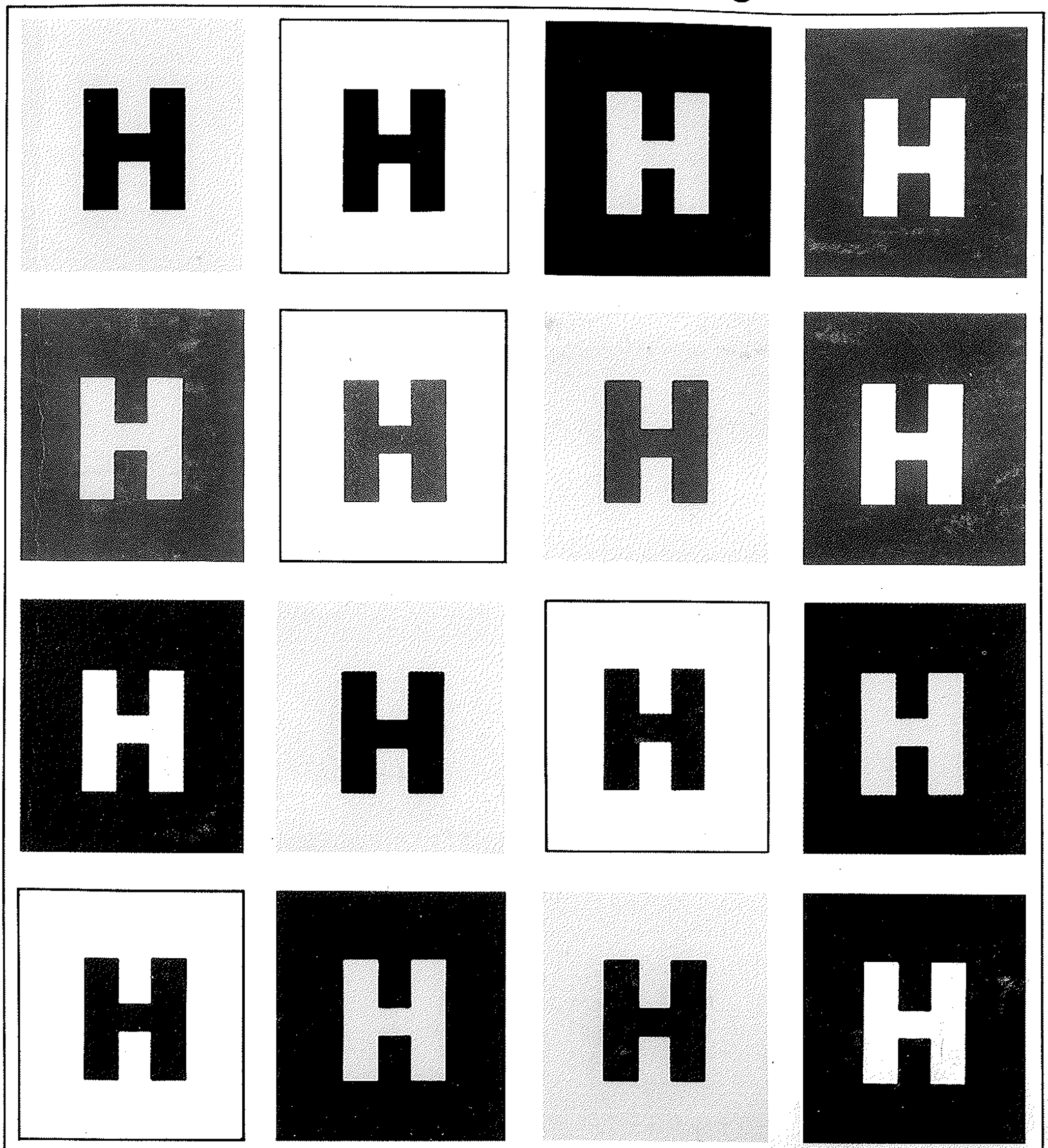
visual communication through signage

By Drs. Karen and R. James Claus

volume 1: perception of the message



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volume 1: perception of the message

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Published by
SIGNS OF THE TIMES PUBLISHING CO.
Cincinnati, Ohio, U.S.A.

FIRST EDITION

INTERNATIONAL STANDARD BOOK NUMBER 0-911380-32-9

ACKNOWLEDGMENTS

The kinds of support that have made this series possible are varied and many. The original germ that became this series was provided by Professor Walter G. Hardwick of the University of British Columbia. In the earliest stages, the encouragement of Robert Oliphant of Neon Products Ltd. of Vancouver kept the idea alive. Once the collection of materials was begun, other help came readily from John Chamberlain of Q.R.S. Corporation; Herman Green of United Advertising Corporation; Charles Novel of Holiday Inns, Inc.

Important financial support has consistently come from Combined Communications Corporation, thanks to the efforts of Karl Eller and Harry Goss, who took time to review chapters and who displayed confidence in the authors' judgment. It was a grant in aid from their organization which in fact made possible the completion of the manuscript. There were times when the entire project might have been abandoned had it not been for the enthusiasm and support of Luke and Chuck Williams of American Sign and Indicator Corporation.

Many other people have made significant contributions that helped make this undertaking a worthwhile experience for the authors. Prominent among these is Charles Magliozzi of Mack Advertising, Inc. Many talented people were important in offering encouragement: Herbert Moulton, Roger Goins and Robert Hauser of Rohm and Haas Company; Paul Havig of General Electric Company; Dennis McLaughlin and Robert Loudon of American Sign and Indicator; Edward Walters of France Manufacturing Company; Edward Batten of Batten Brothers Signs; Vern Clark, legislative director of the Outdoor Advertising Association of America, Inc.; Frank Blake, legislative director for the National Electric Sign Association; Jim Goff, Ken Kline and Gene Lathrop of the San Diego Planning Department; Chris Snodgrass and Guy Gelbron; Frank Montroy, Montroy Supply Company; Ms. Karin Welch; Kurt Pressman.

Other individuals made contributions to particular chapters: Chris Hoversten, Sign Appraisal; Robert Venturi and Denise Scott Brown, Signs as an Art Form; Ray T. Anderson, director of research, Walter Meyers, president, and Geri Warning, all of 3M National Advertising Company, who helped generously with many chapters.

The people who have opened their "archives" to the authors are too numerous to mention but are all deserving of thanks.

FOREWORD

Since the completion of their graduate studies, the authors have been vitally concerned with the vastness of the unexplored common ground shared by the American public and American industry: their goals are virtually the same, particularly with respect to the improvement of the visual environment. From this orientation the authors approached an industry that they felt to be extremely significant as a communications industry. The hypothesis being tested in this approach was that the use of information available from industry sources might enable decision makers in the public forum to reach a valid and intelligent basis for judgments and policy decisions concerning the visual environment. The authors looked to this series as one link between industry and the people in need of information.

The hope of finding information was never left unsatisfied. In fact, such massive amounts of material were made available that the authors may not have handled it as masterfully as they would have wished. This may have caused certain weaknesses in the text that should not be thought to come from any want of cooperation from the industry. If this series makes it a little easier for one communications industry to tell its story to the public, it will have found its mark.

This series is the culmination of a research effort begun some four years ago. An important element in its content is the body of contributions made by specialists with various perspectives. Their written contributions were gratefully accepted and, for the most part, left unchanged. For this reason there may seem to be some inconsistencies in the series. The reader is asked to be patient with this minor imperfection.

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LEGIBILITY OF THE SIGN MESSAGE

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CHAPTER 1
LEGIBILITY OF THE SIGN MESSAGE

The first purpose of an advertising sign is to attract attention. It must then also convey a message in a manner quickly and easily understood by viewers who have a wide range of comprehension and differing powers of observation.

When signs are erected on highway and roadways, their messages must be assimilated in a short period of time, and each year the demands on any traveler's powers of concentration become progressively greater, not only because vehicle speeds tend to increase with the passage of time, but certain areas continue to add more signs to the landscape.

Sixteen years ago, J. A. Prince, Professor of Ophthalmology at Ohio State University, discussed the importance of speed in conveying messages to high speed traffic and gave a formula for computing the number of seconds available for comprehension of a message at given rates of speed.[1] Dr. Prince concluded that the permissible viewing times for drivers travelling at different rates of speed differ, especially when one considers how much viewing time is safe. Travelling at 40 MPH, the driver has about 8.5 seconds at his disposal. At 60 MPH, the safe viewing time is about 2.5 seconds, and at 70 MPH, the driver can only afford to spend 1 second looking at anything other than the highway.

Nevertheless, Dr. Prince acknowledges that "well-designed and strategically placed signs are a safety factor on a monotonous road, for they encourage the driver to give his attention to his surroundings when his alertness may be lagging, and he is developing what is called "Highway Hypnosis." [2] Therefore, legibility of the sign copy which must be read in only seconds is a foremost concern for signmakers.

A sign can be no more legible than the letters and numerals which comprise it. The primary factors which determine legibility include the legibility of individual letters and numerals; letter height, proportion, and spacing; the relationship between the size of the displayed information and the viewing distance; color combinations; illumination; and sign placement angle. When viewing conditions are adverse, when available reading time is limited, or when accuracy is very important, these factors assume major importance.

A few preliminary definitions are necessary in order to avoid confusion and make the various terms we will use in this chapter more clear:

Visibility: The quality of a letter or number which enables the

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[1] J. A. Prince. "Speed in Conveying Message Becomes More Vital Each Year." Signs of the Times, October, 1957, pp.
[2] Ibid., pp.

observer to distinguish it from its surroundings.

Legibility: The characteristics of letters or numbers which make it possible to differentiate one from the other.

Readability: The quality which enables the observer to correctly perceive the information content of letters or numbers grouped together in words, sentences, or other meaningful relationships.

Various studies have been conducted over the years to determine the relative legibility of different letters, and different sizes, styles and spacing of letters. Interest in the effect of these and other factors upon legibility can be traced back into the nineteenth century; most of these early observations stemmed basically from the opinions and experience of printers and typographers. The first controlled study on the legibility of alphabet letters was done by Cattell in 1885.[3] Since then a number of researchers have conducted many thousand investigations on this subject, most of which deal with the legibility of alphabet letters.

Most of these earlier investigators agreed that capital letters were generally more legible than lower case letters. This is because differences in the visibility of various letters are due mostly to the number of strokes and junctions and their positions in the letters; and capitals consist almost exclusively of straight lines and sharp angles. These studies reported an order of legibility among the letters, determined largely by using a short viewing distance. A comparison of the results achieved show extensive variation between letters.[4] Variations can be attributed in part to differences in the kind of type used and to differences in method. In a later study by the National Electric Sign Association (NESA)[5] which transposed visibility distances into factors, the results indicated that the letters L, I, U, J, and A were the most legible, and that M, W, B, Q, and S were among the least legible. Considering all studies reported, the capital letters which were consistently among the most legible were A and L, while those consistently least legible were B, G, and Q.[6]

To illustrate, Prince reported that the letter "L" requires only 63

[3] J. McK. Cattell. "The Inertia of the Eye and the Brain." Brain, 1885, Vol. 8, pp. 295-313.

[4] M. A. Tinker. "The Relative Legibility of the Letters, the Digits, and of certain Mathematical Signs." Journal of General Psychology, 1928, Vol. 1, pp. 472-96.

[5] National Electric Sign Association. Reference Manual. Chicago: Research and Development Foundation of NESA, 1960.

[6] M. A. Tinker. Legibility of Print. Ames, Iowa: Iowa State University Press, 1963.

percent of the visual acuity needed to see a "B".[7] This means that for the letters to be equally visible, the letters should not be the same size. We will discuss this problem later on.

Tinker summarized the results of seven reports on the relative legibility of lower-case letters, using the methods of short exposure, distance, and peripheral vision (the farthest distance from fixation that a letter can be accurately perceived). He found a fairly close correlation between these studies. The trends indicated that letters of high legibility were d, m, p, q, and w, while letters of low legibility were c, e, i, n, and l. Many letters, both upper-case and lower-case ranked low in legibility because of the frequency with which they were confused with other letters; B with R, G with C, n with a, c with e.

A more recent study[8] reported the relative legibility of lower-case letters, both for square letters and for 5x4 letters, whose width was 80% of their height. The results show a marked variation between the two sizes of letters; sometimes the square letters were more legible, on other occasions the 5x4 letters were. Among the square letters, c, v, o, and x were most legible, whereas for the 5x4 letters, j, p, h, and l were most legible. There were, obviously, certain letters which cannot be square (i,l) and some which cannot be 5x4 (m,w). (See Table 1).

[7] J. A. Prince. "Differences in Legibility of Letters." Signs of the Times, December, 1957, p. 48.

[8] NESA, 1960.

TABLE 1

LETTER LEGIBILITIES (LOWER CASE)

Letter	Legibility Factor		Letter	Legibility Factor		Letter	Legibility Factor	
	square	5x4		square	5x4		square	5x4
a	1.05	1.05	k	1.14	-----	u	-----	1.20
b	1.21	1.24	l	-----	1.26	v	1.56	1.22
c	1.56	1.13	m	1.00	-----	w	1.07	-----
d	1.20	1.29	n	-----	1.13	x	1.45	-----
e	1.00	1.00	o	1.45	-----	y	-----	1.26
f	1.05	1.18	p	1.14	1.29	z	1.40	-----
g	1.14	1.20	q	1.12	1.13			
h	1.19	1.27	r	-----	1.25			
i	-----	1.27	s	1.24	1.13			
j	-----	1.50	t	-----	1.14			

From all these results we can draw several conclusions about the factors which are most influential in determining the legibility of individual letters. First, it appears that simplicity of outline plays an important role — L, I, U, d and p, all having simple outlines, were generally most legible, while M, B, W, e and g were among the least legible. Also the amount of surface area of the letter also exerts an influence — e.g., compare w or p with i or l. In addition, letters which have a stroke which distinguishes them from others also rate high in legibility, such as b, q, p, and k. Shading, too, seems to affect legibility; the combination of thin and thick strokes and the amount of white area within a letter determine the visibility of the letter to some extent.

Much less research has been done on the relative legibility of numerals. The NESA[9] study showed that the order from most legible to least legible was: 1, 7, 4, 3, 2, 6, 9, 5, 8. A study by Tinker (1930) reported approximately the same results. As with letters, numerals were perceived more accurately when in isolation than when in groups. A study of the relationship of Roman numerals to Arabic ones[10] indicates, as might be expected, that the Roman numerals have a much lower legibility. When speed and accuracy of reading various sizes of Arabic and Roman numerals were compared, in every instance the Arablic numerals were read faster and more accurately. This fact can be attributed both to the relative unfamiliarity of Roman numerals to the ordinary reader and to the complexities of larger numbers in Roman form. It is quite obvious that for maximum legibility, Arabic numerals should be used instead of Roman numerals wherever possible.

