contrast between the letter figure and the background. In most situations optimum legibility is achieved with dark typeforms on light backgrounds. Color can be effective in adding to attention, not to legibility, in all formats. Too great a contrast on a printed surface can detract from legibility, as it can when reflected from a projected surface.

It is the nature of the two formats that, except for in a few areas, legibility standards are not the same. Projected images are not printed images. Just as 16-point is not 4-point type that has been quadrupled in size, projected type, to be legible, cannot be printed type copied onto a transparency. Some degree of legibility will be lost in the translation.

There do exist some similarities in legibility standards. Text information should be in lower case, except for necessary capitalization. A certain degree of boldness is usually beneficial to legibility. Brightness contrast, within a certain range, is needed for both formats.

Some differences will not be as apparent in future years. The dichotomy between serif and san serif typeface legibility will lessen as they are interchanged in various communication systems. In this regard one might say, "familiarity breeds acceptance." Human beings are very adaptable. Paterson and Tinker suggest that the evolutionary principle of "survival of the fittest" can be applied to typefaces. I feel it will be a mutually mutating process between typeface design that is technically appropriate, aesthetically pleasing, and perceptually acceptable.

Limitations of the Study

Research into these two areas was limited by the absence of some primary source material from the library. This consisted of a number of periodicals which were absent altogether, or which did not include the necessary volumes.

Technical information, particularly in the projected type area was likewise not available. Because of the diversity of disciplines which have done research in typographic legibility to any extent, it was difficult to track down in-depth information in all areas. Television type legibility studies in particular fell into this category.

Implications for Further Research

Any further research into the relationships between printed and projected type legibility should deal with practical research where specific elements are compared in tightly structured research formats. The speed of reading technique seems the most applicable method of testing in both areas, although I believe that a study of subjects' eye movements would be even more accurate if an accurate and unobtrusive instrument could be developed. It would also be necessary to include a test of comprehension with such a research technique.

It would be very valuable to look at single variables with all other elements controlled. This would be slow and painstaking, but the benefits in singling-out how closely related or unrelated individual elements such a line length and type size are would be enormous.

Finally, the results should be disseminated in as many periodicals and professional journals as possible to reach other professionals who would be interested and could use this for further development. Of particular value would be the periodicals, *Visible Language*, *Journal of Applied Psychology*, *American Journal of Psychology*, and *Instructional Innovator*.

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