The NESA study also investigated the relative legibility of numerals compared with that of upper-case letters. Their results showed that the letters had a considerably higher legibility than did the numerals. In fact, half of the 26 letters had a higher legibility factor than did any of the numbers. The letters B, W, S, Q, and R ranked equally low in legibility with the numberals 8, 5, 9, and 6. (See Table 2.)

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[9] NESA, 1960.

[10] D. K. Perry. "Speed and Accuracy of Reading Arabic and Roman Numerals. Journal of Applied Psychology, 1952, Vol. 36, pp. 346-47

TABLE 2

LETTER AND NUMERAL LEGIBILITIES (UPPER CASE)

Letter or Numeral	Legibility Factor	Letter or Numeral	Legibility Factor	Letter or Numeral	Legibility Factor
	high leg.				
l	1.92	H, Y, P	1.69	2	1.26
I, U	1.90	4, 7	1.64	R, 6	1.23
J	1.85	X, D, O	1.61	Q	1.22
T	1.83	Z, 3	1.56	W, S	1.20
A	1.814	K	1.54	9	1.19
C, F, N	1.77	M	1.47	5, B	1.15
E, V	1.72	G	1.43	8	1.00
				low leg.	

READABILITY

Determining the legibilities of individual letters and numerals provides us interesting information, but is not complete enough to help us deal with the form in which most letters appear — grouped into words. Legibility of all letters seems to be significantly reduced when grouped together, especially if they are closely grouped. The results of a Janesville Survey[11] reveals that there is an average reduction in their legibility of more than 12%. Even when letters were grouped into nonsense syllables, the individual recognition thresholds of each letter was affected by the close proximity of other letters.

An important factor to consider when grouping letters together is the amount of solid color and the white or light colored background in the area of the words. Where strokes join each other there is much more solid color, and this reduces the sharpness of the image in that area. Figure 1 shows that the reduction of the amount of solid color at these points of union in letters having more than two strokes increases the visibility of the letters.

[11] National Advertising Company, 660' Janesville Survey, Bedford Park, Ill., 1966.

FIGURE 1. Increased legibility has been obtained for these letters by tapering the junction points of strokes so that there is less black (color) in those areas. While this also might not be entirely practical in lettering a sign, it does emphasize characteristics that increase legibility of letters.

For those people who have lower than average visual acuity, a slight extension of the corner points helps to increase the sharpness and visibility of the letters, shown in Figure 2.

FIGURE 2. Another method of increasing legibility of letters is to extend the corners of the strokes slightly. This neutralizes the tendency of ends to appear rounded to a person whose defective eye-sight causes the letters to appear blurred.

Grouping letters immediately reduces their visibility, because visibility has been found to depend to a large extent on the amount of light-colored background behind and around a letter. Figure 3 illustrates this.[12]

[12] Figures 1, 2, and 3 were taken from an article by J. A. Prince. "Differences in Legibility of Letters." Signs of the Times, December, 1957, p. 49.

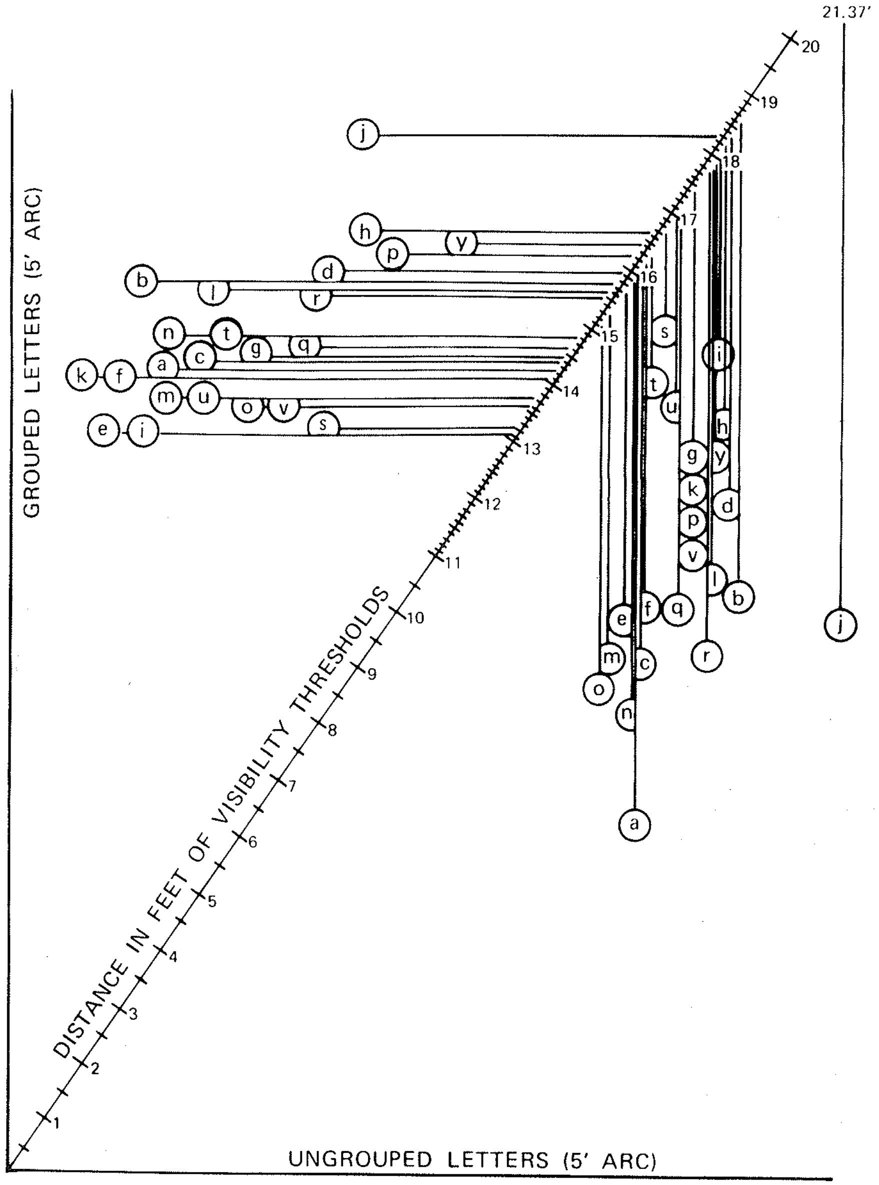

FIGURE 3. Grouping of letters reduces legibility. This is shown in chart, which indicates the distances at which lower case letters of certain sizes are seen individually. On the right, the distances represent the thresholds when the letters are viewed singly, and on the left the thresholds are for letters placed in meaningless groups of four.

Once letters are grouped into meaningful words, their legibilities depend to a certain extent upon the reader's familiarity with the words. An experiment by Vernon[13] indicated that the extent to which the reader confused similarly shaped letters like c and e depended on the extent to which the reader was familiar with the context and meaning of the words in which it occurred. In ordinary, comprehensible reading matter, confusion of letters was insignificant.

Readability, as defined before, is the recognition of the information content of letters grouped together into words. At the same time, as has just been indicated, this does not necessarily imply the comprehension of each letter in the word, but rather the ability to understand a familiar word even if only a few of the letters have been seen clearly. This concept is applicable for constructing signs when it is more important that the reader understand the message than that he be able to perceive each letter. However, to avoid misinterpretation of the message, it is important to design the copy of signs for maximum legibility and readability so that it reaches as much of the viewing population as possible.

As far as readability of upper-case letters versus lower-case letters is concerned, Tinker reports that lower case printing is much more legible than all-capital printing. He attributes this to the fact that "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."[14] These results are probably also due in large part to the unfamiliarity of people with reading a text which is totally in capital letters. People can comprehend the meaning of certain groupings of lower-case letters into a word without reading each letter, because they have seen it so often. However, other results have revealed that for words used as labels (such as for identification or on instrument panels) capital letters were more readable than lower-case or mixed letters (Hodge, 1962). This study further indicated that for use as labels, the optimal spacing between letters was about 75% of the letter width.

Studies have also tested the relative legibility of various styles of type. NESA[15] reported an experiment in which four styles of type — Egyptian (uniform stroke-width of one-fifth of letter height), Roman (thin strokes for parts of the letter), Old English, and Script — were tested for readability at a distance. The results of these tests placed

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[13] M. D. Vernon, III. Studies in the Psychology of Reading. London: H. M. Stationery Office, 1929.
[14] M. A. Tinker. Legibility of Print. Ames, Iowa: Iowa State University Press, 1963.
[15] NESA, 1960.

the readability of words in all alphabets much higher than the legibility of single letters. For the readability of words, the Egyptian style was most readable, followed in order by Roman, Old English, and Script. The lower readability of the Roman letters was attributed to the thin strokes remaining invisible until the viewer gets comparatively close. The tests with these four styles of type also involved using four colors — red, black, blue, and green — and found all four to be equally readable on a white internally illuminated panel.

A recent experiment was conducted to determine (1) whether or not certain signs used by Northwestern University are communicating their messages to the public, and (2) whether or not they communicate as well as similar signs in more familiar type styles. [16]

The tests were of a reproduction of an actual sign on the campus, referred to as Sign A, and of two test signs B and C. See Figures 4, 5, and 6. [17]

Northwestern
University
Chicago Campus

FIGURE 4

[16] Stewart H. Britt. "An Experiment on the Perception of Signs." International Journal of Symbology, March, 1972. Vol. 3, No. 1, p. 9.

[17] Ibid., pp. 13-14.

Northwestern
University
•
CHICAGO CAMPUS
•

Figure 5

Chicago Campus
NORTHWESTERN
UNIVERSITY

GRADUATE SCHOOL OF BUSINESS ADMINISTRATION
DENTAL SCHOOL · MEDICAL SCHOOL
LAW SCHOOL · EVENING DIVISION

Figure 6

Although only a small number of people were tested, each subject's visual acuity was taken into account, and the experiment itself contained good control of the stimuli; therefore the results are worth noting.

Each subject viewed one of the three signs in a tachistoscope or "flashbox" that facilitated controlled time exposures as well as controlled degrees of illumination of visual stimuli.

The speed of recognition of the sign was determined by measuring the number of exposures necessary for an individual to recognize all elements of the sign. Table 3 contains the raw scores of all subjects, in terms of seconds above each one's threshold, at which the content of the entire sign was recognized.

We can see that Sign B communicates its message much quicker than either Sign A or C. In addition, since the median score for Sign B is lower than Sign A's lowest score, Sign B is apparently superior to A in its ability to communicate rapidly. [18]

TABLE 3

SPEED OF RECOGNITION OF CONTENT OF ENTIRE SIGN
(in seconds)

Sign A (Old English, with "Chicago Campus" at bottom)	Sign B (Sans-Serif Roman, with "Chicago Campus" at bottom)	Sign C (Sans-serif Roman, with "Chicago Campus" at top, plus list of five schools
7	1	3
7	2	4
7	2	7
7	2	9
10	3	10
10	3	11 (median)
10	3	12
11	6	13
11 (median)	7 (median)	15
11	7	
12	7	
12	8	
13	11	
13	12	
15	12	

[18] Britt, pp. 10-11.

Table 4 shows Sign B to be superior in its ability to quickly communicate the sign's essential message — that this is Northwestern University.

TABLE 4

SPEED OF RECOGNITION OF "NORTHWESTERN"
(in seconds)

Sign A	Sign B	Sign C
0	-2	-2
2	-2	1
2	-1	1
3	-1	4
5	0	5 median
6	0	6
6	0	7
7 median	1 median	8
8	1	10
9	1	
9	2	
10	2	
12	2	
13	5	
13	7	

Sign A was also perceived incorrectly. People tended to perceive or interpret it as designating the University of Chicago instead of Northwestern University. This points out the importance of placement of the words in a message, as well as the type of lettering used.

Another interesting experiment which dealt with style of type was one by Lansdell[20] in which the legibility of off-beat, modernistic numerals was compared experimentally with that of a more traditional numeral style. Although the Lansdell numerals were initially strange to most viewers, it was found that people could learn to identify them quickly. Results further indicated that the legibility of these numerals was significantly better than that of the traditional numeral style for both direct viewing and for different viewing angles.

In summary we can make several general statements about various factors of legibility and readability. Considerable variations in the

[20] H. Lansdell. "The Effect of Form on the Legibility of Numbers." Canadian Journal of Psychology, 1954, Vol. 8, pp. 77-79.

legibility of both capital and lower-case letters exist, determined largely by simplicity of outline and the amount of surface area and background provided for the letters. Variation also exists in the legibility of numerals; but the evidence strongly supports the thesis that Arabic numerals can be read far faster and more accurately than Roman numerals. Individual capital letters are more legible than lower-case letters in terms of visibility at a distance; but when grouped together into words, lower-case letters promote readability more than do capital letters. Finally, Roman-style type, in which all the strokes of the letters have a uniform thickness, is generally considered to be more readable than other styles which combine thick and thin strokes.

LETTER SPACING AND PROPORTIONS

The width and spacing of letters is an important factor in the readability of signs and printed material. In 54% of all letters there is a close relationship between area and legibility.[21] Little known psychological factors play an important part in the recognition of letters once they are formed into words, and this could be to some extent because of the familiarity of the words themselves. It also relates to the positions of the letters in the words. But legibility is also largely a function of both strokewidth (the ratio of the thickness of the stroke to the height of the letter or numeral) and the space between letters. An optimal strokewidth and spacing can be determined for various viewing conditions. Any ornamentation such as serifs becomes a complicating factor which tends to reduce the legibility of the letters. This has been known for a long time, but it is doubtful if the reason for it was apparent to the non-scientist. Serifs overlap the spaces between strokes and thus make them less effective, so that unless a letter with serifs is made a little larger than one without serifs, the strokes will tend to merge with each other.

Figure 7a shows a letter "E" with serifs, and one the same size without serifs. Figure 7b shows two similar letters, one with and one without serifs when viewed by a person with a moderate degree of visual impairment. [22]

[21] NESA, 1960.

[22] J. A. Prince. "Differences in Legibility of Letters." Signs of the Times, December, 1957, p. 48.

FIGURE 7a. Serif letter (left) provides considerable variation of appearance from non-serif letter (right).

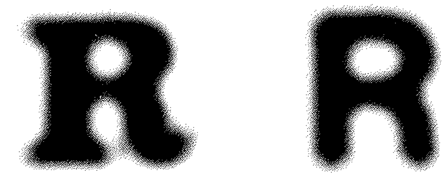

FIGURE 7b. To a person with visual defect, letters appear blurred, and because of its more complicated pattern, the serif letter is not as legible as the sans-serif letter. This emphasizes that in situations where legibility at great distance is required or where small lettering must attain maximum legibility distance, a sans-serif letter will be more effective.

Concerning the spacing of letters, it was found in the NESA study referred to on page 14 that legibilities do vary in relation to the amount of space between letters; when inter-letter spacing is increased from 20 percent to 40 percent of the height of the letter, the increase in the speed with which a message can be read will be as much as 25 percent. In fact, experiments have revealed that visibility of words can be varied as much as 200 percent by changing the widths of the spaces between the letters. Dr. Prince states that "results of several hundred thousand controlled observations have shown that so long as non-serifed letters are used which subtend an angle of five minutes of arc to the eye at the threshold distance for their height, and not less than 4 minutes of arc (1/15 degree) for their width (excluding "M" and "W", which must be 5 minutes of arc both ways), the spaces between the letters will give maximum visibility if they are 2 minutes of arc (1/30 degree). In other words, each space should be half the width of a letter "O" as can be seen in Figure 8. [23]

[23] J. A. Prince. "Criteria For Word Formation for Maximum Legibility." Signs of the Times, January, 1958, pp.42-3.

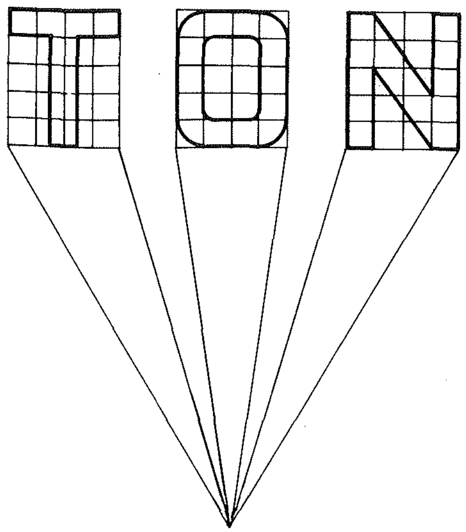

FIGURE 8. Results of several hundred thousand controlled observations have shown that spaces between letters will give maximum visibility if the arc of angle b is 2 minutes (1/30 degree), so that the space is one-half the width of the letter "O", which subtends an angle (a) of 5 minutes of arc to the eye at the threshold distance for the letter's height. This is a guide to legibility, especially of signs to be viewed at a great distance or where lettering is extremely small. Once functional legibility is assured, attractive and expressive appearance must also be considered.

The same principle may be applied for lower case letters in words, ignoring the capitals when calculating the angle to the eye. Figure 9 shows how this spacing technique can be applied to ordinary reading.[24]

[24] Prince. "Criteria For Word Formation . . ." p. 43.

The habits of birds are known in great detail through studies by many professional and amateur students. The distinctive coloration and voices of birds appeal to human eyes and ears, and many bird species are of economic importance because of their food habits. Certain kinds are hunted as game, and the few domesticated species contribute to man's food supply. The ancient classical names for birds are perpetuated in the name of the class.

Birds are the best known and most easily recognized of all animals, because they are easily seen, are common, and are active by day. All birds have feathers that clothe and insulate their bodies to make regulated body temperature possible, and those of the wings and tail provide flight. No other animals possess feathers. The ability to fly enables birds to occupy some habitats denied to other animals, and to move about actively.

FIGURE 9. Increased visibility resulting from more adequate spacing between letters is demonstrated in the contrast of the two paragraphs above. The print of the paragraph at the top has been spaced so that the angle subtended to the eye between any two letters is 2 minutes of arc at a specified distance, or half that subtended by the letter "o" in its horizontal dimension. The lower paragraph is print of exactly the same size but with conventional spacing between letters. This print is less visible than that with the wider spacing.

The visibility of most lower-case letters varies according to their position; most are less legible in the middle of a word than they are at either end. This can be minimized when the letters are well spaced in the proportion suggested earlier.

Figures 10, 11 and 12 show three of the various designs of letter used in the experiments to which Dr. Prince refers.[25]

[25] Prince. "Criteria For Word Formation . . ." p. 43.

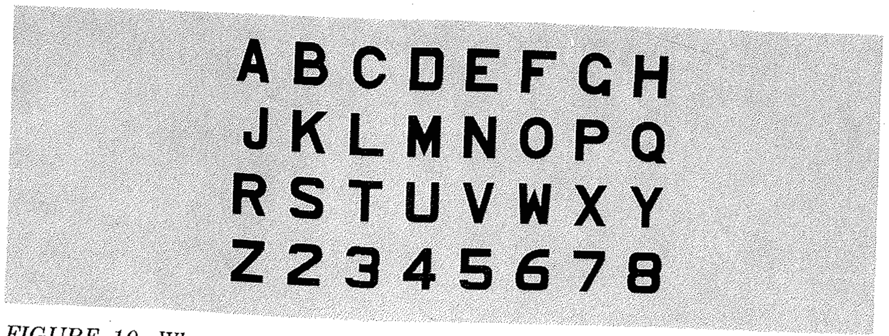

FIGURE 10. When these letters are placed at the threshold of visibility, they subtend an angle to the eye of 5 minute arc vertically and 4 minute arc horizontally, a ratio of 1 to 0.8.

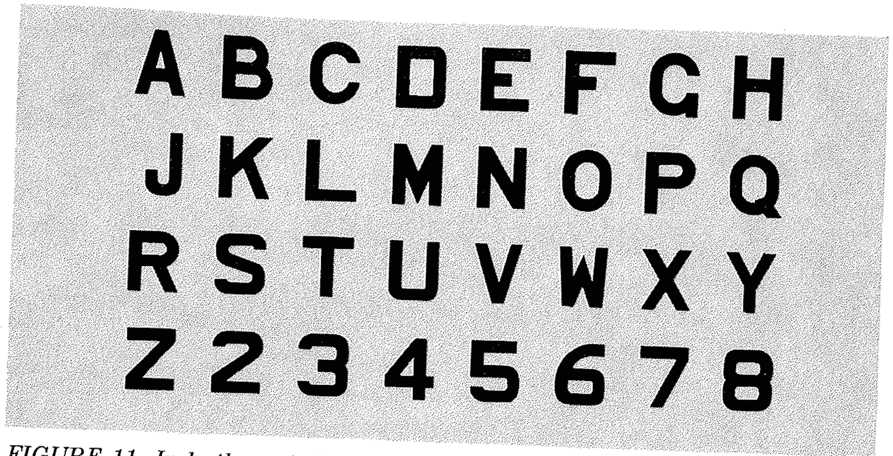

FIGURE 11. In both vertical and horizontal directions, these letters subtend an angle to the eye of 5 minute arc in both vertical and horizontal directions at the threshold distance.

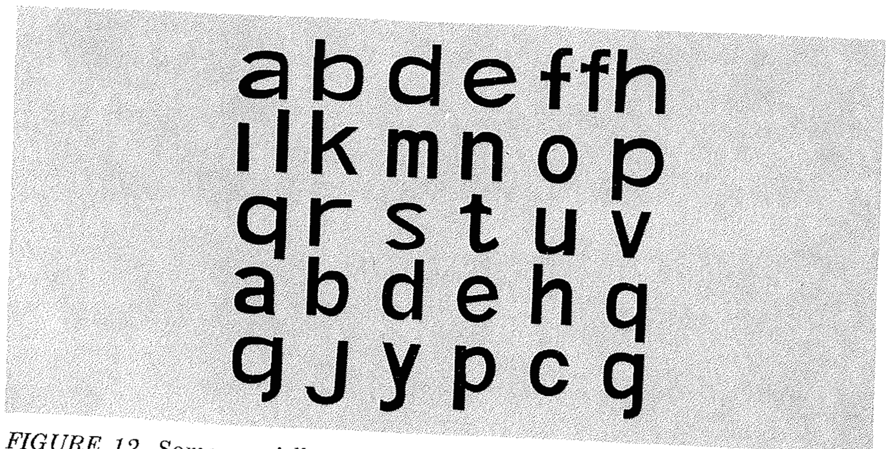

FIGURE 12. Some specially designed lower case letters, showing 5-minute arc horizontal dimension in some and 4-minute arc in others.

Dr. Prince states that for advertising signs the following well known lower-case designs can be copied with results almost equal to those of the specially designed letters shown in Figure 12.[26]

1. Gils sans serif.
2. Spartan semi-bold.
3. Spartan medium.
4. Futura medium.
5. Monsen medium Gothic.
6. Bernhard Gothic medium.
7. Sans serif medium or bold.
8. Vogue bold.

Studies have also been made[27] to determine maximum legibility for letters and words in a limited space (as on license plates, instrument panels, etc.). The results show that if there is a restricted space, the letters or words are most readable when they fill up that space as much as possible, with only a strokewidth or so separating them from the margin. For letters of given size, however, it was found that if there were no spatial restrictions, a border which allowed a large amount of space between itself and the letters was more legible than a border which fit tightly around the letters or numbers, and was also more legible than having no border at all.

Strokewidth and the relation of letter width to height are both decisive factors in legibility. In an important experiment measuring the relationship of strokewidth to viewing distance, Berger[28] varied the strokewidth-height ratio of the numerals on a license plate, for both white and black numerals, from 1:5 to 1:40, to determine the distance at which each ratio became legible. He found that the distance at which the various strokewidth-height ratios became legible differed considerably. For white numerals on a black background, the greatest reading distance occured with a 1:13.3 ratio, whereas for black letters on a white background, the optimal ratio was distinctly lower, around 1:8. This difference has been attributed to the phenomenon of irradiation, in which white characters seem to flow into surrounding black areas, but not the converse. Under highly illuminated conditions Berger found this phenomenon to be even more marked.

Other studies confirm this indication that white characters on a

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[26]Prince. "Criteria For Word Formation . . ." p. 43.

[27]C. S. Bridgman & E. A. Wade. "Optimum Letter Size for a Given Display Area." Journal of Applied Psychology, 1956, Vol. 40, pp. 378-81.

[28]C. Berger. "Strokewidth, Form, and Horizontal Spacing of Numerals as Determinants of the Threshold of Recognition." Journal of Applied Psychology, 1944, Vol. 28, pp. 208-31, 336-46.

black background should have a thinner strokewidth than black characters on a white background. McCormick generalizes that from various studies it can be said that for black on white, the best ratio is from 1:6 to 1:8, and for white on black from 1:8 to 1:10 (See Figure 13).[29]

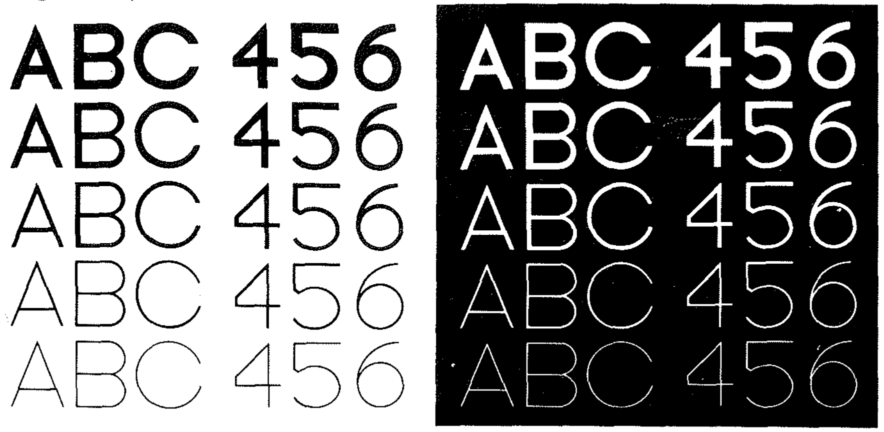


FIGURE 13. Illustrations of strokewidth-height ratios of letters and numerals.

Researchers have also investigated the relationship of letter width (as well as strokewidth) to letter height. Soars, using a short-exposure method, examined this dual relationship; his results indicated that the most readily perceivable combination of the three factors for all numerals was a strokewidth-height ratio of 1:10 and a width-height ratio of 7.5:10.[30] In their research, Rohm and Haas determined that the strokewidth-height ratio should be about 1.5:10 and the width-height ratio about 6:10.[31] An experiment on width-height ratios by Brown and Lowrey found the best ratio for capital letters to be a bit lower, with the best legibility occuring with a ratio of between 8.5:10 and 1:1.[32] From all these results, we can conclude that for the highest visibility the width of the numeral or letter should range between two-thirds of the height and equal with the

[29]E. J. McCormick. Human Factors Engineering. (3rd Ed.) New York: McGraw-Hill, 1970.

[30]R. S. Soars. "Height-width Proportion and Stroke Width in Numerical Visibility." Journal of Applied Psychology, 1955, Vol. 39, pp. 43-46.

[31] Plexiglas: Sign Manual. Philadelphia: Rohm and Haas Company, 1969, p. 46.

[32]R. R. Brown & E. A. Lowery. A Study of the Requirements for Letters, Numbers, and Markings to be used on Transilluminated Aircraft Control Panels. Part 1. "The Effect of Stroke Width upon the Legibility of Capital Letters." Naval Air Material Center, Aeronautical Medical Equipment Laboratory. Report TED NAMEL-609, part 3, 1951.

height.

There are a number of common mistakes made regarding letter spacing and proportion that can easily be avoided. The following six examples that illustrate these problems are from Institute of Outdoor Advertising.

One frequent problem, for instance, is crowding too many letters into a given space, which tends to repel the viewer's eye and which thereby defeats the purpose of the crowding — to use type as large as possible.

CRAMMED

Creating too great a contrast between thick and thin strokes can often confuse the viewer and result in a loss of identity of basic shapes and letters, as shown below.

INDISTINCT

Aesthetic attempts to minimize differences between letters by rounding uniformly the tops of the letters or by lining up all the horizontal centers, as shown below, also tends to decrease legibility.

ABREGH

Strokes that are too thin do not utilize totally the basic shapes and tend to fade into the background, becoming invisible at a distance.

OBSCURE

Letters that are too thick or heavy, on the other hand, also become illegible at a distance, turning into shapeless blobs.

OVERHEAVY

Artistic letter styles, like the one shown below, although they may be suitable for other printing purposes, sacrifice legibility when used in signs; they sacrifice the basic shapes for the decorative aspect, and make it difficult to distinguish individual letters.

Unreadable

LEGIBILITY OF VARIOUS LETTER SIZES AT VARIOUS DISTANCES

To determine the proper size of the letters or numerals on a sign, be it a road sign or an instrument panel, the decisive factor is the distance at which the letters or numerals first become legible.

It is generally accepted by sign manufacturers that under normal conditions a person with normal visual acuity — 20/20 vision, can see an object that subtends a visual angle of at least one minute. In other words, the object must be at least 3.5 inches in diameter at 1000 feet. To distinguish lines, the minimum angle can be as small as 4 seconds. Such visual acuity is unusual, however. For a person with normal 20/20 vision, one inch of additional letter height is necessary for every 55 feet of distance. In light of the fact that the minimum visual acuity required of most licensed drivers is 20/40 vision, one inch of letter height for every 50 feet of distance has been accepted as the rule of thumb by most sign manufacturers. Tests have also shown that for most people to read an unfamiliar name at 1000 feet, the letters must be at least 18 inches high.

The legibility of different sized letters cannot, of course, be discussed in an isolated context. Other factors such as automobile speed, size of the highway, and nature of the road will affect the necessary size which letters must be in order to be seen. A study conducted for Baltimore County determined the following complex reaction times of drivers on different kinds of roads:[33]

2 lane road	- 8 seconds	6 lane road	- 11 seconds
4 lane road	- 10 seconds	expressway	- 12 seconds

[33] Baltimore County Planning Department, et al. Study Presented to Baltimore County: Legibility Analysis of Signs, 1968.

In other words, a motorist travelling at 45 miles per hour on a four lane road will travel 660 feet before he can comprehend a sign by the road. Assuming that every 50 feet of viewing distance requires one inch of letter height, the letters for such a sign would have to be at least 13 inches high. If the sign is to have, for instance, 30 letters, the copy would occupy an area of about 36 square feet. Since the copy area of a sign should generally be about 40% of the total sign area, the sign itself should be 90 square feet. If the motorist were travelling at 30 miles per hour, these calculations would indicate that the total sign area should be 40 square feet; at 60 MPH it should be 150 square feet. (Costa Mesa Planning Department, 1972).

Several other studies have been undertaken to determine the relationship between the threshold distance (the distance at which the letters or numerals first become visible) and the size of the letter or numeral. The Janesville 660' survey determined experimentally the threshold distances of roadway signs of various sizes, which were situated 660 feet off the road.[34] Using a number of respondents, they measured the maximum viewing distance for signs whose letters varied in size from three feet to eight feet. This viewing distance was computed to be the hypotenuse of the triangle formed by the 660' perpendicular setback from the road and the viewer's distance from this perpendicular. It could then be determined what the maximum visibility for each size sign (under specified conditions such as day or night, color contrast and background) would be. Their results indicated, for example, that the maximum visibility for a letter five feet high was 2770 feet, or a maximum visibility in feet per inch of letter height of 46 feet.

A NESA study[35] took a different approach and determined the threshold distances for various size letters by purely mathematical means. When a person views a sign, rays of light from the left side of the sign and rays of light from the right side converge on his eye, delimiting a certain angle. As the viewer approaches the sign this angle will get larger, whereas if he moves away from the sign, the angle will grow correspondingly smaller. If one knows the smallest angle of sight at which the letter will still be legible, one can calculate the threshold distance. Consequently, the minimum letter size which can still be legible at any distance can be determined.

[34] National Advertising Company. 660' Janesville Survey. Bedford Park, Illinois: Author, 1966.
[35] NESA, 1960.

TABLE 5

SIZES OF LOWER CASE LETTERS
CALCULATED FOR LEGIBILITY AT GIVEN DISTANCES
WHEN THE LETTERS ARE GROUPED TOGETHER

These letter sizes are an absolute minimum to afford legibility for distances shown.

Size (inches)		Distance (feet)	Size (inches)		Distance (feet)
2-3/8	(2.37)	100	20-1/8	(20.14)	850
3-9/16	(3.56)	150	21-5/16	(21.33)	900
4-3/4	(4.74)	200	22-1/2	(22.52)	950
5-15/16	(5.92)	250	23-11/16	(23.70)	1000
7-1/8	(7.11)	300	26-1/16	(26.07)	1100
8-5/16	(8.30)	350	28-7/16	(28.44)	1200
9-1/2	(9.48)	400	30-13/16	(30.81)	1300
10-11/16	(10.66)	450	33-3/16	(33.18)	1400
11-7/8	(11.85)	500	35-9/16	(35.55)	1500
13-1/16	(13.04)	550	37-15/16	(37.92)	1600
14-1/4	(14.22)	600	40-5/16	(40.29)	1700
15-3/8	(15.40)	650	42-11/16	(42.66)	1800
16-5/8	(16.59)	700	45	(45.03)	1900
17-3/4	(17.78)	750	47-3/8	(47.40)	2000
19	(19.00)	800			

Dr. Prince's findings are also based on laboratory experiments and mathematical calculations. Because of their complexity, we shall quote Dr. Prince directly:

"The retina contains many minute light receptors . . . which convey the message received in the form of light to the brain. There are about 200,000 of these receptors to the square millimeter in the central part of the retina . . . which is equivalent to about 125 million to the square inch . . . only three rows of them need to be stimulated to produce a recognition of form. Figure 14 shows this more clearly than any word description . . . A smaller image falling on fewer receptors would appear only as a blob without recognizable form.

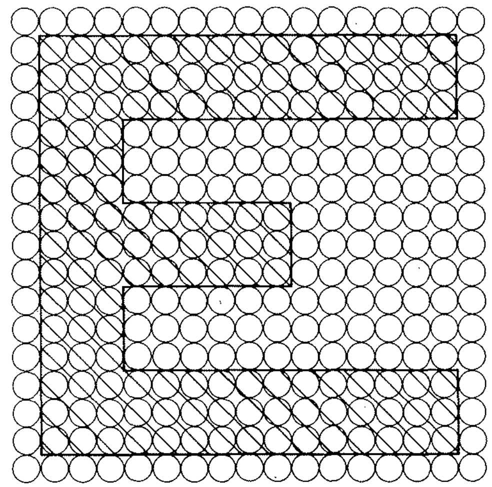


FIGURE 14. When the tightly packed light receptors in the eye are stimulated by the formation of an image on the retina, each stroke and each space of a letter must affect at least three rows of them if the actual shape and form are to be perceived. When less than this number are stimulated, the letter will be a blur. With this knowledge we can assess the size an image of any object must be in order to be recognized at the greatest possible distance.

"The size of this image will depend on the size of the letter looked at, and so, as we know the minimum size of image required to produce threshold vision, we can calculate the size of letter required to produce this. If the letter is to be viewed at six meters (20 feet), then it must be not less than 8.75 mm. (0.344 inch) high and not less than 7.0 mm. (¼ inch) wide, but preferably as wide as it is high, i.e., 8.75 mm. square.

"Figure 15 shows another principle in the calculation. The letter subtends an angle to the viewing eye which in the case of the scale given in the last paragraph is 5 minutes of arc (1/12 degree). As soon as this angle is reduced below this point, the image on the retina becomes too small for recognition. It must be understood that this is an average. Some people see better, some a little less than average.

"We can therefore say that if a sign consisting of one familiar letter is to be seen at 2,000 yards, that letter must be not less than 262.5 cms. high. That is 8 feet 7½ inches. But letters are not all equally visible."[36]

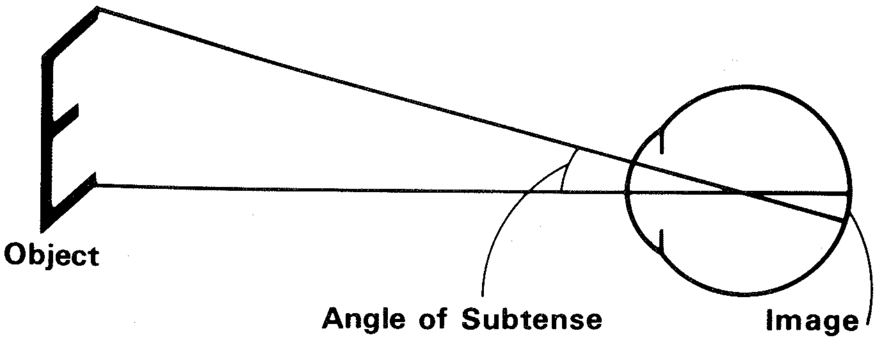


FIGURE 15. Since we know the minimum size of image that must be formed on the retina to enable an object to be recognized at the threshold of vision, the necessary size of that object can be calculated for any distance from the eye. In this illustration a letter is used to show this.

Several researchers have worked out formulas by which to calculate necessary letter size for given viewing distances. Rohm and Haas[37] used the equation H = MRD/600, in which H is the height of the letter in feet, and MRD is the maximum readable distance, or threshold distance. Thus, if the desired threshold distance is 1200 feet, the letters must be two feet high. Using the Rohm and Haas formula for calculating strokewidth and width of the letter already mentioned, one can determine all the dimensions of the letters.

Similarly, Peters and Adams formulated a method to calculate minimum letter height, especially for smaller distances, which takes into account other factors affecting legibility, such as illumination, reading conditions, and the importance of reading accuracy:[38]

[36] J. A. Prince. "Letter Formation For Greatest Legibility." Signs of the Times, November, 1957, pp. 50-51.

[37] Plexiglas: Sign Manual. Philadelphia: Rohm and Haas Company, 1969, p. 46.

[38] G. A. Peters & B. B. Adams. "Three Criteria for Readable Panel Markings." Product Engineering, 1959, Vol. 30, pp. 55-57.

$$H + 0.0022D + K_1 + K_2$$

where H = letter height in inches

D = viewing distance

K_1 = correction for illumination and viewing conditions

K_2 = correction for importance of accuracy when applicable of .075.

This variety of approaches indicates that there are a number of ways to determine accurately what the size of the symbols on a sign should be for certain viewing distances.

COLORS

Various studies have examined the effects of colors upon legibility and the ways in which different colors exert different influences upon the viewer.[39] Such findings can be especially useful to sign manufacturers in designing more effective displays.

Yellow is the most easily focused color so far as the human eye is concerned, so it frequently tends to look larger as well as brighter than other colors when the areas are the same. White has about the same effect. Next in order of largeness comes red, then green, and finally blue, if there is a high contrast or level of illumination. As the illumination is reduced, red is the first color to fade out.

Blue light focuses in front of the retina of the eye, while red focuses behind it. For example, a blue letter placed upon a red illuminated background would stand out in bold relief. This combination could possibly be used for special effects if the wavelengths were carefully chosen.

Each color or color combination seems to produce a certain effect upon the viewer. If good contrast is maintained, yellow, yellow-orange, or yellow-green form the most comfortable and pleasing backgrounds. Red colors are found to be stimulating, raising the blood pressure and increasing the pulse rate. Orange is found to have a high appetite appeal, recommending it for restaurant and food services. Greens and blue-greens tend to reduce tension, while a combination of blue-green and peach improve the effect of each other. Blue professes to lower the blood pressure and slow the pulse rate, being the opposite of red. Pale blue, because it is never quite in focus, irritates some people's eyes, and will even make things seem a little blurred, especially if they are close. Blue is also likely to cause wandering attention, but not when used with contrasting colors. Violet is less visible to older people than other colors because aging

[39] Hans Kreitler and Shulamith Kreitler. Psychology and the Arts. Durham, North Carolina: Duke University Press, 1972, Chapters 2 and 3; Martin S. Lindauer, "Form Imagery to Colors." Perceptual and Motor Skills 1973, Vol. 36, pp. 165-166.

of the lens within the eye produces a yellow filtering effect which tends to neutralize or enhance some colors.

With these few factors alone to consider, the designing of signs becomes even more of a challenge than is generally supposed, and perhaps more attention can now be given to color combinations when designing both electric and non-electric signs.

The relative legibility of black print on a white background versus white print on a black background has been the subject for many experiments. The results indicate that although white print on a black background is considerably more striking to the viewer and thus tends to attract more attention, it is also significantly less legible than black print on a white background. In the study by Berger, it was found that single white numerals on a black background were 8.2% more recognizable than black numerals of the same size on a white background.[40] But a decisive experiment by Starch revealed in a speed-of-reading test that black type on white paper was read 42% faster than white on dark gray.[41] In a similar test, Paterson and Tinker found that the black print was read 10.5% faster than the white; and among the 280 readers who took the test, 77.7% considered the black more legible.[42] The reason for the faster reading speed of black type stems from the same condition which make white type more attention-getting. A study on eye-movement by Taylor showed that the eye tends to fixate on white print more readily; he also found that the total number of fixations, the average pause duration, and the total perception time were all significantly greater for white print than for black print.[43]

As another part of this study, Taylor found that the black symbols were more legible and were seen farther out in peripheral vision than the white symbols. Although both sets of symbols could be read more easily after practice with peripheral vision, the improvement was greater for the black than for the white letters. In addition, when testing the relative legibility of various sizes and styles of black and white type, Taylor's data showed that in every comparison, the white

[40] C. Berger. "Strokewidth, Form, and Horizontal Spacing of Numerals as Determinants of the Threshold of Recognition." Journal of Applied Psychology, 1944, Vol. 28, pp. 208-31, 336-46.

[41] D. Starch. Principles of Advertising. Chicago: A. W. Shaw & Co., 1923.

[42] D. G. Paterson and M. A. Tinker. "Studies of Typographical Factors Influencing Speed of Reading: VI. Black Type Versus White Type. Journal of Applied Psychology, 1931, 15, pp. 241-47.

[43] C. D. Taylor. "The Relative Legibility of Black and White Print. Journal of Educational Psychology, 1934, 25. pp. 561-78.

type was much less legible than the black type. When nonsense syllables were used, this difference was ever greater, indicating that a decrease in meaningfulness in the stimulus used produced an even greater percentage advantage for the black print. Taylor concluded from all this that the universal inferior legibility of white print can be attributed largely to the influence of irradiation; irradiation not only tends to make white letters seem bigger, it also tends to blur the outlines, close the open spaces, and fuse together the different parts of the letters. These effects are especially heightened when the white letters are small or have a relatively large strokewidth. This points back to Berger's conclusion that the strokewidth of white letters should be thinner than black letters in order to attain maximum legibility.

Assuming that black print on a contrasting background is more legible than white print on a black background, the question arises as to the relative legibility of black print on variously tinted backgrounds. An investigation by Luckiesh and Moss as to the visibility of ten different tinted papers was compared, as well as the reading speed, rate of blinking, and readers' perference for four of these papers.[44] They found that in general the visibility of print seems to be dependent upon the reflectance of the paper. The white and white-related papers produced the highest visibility. Of four tints — white, cream-colored, yellow, and reddish-orange — there was only a slight difference in reading speed; but there were relatively more blinks for the yellow and the reddish orange papers, and the readers indicated a preference for the white paper over these colors.

A study by Stanton and Burtt determined the effects of paper surface and color on reading speed, using white and yellowish tinted papers. They found no significant differences in reading speed for the different papers.[45] Apparently paper surface and color have little influence upon reading speed. We can conclude from these studies, that although black print appears somewhat more visible on white paper, legibility and reading speed are, for most reading purposes, not especially influenced by the tint of the paper, as long as the reflectance of the paper is relatively high.

[44] M. Luckiesh and F. K. Moss. "Visibility and Readability of Print on White and Tinted Papers." Sight-Saving Review, 1938, Vol. 8, pp. 124-34.

[45] F. W. Stanton and H. B. Burtt. "The Influence of Surface and Tint of Paper on Speed of Reading." Journal of Applied Psychology, 1935, Vol. 19, pp. 683-93.

LEGIBILITY OF COLORED PRINT ON COLORED BACKGROUND

Recently, there has been an increasing usage of colored print on colored background. By determining the relative legibility and difference in reading speeds of these different combinations, the effects and advantages of each combination for certain situations can be determined. Three methods have generally been used in investigations in this subject — threshold distances, short exposures, and reading speed.

Sumner used maximum viewing distances as a gauge of legibility in a comparison of 42 different color combinations of print and background.[46] His data indicated that the contrast in brightness between symbol and background was the most decisive factor in determining legibility. Gray provided the most legible background; the three most legible combinations were blue on gray, black on gray, and black on yellow. The worst combinations were black on blue, yellow on white, and blue on black. The degree of legibility generally corresponded to the viewer's preference.

An experiment by Preston, Schwankel, and Tinker produced data which agreed with Sumner's conclusions that the contrast in brightness between symbol and background largely determined legibility.[47] The distance method was used to examine the effect of ten variations of print-background combinations on the perceptibility of isolated words. In order, blue on white, black on yellow, and green on white were the most perceptible combinations from a distance. Luckiesh reported a similar order of legibility for color combinations — black on yellow, green on white, red on white, and blue on white.[48]

Similar results were determined in a study sponsored by the Outdoor Advertising Association of America (OAAA), which conducted tests for readability at a distance, using the following 18 color combinations (using primary and secondary colors of full hue and value).[49] The results average out in the sequence shown, with No. 1 the most legible and No. 18 the least legible. (See Figure 16 and cover jacket)

[46] F. C. Sumner. "Influence of Color on Legibility of Copy." Journal of Applied Psychology, 1932, Vol. 16, pp. 201-4.

[47] K. Preston, H. P. Schwankel and M. A. Tinker. "The Effect of Variations of Print and Background on Legibility." Journal of General Psychology, 1932, Vol. 6, pp. 459-61.

[48] M. Lukeish and F. K. Moss. "Visibility and Readability of Print on White and Tinted Papers." Sight-Saving Review, 1938, Vol. 8, pp. 124-134.

[49] Institute of Outdoor Advertising. Type, Lettering, and Color. New York: Author.

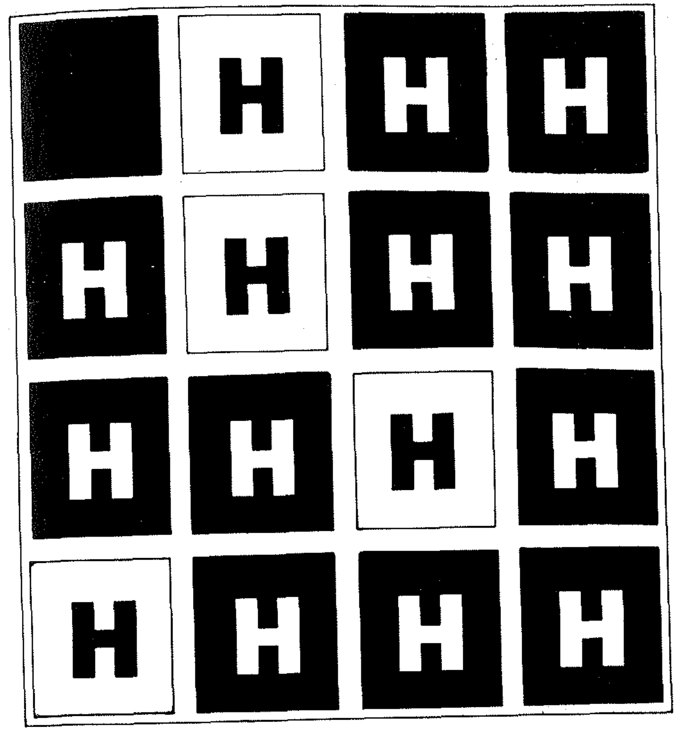


FIGURE 16

The 660' Janesville Survey also used the distance method to determine the legibility of various color combinations used in road signs.[50] They placed a series of four-foot high letters in different color combinations on the same sign panel, and then had the respondents approach the sign until the letter became legible to them. They used ten respondents and seven color combinations and tested both day and night visibility. White on black and saturn yellow on black were found to be the most visible, while light blue on white and red-orange on white were the least visible. By knowing the distance at which each color combination became legible, one can compute the necessary height which the letters in a sign must be to be visible for a given distance. Thus for average day-night viewing, fluorescent yellow letters on a black background must be one inch high for each 42 feet of viewing distance. (See Tables 6 and 7)

[50] 660' Janesville Survey: A Special Study of Letter Sizes and Color Combinations for Interstate Type Advertising Signs Which Are Set Back 660' from the Highway. Prepared by the Research and Art Departments, National Advertising Company, Bedford Park, Illinois, 1966.

TABLE 6

	AVERAGE	PER CENTS	VISIBILITY IN FT. PER INCH OF LETTER HEIGHT
White on Black	2020	100%	42
Saturn Yellow on Black	2019	100%	42
White on Red	2035	98%	41
Black on White	1985	98%	41
Red on White	1888	93%	39
Lt. Blue on White	1482	73%	31
Red-Orange on White	1529	51%	21

TABLE 7

COLOR AND LETTER SIZE CHART FOR 660' SETBACK SIGNS
(Size of letters in inches of height)

Maximum Viewing Distance	Driving Time in Seconds	Saturn Yellow S/C on Black	White on Red	Red on White	White on Black	Black on White	Blue on White Enamel	Red-Orange S/C on White
8,000	91	192	196	204	192	198	258	384
7,500	85	180	186	192	180	186	240	354
7,000	80	168	174	180	168	174	228	336
6,500	74	156	162	168	156	162	210	312
6,000	68	144	144	156	144	144	192	288
5,500	63	132	132	144	132	132	180	264
5,000	57	120	120	126	120	120	162	240
4,500	51	108	108	114	108	108	144	216
4,000	45	96	96	102	96	96	132	192
3,500	40	84	84	90	84	84	114	168
3,000	34	72	72	78	72	72	96	144
2,500	28	60	60	66	60	60	84	120
2,000	23	48	48	54	48	48	66	96
1,500	17	36	36	36	36	36	48	72
1,000	11	24	24	24	24	24	30	48

Using the short exposure (quick glance) method, Miyake, Dunlap and Cureton compared the legibility of black print on variously colored papers to that of various colors on black paper.[51] Black type on a colored background generally was more legible than colored print on black. The most legible combinations were black on green, black on yellow, black on white, and white on black.

To compare the relative legibility of homgeneously colored letters on a white background versus heterogeneously colored letters on a white background, Paterson and Tinker used eight different colors in various combinations.[52] They, too, found contrast between letter and background to be an important factor determining legibility; the greater the brightness difference between a certain letter and the white background, the more likely it was to be perceived.

Tinker and Paterson also did tests to determine the effects of different color combinations upon reading speed. They selected 850 people to read 11 different combinations and compared the results for each combination to the standard, black on white. In every comparison, the black on white print yielded the fastest reading speed. They noted that for the next three combinations that were read fastest, the differences in speed from the black on white were barely significant — between the two and five percent levels. These three combinations were green on white, blue on white, and black on yellow. The remaining color combinations yielded noticeably retarded reading speeds. The worst - orange on white, red on green, and black on purple — were considered so illegible as to be inadvisable for use. (See Table 8) The readers also indicated a preference for the various color combinations which corresponded closely to the order of reading speed recorded. (See Table 9) It was thus concluded that the degree of brightness contrast between print and background is the single most important factor in the legibility of various color combinations.

[51] R. Miyake, J. W. Dunlap and E. E. Cureton. "The Comparative Legibility of Black and Colored Numbers on Colored and Black Backgrounds." Journal of General Psychology, 1930, Vol. 3, pp. 340-343.

[52] D. G. Peterson and M. A. Tinker. "How to Make Type Readable," Harpers, 1940, xix-209.

TABLE 8

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.

Comparison of reading speed for different color combinations in relation to black on white (taken from Tinker, 1963)

TABLE 9

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

Reader's preferences for different color combinations

Signs of the Times reported a test made several years ago to find out the relative legibility of various color combinations.[53] The test revealed that the combination of black letters on a yellow background was seen at the greatest distance. Black letters on white ranked in second place. It was also noted that black on yellow could be read at an average of 260 feet, while the red on green could not be read until one approached to within approximately 90 feet. This test pointed to value contrast as first in importance for distant legibility, with chroma being a contributory factor. Therefore, in order to get maximum legibility, one should use dark colored letters and a light colored background, having one a strong color and the other a dull color.

In review, we can draw a number of conclusions about the relationship of color combinations to legibility. As far as the choice between white print on a black background and black print on a white background is concerned, it seems clear that for most ordinary reading situations, black on white is much more legible than white on black, due largely to the factor of irradiation (which tends to blur white letters) and the attention-holding character of white print (which produces more fixation pauses and blinks). Black type on variously tinted papers can be nearly as legible as on white paper if the tinted paper has a reflectance of 70 percent or more. Different colors vary in legibility to a great extent; some, such as yellow on black, are as legible or more legible than ordinary black on white. The legibility of different color combinations seems to be influenced greatly by the amount of brightness contrast (not color contrast); people's judgment of the legibility of different combinations corresponds to a large extent to experimental findings of legibility.

ILLUMINATION*

Sign illumination of most signs falls into three general classifications:

Direct Illumination, where letters or characters are the principal source of light and appear against a dark background. Types include neon luminous tubing whether it be of the neon, mercury, or fluorescent type, the use of exposed filament lamps, or the use of glass or plastic letters with interior illumination. Table 10 lists the light output per foot of various colors of 12 mm. fluorescent tubing at 25 ma., which is the popular size most used in neon sign work.

[53] "Letter Legibility Distance Is A Variable Factor." Signs of the Times, November, 1957, p. 51.

*Most of the general information, tables and definitions in this section that have not come from particular studies is taken from: Electric Signs, New York: Edison Electric Institute, July, 1952, Publication No. 52-9.

TABLE 10

LIGHT OUTPUT OF 12 MILLIMETER FLUORESCENT SIGN TUBING OPERATED AT 25 MA. (30 MA. TRANSFORMER)

Color Number	Color Name	Approx. Lumens per Foot
10	Deep Red	7
20	Yellow Gold*	100
30	Cream White	155
31	Warm White*	145
32	Daylight*	125
33	Pink White	100
34	3500 K White	140
35	Soft White	110
36	4500 K White	135
40	Green*	250
40	Amber Gold*	90
41	Deep Green	85
50	Blue*	80
50	Rose Pink*	70
51	Deep Blue	20

*National Electric Sign Association Standard Colors

Luminous Background, whereby the message is shown in silhouette or in color against a large luminous background lighted from within. Slimline fluorescent lamps, filament lamps and neon tubing are the common light sources for these signs. Table 11 lists the brightness considered satisfactory for luminous background signs under different conditions. Table 12 shows the typical light output for the slimline and filament lamps commonly used in these applications.

TABLE 11

RECOMMENDED BRIGHTNESS OF LUMINOUS ELEMENTS IN FOOT LAMBERTS

	General Brightness of District		
	Low	Medium	High
Decorative Elements	30- 60	40- 80	50-150
Luminous Backgrounds Signs	90-150	120-200	150-350
Luminous Letter Stroke Signs	150-200	200-400	300-600

TABLE 12

LIGHT OUTPUT OF STANDARD ILLUMINANTS

Filament General Service Lamps 115-125 Volt

Watts	Bulb	Base	Description	Lumens
10	S11	Intermediate	Clear	80
10	S14	Med.	Clear	79
15	A-15	Med.	Inside Frosted	141
25	A-19	Med.	Inside Frosted	260
40	A-19	Med.	Inside Frosted	465
60	A-19	Med.	Inside Frosted	835
100	A-21	Med.	Inside Frosted	1620
150	PS-30	Med.	Inside Frosted	2600

Fluorescent Lamps

Bulb	Lamp Type	Color	Approx. Lumens per foot	Lamp Current
T6	42" Slimline	Cool White (std.)	490	300 ma.
	64" Slimline	Cool White (std.)	490	300 ma.
T8	72" Slimline	Cool White (std.)	500	300 ma.
	96" Slimline	Cool White (std.)	500	300 ma.
T12	48" Slimline	Cool White (std.)	575	425 ma.
	72" Slimline	Cool White (std.)	575	425 ma.
	96" Slimline	Cool White (std.)	575	425 ma.
	40-W Inst. Start	Cool White (std.)	575	425 ma.

Notes:

1. Use ballasts designed for low temperature operation. Regular "series-sequence" ballasts should not be used in places where ambient temperatures may fall below 50° F.
2. Light output will be reduced under very cold conditions. Typically the light output for unprotected lamps in still air at 0° F. is as follows:

   T 6 @ 300 ma. - 75%
   T 8 @ 300 ma. - 50%
   T12 @ 425 ma. - 25%

   Enclosing the lamps will increase these values.
3. For light output of other colors, see lamp manufacturer's most recent publications.

Floodlighted, where the sign is lighted from external sources. In addition there are variations such as silhouetting by means of lighting mounted in the backs of letters. Sign floodlighting can be accomplished in several different ways. Standard sign reflectors designed for the use of filament lamps in wattages of 75 to 1000 watts may be used for lighting from the top or bottom of the sign panel. Reflector lamps mounted in cornices or channels may also be used, or fluorescent lamps or tubing may be mounted in cornice strips. Table 13 provides multipliers for determining footcandles at distances which vary from 10 feet as shown in Table 14.

TABLE 13

MULTIPLIERS FOR DETERMINING FOOTCANDLES FOR DISTANCES OTHER THAN 10 FEET

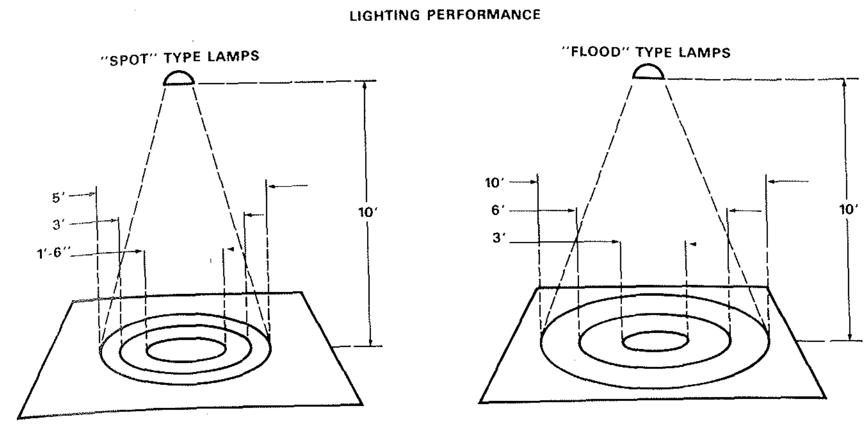
Distance in feet	Multiply diameter by	Multiply footcandles by
5	.5	4.0
7	.7	2.0
15	1.5	.45
20	2.0	.25

We have seen that the readability of a sign depends to a large extent upon the size and proportion of the letters, the letter spacing, and the brightness contrast between letter and background. Along with these, the next most important factor is the illumination of the sign face, which sometimes determines the previous factors. For in addition to making the letters the proper width and strokewidth for daylight conditions, one must also take into account the effects of background brightness upon the legibility of the letters. Otherwise there may be a blending of the letter lines or loss of clarity due to halation* from high background illumination. Finely detailed letters or script often gets blurred or illegible if there is a strong light coming from behind, especially if these letters are to be viewed from

*Halation: spreading of light beyond its proper boundary by background reflection and illumination and consequent blurring.

TABLE 14

LIGHTING PERFORMANCE OF REFLECTIVE LAMPS AT 10 FEET
TABLE 14



FOOTCANDLES AT TEN FEET . . .

Lamp	Max.	1½ ft. Diam. Ave.	3 ft. Diam. Ave.	5 ft. Diam. Ave.	3 ft. Diam. Ave.	6 ft. Diam. Ave.	10 ft. Diam. Ave.
75 W.R-30*	20	19	15	11	4½	4	3
150 W.R-40	70	65	45	30	13	12	9
150 W.PAR-38	120	115	95	55	34	27	17
300 W.R-40	160	145	110	65	26	23	17**
500 W.R-40	255	230	175	100	42	37	27

*For comparison only—usually used at shorter distances
**Values exceed those for 150 W.PAR-38 over larger areas

a great distance. Three dimensional letters on signs must be spaced in such a way that they are deep enough to stand in relief, but not so deep that they obstruct the background illumination when viewed at an acute angle.

The 1960 NESA study mentioned many times in this chapter showed that a strokewidth of between 15 percent to 20 percent of the letter height will provide maximum legibility if the illumination of the background panel does not drop below 300 footlambets (f.l.) (See Figure 17) There is a rapid deterioration in legibility when the stroke is increased in thickness beyond 20 percent, and a somewhat less rapid reduction in legibility as the stroke is thinned below 15 percent. If the illumination is reduced below 300 f.l., however, the stroke must be thickened to compensate for the lowered illumination.

The brightness of the sign face will vary in accordance to the type and intention of the sign itself. Brightness definitely influences readability, insofar as too bright a sign will create a blurring halo around the letter, while insufficient lighting will reduce the distance at which the sign can be seen. Rohm and Haas worked out a set of guidelines for the brightness of sign faces, determined by the environment and the intended purpose.[54] (See Table 15) They distinguish between three "brightness districts" — a high brightness district for urban centers and shopping centers which contain a high density of illuminated signs already; medium brightness districts, such as suburban areas where such a high level of illumination is unnecessary or offensive; and low brightness districts, such as rural areas. They also suggest specific brightnesses for typical sign functions. (See Table 16) A properly lighted sign is one which is not overshadowed by the signs in its immediate vicinity, but also one which is not so bright as to cause annoyance.

[54] Plexiglas: Sign Manual. Philadelphia: Rohm and Haas Company, 1969, p. 38.

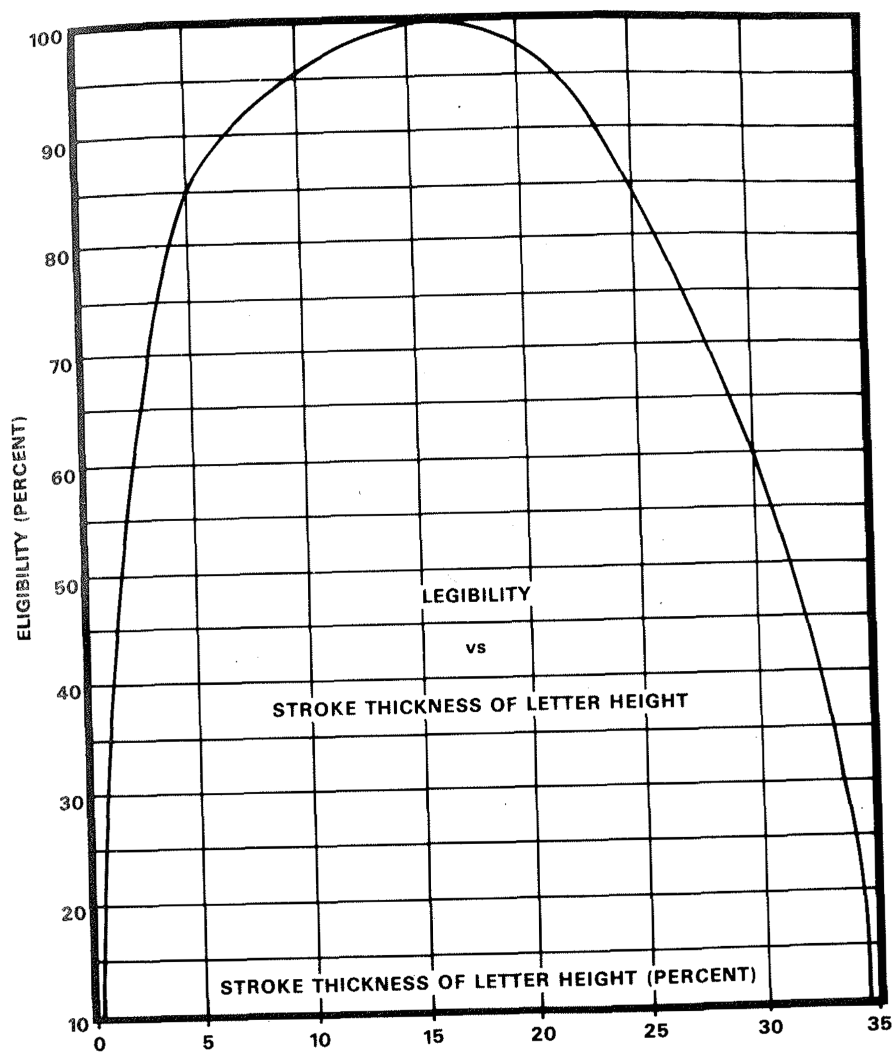


FIGURE 17

TABLE 15

BRIGHTNESS DISTRICTS FOR SIGN LIGHTING

	Brightness District	Sign Brightness, Footlamberts
High	Urban center locations and shopping centers where high prevailing illumination exists; areas of high sign density	200 - 350
Medium	Suburban areas where sign competition and illumination are moderate	100 - 200
Low	Rural area	25 - 100

TABLE 16

FUNCTIONAL SURFACE BRIGHTNESS LEVELS FOR ACRYLIC SIGNS

Surface Brightness, Foot Lamberts	Descriptive Word for the Illuminated Visual Appearance	Typical Function
20 - 100	Subtle	Fascia signs
75 - 150	Lustrous	Belt signs above storefronts
125 - 200	Vivid	Business signs in shopping centers
200 - 300	Radiant	Gasoline service stations and motel signs
300 - 400	Brilliant	Large or high-rise signs which must "carry" over long distances
400 - 500	Dazzling	

As one might expect, the degree of legibility of a sign is very much proportional to the amount of illumination. This is not to say, however, that as one increases the background brightness, the legibility will also continue to improve. The theoretical efficiency of legibility drops off after a certain point.[55] It was calculated that 100 percent legibility would be reached at a level of about 50,000 f.l.

[55] NESA, 1960.

However, at 2,000 f.l. efficiency is 98 percent, so that it would be uneconomical to provide more illumination than that. Experimentally, it was found that efficiency peaked at 990 f.l., which had a theoretical efficiency of 97 percent. (See Figure 18) This was considered to be satisfactory illumination. These figures, however, dealt only with black letters on a white background, and are influenced by the contrast in brightness between the letters and the background. Any use of different color combinations would involve different efficiency levels.

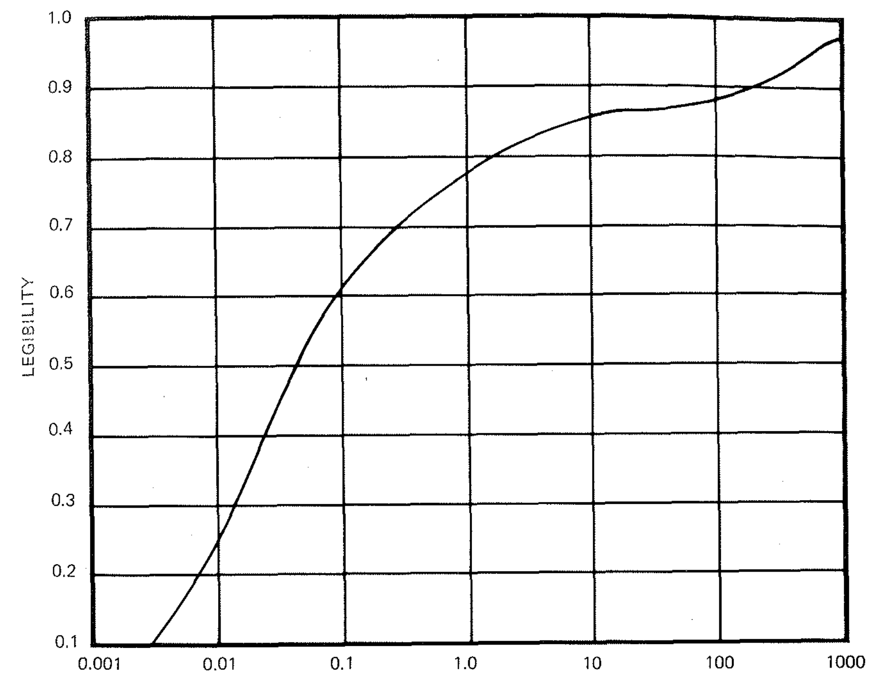


FIGURE 18. Background (Footlamberts)

As background illumination is reduced, legibility is reduced accordingly, unless some alternative means of improving legibility can be added. This study also reported that as the inter-letter spacing was increased, legibility did in fact increase. When the inter-letter spacing was changed from 20 percent of letter height to 40 percent of letter height, the amount of background illumination or light intensity could be reduced without any reduction of the legibility of the letters. It was found that a background of 68 percent reflectance will give less legibility to inter-letter spaces of 20 percent of their height than a 19 percent reflectance background gives words with inter-letter spacing equal to 40 percent of their height. In other words, with the spacing being equal to 40 percent of the letter height, the legibility can be 12 to 15 percent greater than when the spacing is equal to 20 percent of the letter height.

Letters differ so considerably from each other in their legibility and with the position they occupy in a word, that it would be impractical to do anything but make an average of all these legibilities for purposes of calculation. This means that a theoretical 100 percent legibility can never be attained in any factor compiled unless only single letters are dealt with. Words can never reach 100 percent legibility.

Bearing this in mind when we relate legibility to illumination, it is possible to accept the figures found in the tests of 70 percent legibility at 100 f.l., 77 percent at 400 f.l., and 84 percent at 900 f.l. The important thing is to recognize that increased illumination beyond the 900 f.l. level will not increase legibility proportionately and that a point must be reached where the relationship between higher illumination and increased legiblity becomes uneconomical. So long as maximum contrast in color is maintained, such as black letters on white or yellow panels, the two main factors to consider for internally illuminated signs are the level of illumination at the panel surface, and the design and spacing of the letters.

Rohm and Haas worked out the details for calculating the necessary background brightness for a plastic sign, formulating an equation which took into account what they considered to be the four factors determing surface brightness — lamp spacing, lamp-to-plastic distance, lamp characteristics, and the light transmittance of the plastic. Assuming the lamp spacing to equal to lamp-to-plastic distance, their equation is:[56]

$$LS = \frac{9.4 \times T \times L/FT.}{B}$$

where LS is the lamp spacing,
9.4 is an experimentally developed concept to compensate for internal relections for both single and double face signs, T is the light transmittance of the plastic sign face, expressed in decimal form, L/FT. is the lumen output of the fluorescent lamps per foot, and B is the required surface brightness in footlamberts.

By knowing the light transmittance of different thicknesses and different colors of plastic, one can estimate the amount of lighting needed to maintain a certain surface brightness. Consequently, colored surfaces can be used without fear of being overshadowed by nearby white sign faces merely by taking into account the transmittance of the colored plastic and adjusting the lamp strength

accordingly.

For internally illuminated signs, Rohm and Haas recommend a light-colored, high brightness background and contrasting dark letters rather than a dark background-light letter combination, because a large bright area attracts more attention. They report that black opaque letters on light luminous backgrounds such as white, ivory, and yellow, provide maximum legibility. But other dark-colored letters such as red, green, violet, and blue can add color to the sign without any considerable loss of readability. Below is Table 17 which indicates the relative readability of different colored letters on light backgrounds.

TABLE 17

RELATIVE READABILITY OF VARIOUS COLORED LETTERS ON WHITE, IVORY AND YELLOW BACKGROUNDS

Maximum Readability	Excellent Readability	Average Readability
No. 2025 Black	No. 2415 Red	No. 2051 Blue
	No. 2283 Red	No. 2330 Coral
	No. 2119 Orange	No. 2308 Turquoise
	No. 2030 Green	No. 2024 Green
	No. 2287 Violet	No. 2047 Green
	No. 2114 Blue	No. 2648 Blue
	No. 2178 Red	No. 2328 Peach
	No. 2215 Olive Green	No. 2254 Yellow-Orange
		No. 2324 Aqua
		No. 2329 Light Blue

Allen and Straub also made a study dealing with the legibility of reflectorized highway signs, and made some conclusions about black on white versus white on black illumination.[57] They reported increasing legibility of black letters on white under high illumination, whereas the legibility of white letters on black was in fact reduced as illumination increased. They concluded that white on black background should be avoided for conditions where high illumination is needed.

When viewing at wide angles is relatively unimportant, reflectors

[57] J. M. Allen and A. L. Straub. "Sign Brightness and Legibility." Virginia Council of Highway Investigation and Research, Reprint 16, 1956.

for increasing the directional candlepower or reflectorized lamps may be used to increase the brightness at the viewed angle. This type of illumination may even be effective in daylight.

The NESA study draws similar conclusions as Rohm and Haas about the surface color of an illuminated sign: it found a slight difference in legibility of black letters on white, light yellow, medium yellow, or peach backgrounds, especially when a large background area is used. For a small background area, the peach-colored background does afford a bit less legibility. This study also concluded that the size of the background itself does not significantly affect legibility. It is the design of the letters and words, along with the relationship of sign area to the placement of the letters, which are more important in determining legibility.

The above results were determined by an experiment in which different colored panels were set successively onto a box containing lamps which could be adjusted to different brightnesses. Letters of a set size were taped onto the panels, and the entire box was moved along a track toward a seated observer until the observer could perceive the words. These tests were done at 100 f.l., 400 f.l., and 900 f.l. and the results mentioned above were recorded.

EXPOSED LAMP SIGNS

Where long viewing distances are involved, or where small, high brightness signs are needed, the exposed lamp signs can provide good visibility and readability. The proper spacing between lamps to obtain an apparently continuous line of light is determined by the minimum viewing distance. Spacing may be estimated by the following formula:[58]

$$s = \frac{Dmin}{1500}$$

where s = spacing between centerlines of lamps (feet).
Dmin = minimum viewing distance (feet).

In very bright locations the above spacing should be decreased by 25 to 35 percent.

The following Tables 18 and 19 are primarily concerned with legibility in relation to effective advertising. They are taken from the previously mentioned publication by Edison Electric Institute, *Electric Signs*, and deal with the desired lamp spacing for exposed lamp signs.

[58] "Lighting for Advertising." IES Lighting Handbook, Section 23, p. 22-3.

TABLE 18

LAMP SPACING AND LAMP WATTAGE
FOR EXPOSED LAMP SIGNS

Letter Height	Surroundings	Spacing (Inches)	Wattage
10" - 15"	Light	2½	15
	Dark	3	10
15" - 20"	Light	3	25
	Dark	3½	10
2' - 3'	Light	3	25
	Dark	3½	10
3' - 5'	Light	3	25
	Dark	4	15
5' - 6'	Light	3½	25
	Dark	5	15
6' - 8'	Light	4	50
	Dark	7	15
8' - 10'	Light	4	50
	Dark	9	15
10' - 12'	Light	8	50
	Dark	12	15
12' - 16'	Light	10	60
	Dark	16	15
16' - 20'	Light	12	100
	Dark	20	15

LETTER HEIGHT AND VIEWING DISTANCE
FOR SILHOUETTE SIGNS
(Background Brightness of 100-250 Footlamberts)

Viewing Distance	Letter Height
200'	5"
400'	8"
600'	12"
800'	16"
1000'	20"

Lamp spacing and concealment in this type sign is subject to the same general design features as "Cove Lighting."

TABLE 19

NUMBER OF SOCKETS IN EXPOSED LAMP LETTERS
EITHER ON BACKGROUND TYPE SIGNS OR ROOF
SKELETON TYPE

Standard block letters - Size of letters:

H. In.	12	16	20	24	30	36	48	60	72	84	96	108	120
W. In.	9	12	14	18	22½	27	36	45	54	63	72	81	90
Stroke	2½	3	3½	4	5	6	7	8	9	10	11	12	13
NUMBER OF SOCKETS IN LETTERS													
A	6	8	10	13	13	16	21	24	26	29	32	39	44
B	8	12	14	16	18	22	29	35	38	42	48	55	64
C	6	7	9	10	11	14	18	20	21	25	28	31	35
D	6	9	12	15	16	20	25	29	30	34	40	45	49
E	8	9	11	14	14	17	22	26	28	32	37	41	44
F	6	7	9	11	11	13	18	20	21	25	28	31	35
G	8	9	10	12	14	17	24	27	28	30	37	40	43
H	7	9	11	14	14	17	23	26	28	32	38	43	46
I	*3	4	5	6	6	7	9	10	11	13	15	17	18
J	5	6	7	8	9	11	15	17	18	23	24	26	29
K	7	9	11	14	15	17	23	27	28	32	38	42	46
L	5	6	7	9	9	11	15	17	18	20	24	26	28

NUMBER OF SOCKETS IN EXPOSED LAMP LETTERS
EITHER ON BACKGROUND TYPE SIGNS OR ROOF
SKELETON TYPE
(Continued)

M	9	13	17	21	21	25	33	37	41	42	57	65	69
N	8	10	13	16	16	20	25	32	34	37	43	49	54
O	6	8	10	12	13	16	24	26	28	31	37	41	45
P	6	8	10	13	14	16	22	25	27	30	33	36	43
Q	7	9	11	13	14	17	26	28	30	33	39	44	48
R	7	10	12	16	17	19	27	30	32	36	44	47	52
S	7	8	10	12	14	17	21	25	27	28	34	37	39
T	5	6	8	9	9	11	15	17	19	20	24	26	28
U	7	8	10	12	13	15	22	24	26	28	35	37	42
V	5	7	9	11	11	13	17	19	21	24	29	34	37
W	9	13	17	21	21	25	33	37	41	49	57	65	69
X	5	9	9	13	13	15	17	19	21	25	29	35	41
Y	4	6	8	9	10	12	17	18	19	20	25	27	30
Z	7	8	9	12	13	16	22	24	27	27	32	36	39
&	9	12	14	16	16	21	32	36	40	44	51	58	63

*This gives number of sockets in vertical stroke of letter.

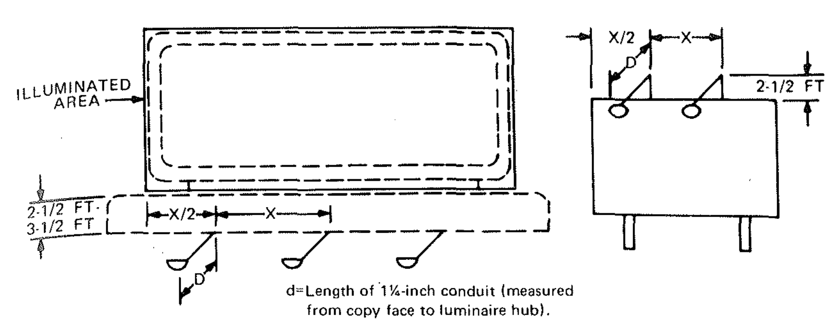
FLOODLIGHTED SIGNS

The most important factors which contribute to the legibility and readability of other types of signs also apply to floodlighted signs — the sign area, size of letters and brightness. The lighting equipment may be located either across the top or bottom of the sign, and several types of light sources may be used effectively. Table 20 is the recommended minimum illumination charted in the *IES Lighting Handbook*, and Figure 19 gives data on various kinds of illumination used in typical floodlighted signs, also taken from the handbook. Table 21 charts the recommended lamp sizes and spaces from Edison Electric Institute's *Electric Signs*.

TABLE 20

RECOMMENDED MINIMUM ILLUMINATION FOR POSTER PANELS, BULLETIN BOARDS, AND OTHER ADVERTISING SIGNS

Average Reflectance of Advertising Copy	Recommended Illumination Levels (Footcandles)	
	Bright Surrounds	Dark Surrounds
Low	100	50
High	50	20



d=Length of 1¼-inch conduit (measured from copy face to luminaire hub).
x=Space between luminaires
$\left(\frac{\text{Length of illuminated area}}{\text{Number of luminaires}}\right)$
x(max.) = 2½d

(a) For Metal Halide Luminaires

Display	Number of Luminaires	(d) Conduit Length	(x) Spacing	Maintained Average Footcandles*
Association Loewy Poster Panel	3	4'0"	8'2"	55
Association Standard Poster Panel	3	4'0"	8'4"	55
Standard Streamliner	6	4'9"	7'8"	50
Deluxe Urban Bulletin	5	4'9"	9'4"	50
Standard Highway Bulletin	4	4'2"	10'5"	50
Junior Highway Bulletin	3	4'0"	8'2"	55

* Based on 400-watt metal halide lamp, Light Loss factor = .71.

(b) For Fluorescent-Mercury Luminaires

Display	Number of Luminaires	(d) Conduit Length	(x) Spacing	Maintained Average Footcandles*
Association Loewy Poster Panel	4	4'0"	6'1½"	55
Association Standard Poster Panel	4	4'0"	6'3"	55
Standard Streamliner	8	4'9"	5'9"	50
Deluxe Urban Bulletin	7	4'9"	6'8½"	50
Standard Highway Bulletin	6	4'2"	6'11"	50
Junior Highway Bulletin	4	4'0"	6'2"	55

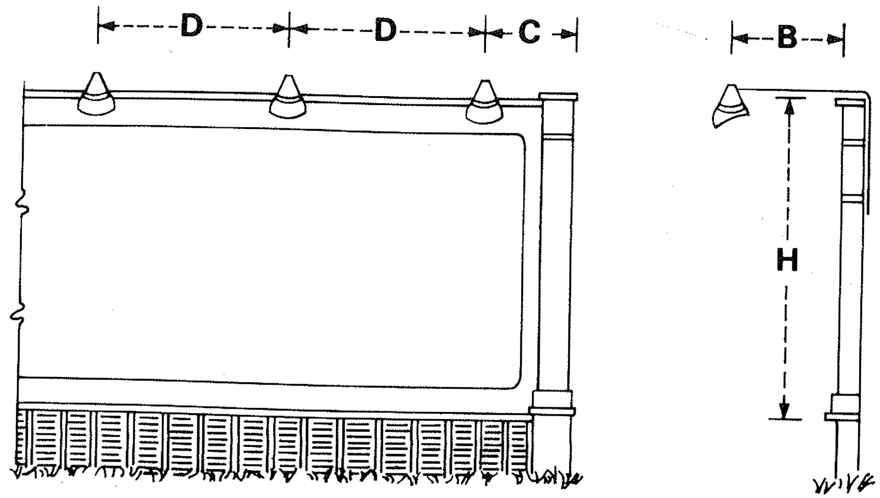
* Based on 400-watt fluorescent-mercury lamp, Light Loss factor = .77.
If same quantities of 250-watt lamps are used, multiply footcandles by .52.
If same quantities of 175-watt lamps are used, multiply footcandles by .37.

(c) For Tungsten-Halogen Luminaires

Display	1500-Watt			500-Watt		
	Number of Luminaires	(x) Spacing	Maintained Average Footcandles*	Number of Luminaires	(x) Spacing	Maintained Average Footcandles*
Association Loewy Poster Panel	3	8'2"	115	4	6'1½"	50
Association Standard Poster Panel	3	8'4"	115	4	6'3"	50
Standard Streamliner	6	7'8"	100	8	5'9"	55
Deluxe Urban Bulletin	5	9'4"	95	8	5'10"	50
Standard Highway Bulletin	5	8'4"	105	7	5'11"	50
Junior Highway Bulletin	3	8'2"	115	4	6'2"	50

* Light loss factor = .89. Distance from sign to luminaire = S-Feet, aiming point is at a distance down from top of sign equal to 1/3 height of sign.

FIGURE 19. Typical floodlighted sign installations and illumination results when using equipment with (a) metal halide lamps, (b) fluorescent-mercury lamps and (c) tungsten-halogen lamps.



DIMENSIONS (feet)				LAMP WATTS*		
H	B	C	D	Dark Surround	Medium Surround	Bright Surround
2 to 4	2-1/2	2-1/2	5	50	75	100
5 to 6	3-1/2	3	6	75	100	150
7 to 8	4	3-1/4	6-1/2	100	150	200
9 to 12	5	4	8	150	200	300
13 to 16	6-1/2	5	10	200	300	500
17 to 21	9	6-1/2	13	300	500	750
22 to 25	12	8-1/2	17	500	750	1,000
25 to 30	15	10	20	750	1,000	
11-5/6x25**	5	4-1/6	8-1/3	150	200	300
12-1/2x42***	5-1/4	4-1/3	8-1/3	150	200	300
18x72****	8-1/2	6	12	200	300	500

* For low-reflectance sign faces use the recommended lamp size for the next brightest surround.
** Standard poster panel
*** Standard City bulletin.
**** Railroad or highway bulletin

Note: These spacings should not be exceeded, and closer spacing will result in a higher sign face brightness.

TABLE 21

ILLUMINATED LETTERS

To a certain extent the problems involved in working with illuminated letters are similar to those of illuminated backgrounds. The same primary factors need to be considered: strong color contrast between letters and background, selection of the proper light source, sufficient light intensity, and readability at maximum viewing distances and acute angles. A light source must be used which is available in a variety of colors, which can be formed easily into letters, and which is compact enough for close spacing within the letter. Tubing with small diameter (from 9 - 15 mm.) generally meets these conditions. Letter spacing and letter size and proportions are vital factors to consider when viewing distance is desired. When the sign is to be viewed from an acute angle, there must be sufficient space between letters so that they do not appear to run into one another. A three-dimensional letter which is too thick will similarly tend to obscure the background and make it difficult to differentiate between letters.

There are many different alternatives for background contrast when using illuminated letters. The background can be natural or coated metals or wood, masonry, or even the sky or natural surroundings. The adequate light intensity is more difficult to determine for lighted letters than for lighted backgrounds. This is because the entire luminous area is usually a single mass of dense color such as red or blue, rather than the larger areas of lighter colors in panel signs.Rohm and Haas recommends pre-production trials with a single letter to provide the most accurate indication of how the letter will appear. Attention must also be given to the light density and the competing illuminated signs in the surrounding area.

Studies have also sought to determine the relationship between the level of illumination of letters on a non-illuminated background to their degree of legibility. The following graph shows the results when white and medium yellow lighted letters were set against a black background. (See Figure 20) The top two curves are intended as comparison, and indicate how the legibility of black letters on an illuminated light-colored panel increases as the illumination of the panel increases until a level off point has been reached.[59] (This situation was discussed earlier.) The bottom three curves show how the legibility of illuminated white and yellow on a black background decreases as the illumination increases; this decrease can be attributed to the effect of irradiation and halation. The uppermost of these three curves shows what happens to the middle one when a small amount of external illumination is thrown onto the black contrasting panel. The legibility increases by a measureable amount by neutralizing the irradiation.

[59] NESA, 1960.

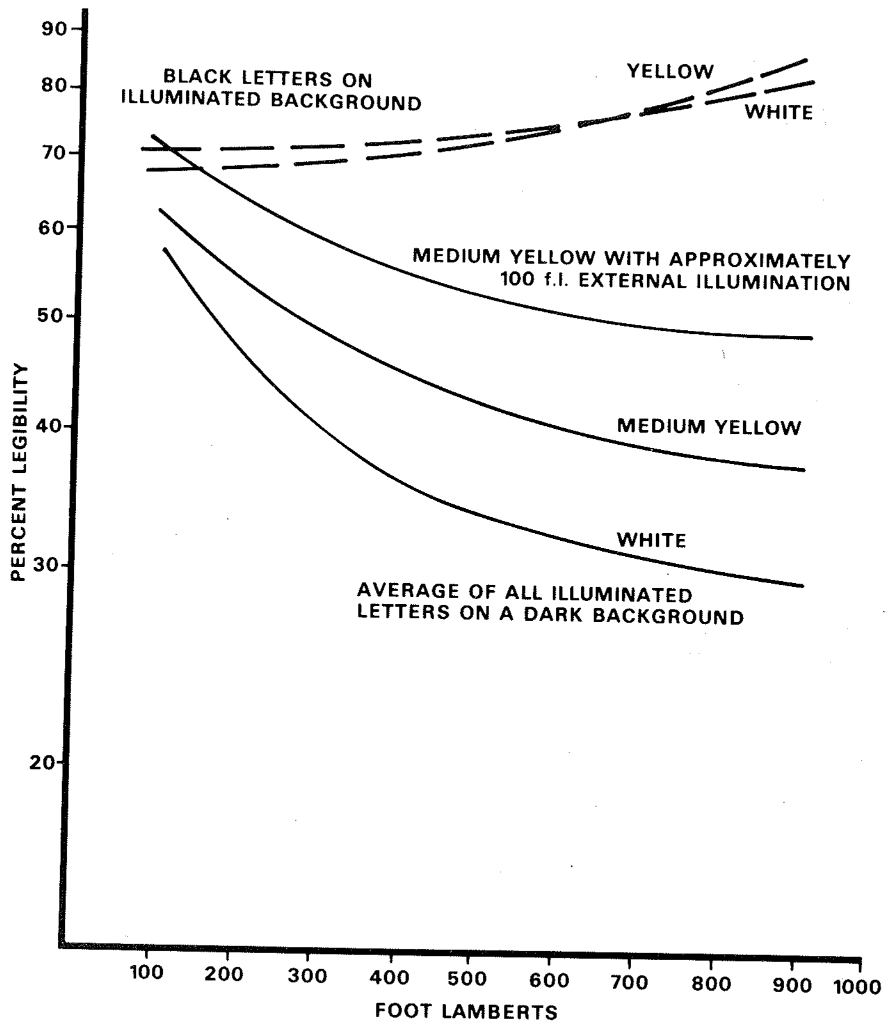


FIGURE 20

Apparently the brightness of neon letters has less influence on their legibility than the degree of irradiation produced by different colors. Some colors produce a very much higher level of irradiation than do others, and all appear to produce more irradiation than do silhouetted letters. This irradiation effect is due to the colored light from the tube reflecting from whatever is adjacent to it or behind it, and by the light scattered in the atmosphere immeditely around it. Not only do all things around the tubing reflect its colored light, but the tubing's own color is affected by the irradiation. Because of this irradiation, unshielded neon tubing has a disadvantage from the standpoint of legibility. Something that is not generally appreciated is that the effects of irradiation on the human eye become greater with the advancing of age. The reduction in legibility by irradiation advancing from people 30 to 50 years of age is from 10 percent to 40 percent.

The luminance level of a variety of different colors can be determined by photometric measurement. One study found the order of brightness of 11 types of colored light to be: [60]

1. clear red	5. noviol gold	9. clear blue
2. powder green	6. white	10. ruby
3. sunset gold	7. turquoise	11. cobalt blue
4. rose	8. powder blue	

The first color, clear red, was approximately 30 times brighter than the last one, cobalt blue. These sets of colors were then shown to both a 30 year old and a 50 year old subject. They were then asked to state their legibility preferences. The 30 year old indicated the following order of preference:

1. rose	4. ruby; noviol gold	7. powder blue
2. clear blue; white	5. sunset gold	8. turquoise
3. clear red	6. cobalt blue	9. powder green

Under the same conditions and at the same time, the 50 year old observer showed the following preferences:

1. cobalt blue	4. sunset gold; rose; white; turquoise
2. clear blue	5. noviol gold
3. clear red; ruby; powder blue	6. powder green

It is obvious, then, that while the brightest neon lights may be the greatest "attention-getters", they are not always the most legible. This is especially true for the group of observers over 45 years of age. Only one color, cobalt blue, appears to remain highly or moderately legible among both older and younger subjects. The absence of irradiation from this tubing aided in avoiding great light scatter

[60] National Electric Sign Association. Reference Manual. Chicago: Research and Development Foundation of NESA, 1960, Section B-1, p. 5.

within the eye, something which is always a problem of the aging. However, it is also a color which suffers considerably in low temperatures. In addition, although the color with the least brightness can be the most legible, it does not follow that those with the greatest brightness are the least legible. There is no direct relationship between brightness and legibility in this medium. The legibility may depend upon the effects of the color and brightness on the surrounding air and background, while the brightness and color are properties of the glass and gas used. It is how the colors appear in their surroundings that affects their legibility.

If we average out the order of legibility preference for the two age groups, we can see that there is no direct relationship between legibility and brightness.

TABLE 22

COLOR	ORDER OF LEGIBILITY	ORDER OF BRIGHTNESS
clear blue	1	9
cobalt blue	2	11
ruby	3	10
clear red	4	1
white	5	6
rose	6	4
powder blue	7	8
sunset gold	8	3
noviol gold	9	5
turquoise	10	7
powder green	11	2

Perhaps the best way to determine the relative distance of legibility for the different kinds of illuminated letters, would be to take letters of the same color and compare them. Table 23 provides this comparison which applies to a person who has average vision. The Edison Electric Institute's *Electric Signs* is the source of the table.

TABLE 23

DISTANCE SIGN LETTERS ARE LEGIBLE
To A Person of Average Sight

Letter Size (Height)	Raised Glass Letters	Neon Letters	Exposed Lamp Letters
2"	100'	65'	
3"	150'	100'	
4"	200'	150'	
6"	275'	200'	
8"	400'	350'	
9"	500'	400'	
10"	550'	450'	
12"	675'	525'	
15"	800'	630'	630'
18"	1000'	750'	750'
24"	1350'	1000'	1000'
2'-6"	1500'	1250'	1250'
3'-0"		1500'	1500'
3'-6"		1750'	1750'
4'-0"		2000'	2000'
4'-6"		2250'	2250'
5'-0"		2500'	2500'
6'-0"		3000'	3000'
7'-0"		3500'	3500'
8'-0"		4000'	4000'
9'-0"		4500'	4500'
10'-0"		5000'	5000'
11'-0"		5500'	5500'
12'-0"		6000'	6000'

FROM: Edison Electric Institute, *Electric Signs.* New York: author, July 1952, Publication No. 52-9, p. 15

ILLUMINATED LETTERS AGAINST PLASTIC ILLUMINATED BACKGROUNDS

It has already been shown that the degree by which the internal illumination of a sign is increased is not necessarily accompanied by an equal degree of improved legibility. We will now examine signs which have both internal and external illumination, particularly night illuminated signs viewed in daylight.

One of the first things we have to grasp in this area is the function of relative brightness in perception. Another is the influence of personal knowledge on what is seen. For example, on a day when the sky is very grey, snow on the ground will give the impression of being brighter than the sky, and yet the snow cannot reflect more light to the eyes than reaches it from the sky. The explanation for this is complicated and will not be discussed here, but it is important to be aware of this phenonmenon.

To take our example a step further, we can view a piece of paper that is reflecting 5 candles per square foot, and it will appear to be white. Then if we take a piece of black marble and illuminate it so brilliantly that it reflects 10 candles per square foot, twice as much as the paper reflected, the marble still looks black. So the amount of light reflected is not the only factor involved. In other words, "perceived" brightness is not the same as "actual" brightness, or stimulus luminance as it is called.

Perception, in fact, can at times remain independent of light variation above a minimum level. By careful control of all the factors in a situation or device, an increase in illumination may produce an increase or a decrease in apparent brightness, or may leave it unchanged. Translated into language the signmaker can understand this means several things:

1. When a white panel is illuminated from behind at night, any black letters on it are silhouetted and their contrast is maximal. When daylight is present, however, the black letters reflect some of this light to the eyes of the observer thus making them less black. But their contrast may not be reduced, because the white panel will also reflect the daylight, even more of it. So once more, we find that black letters on a white ground are a very desirable combination for signs of this nature.

2. This same kind of sign placed close to a vivid competitive light of red neon would not retain this ideal contrast, unless its white background were very well illuminated. The red light reflected by the illuminated white panel would form a mixture with the white when entering the eye. This mixture might have a wavelength nearer yellow, and so would not reduce its contrasting color value appreciably. The black letters on the other hand would reflect the red light if no other colored or white light were around, and this would reduce their relative contrast to their background.

3. Any black letters with considerable surface shine, even though mounted on a white panel, could easily reflect enough light to make them difficult to discern (especially in daylight), if the panel were not well illuminated from within and the sun or some other brilliant light was striking the letters from an angle favorable to maximum reflection into the observer's eyes.

To add to what was said regarding the white paper and the black marble, we should mention that the tendency to see things in relation to their known qualities rather than their actual luminance will often make black letters appear blacker if the external illumination is increased, even though the actual degree of contrast to their background is not changed. This presents us with another possible phenomenon. At different times during one day, a particular sign may be the recipient of light of different qualities that will increase its contrast at one time and decrease it at another.

Some of the problem of the reflection of extraneous light may be solved by changing the surface curves of letters. Instead of the surface being flat as in Figure 21a, it could be made concave as in 21b and 21c. This would split the reflections and scatter them more, making them smaller and less effective.

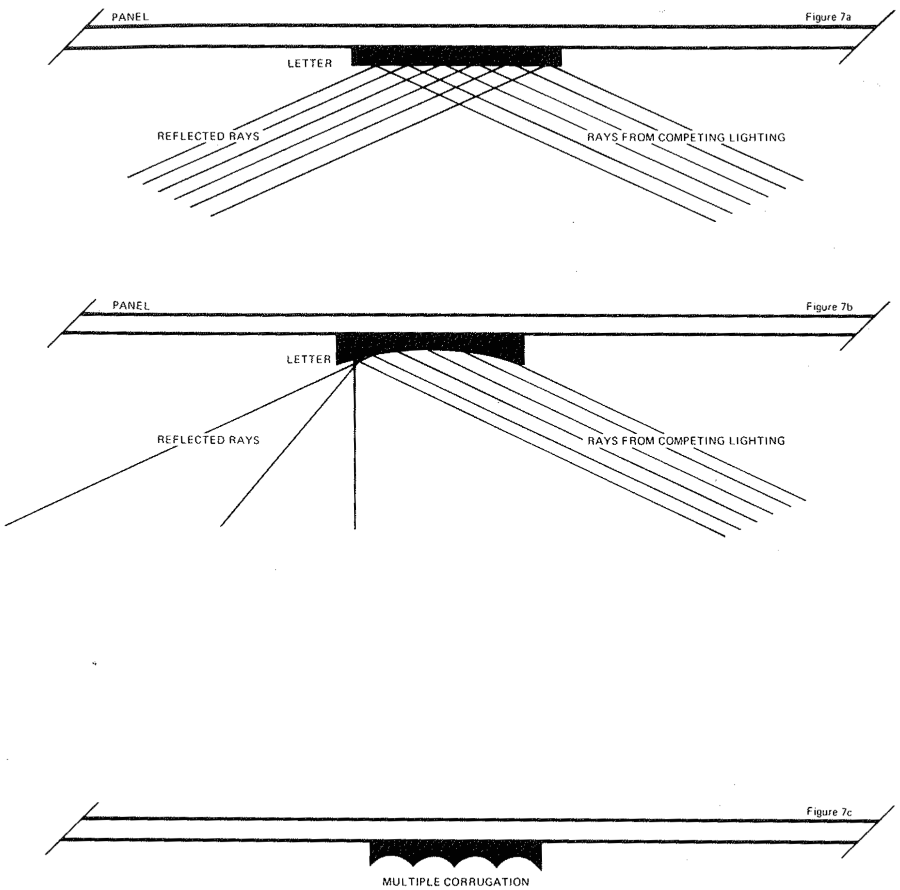


FIGURE 21A, B, C
(NESA, 1960, p. 31)

LIGHTED FASCIA OR BELT SIGNS

Illuminated, long strip, fascia or belt signs have become increasingly more popular recently. These signs, which have a single or double row of light tubes along the upper or lower edge of the sign, produce a comparatively low surface brightness, only about 50 to 125 footlamberts. Rohm and Haas have evaluated the different plastic colors used for these signs, which can be compared in Table 24.[61]

[61] Plexiglas: Sign Manual. Phildelphia: Rohm and Haas Company, 1969, p. 41.

TABLE 24

COLOR EFFECTS AND LIGHT TUBING RECOMMENDATIONS FOR STANDARD PLEXIGLAS SIGN COLORS

Plexiglas Color No.	Color Name	Reflected Light Hue	Transmitted Light Hue	Diffusion Qualities	Light Transmission %	Formed Flat Face Letters	Formed Curved Face Letters	Minimum Distance Ratio	Type of Tube	Best Neon Color
2039	Red	Primary Red	Vivid Red	High	2	OK	OK	1/3	WW/CW	Rose
2115	Red	Primary Red	Red/Tangerine	Good	3	Optional	Optional	1/2	WW/CW	Clear Red
2157	Red	Primary Red	Red/Tangerine	Good	2	Not Recom'd	OK	1/2	WW/CW	Clear Red
2178	Red	Tomato Red	Red/Orange	High	2	OK	OK	1/2	WW/CW	Clear Red
2283	Red	Light Red	Red/Orange	Low	12	Not Recom'd	OK	1/1½	WW/CW	Clear Red
2415	Red	Darker Red	Red/Orange	Low	11	Optional	OK	1/1½	WW/CW	Clear Red
2119	Orange	Brilliant Orange	Orange	High	7	OK	OK	1/2	WW/CW	Clear Red
2564	Orange	Bright Orange	Bright Orange	Good	14	Optional	OK	2/3	WW/CW	Clear Red
2016	Yellow	Chrome Yellow	Chrome Yellow	High	20	OK	OK	1/2	WW/CW	Clear Red
2037	Yellow	Light Yellow	Light Yellow	Low	29	Optional	OK	1/2	WW/CW	Fluorescent Green
2325	Pale Yellow	Pastel Yellow	Pales Slightly	Low	34	Optional	OK	2/3	CW/WW	Fluorescent Green

TABLE 24 (Continued)

Plexi-glas Color No.	Color Name	Reflected Light Hue	Transmitted Light Hue	Diffusion Qualities	Light Trans-mission %	Formed Flat Face Letters	Formed Curved Face Letters	Minimum Distance Ratio	Type of Tube	Best Neon Color
2024	Green	Bright Green	Pastel Green	Good	5	Optional	Optional	2/3	CW/WW	Fluorescent Green
2030	Green	Forest Green	Pastel Green	Medium	9	Not Recom'd	Not Recom'd	1/1	CW/WW	Not Recom'd
2047	Green	Bluish Green	Pastel Blue/ Green	Low	36	Not Recom'd	Not Recom'd	2/1	CW/WW	Fluorescent Green
2108	Green	Primary Dk. Green	Primary Dk. Green	High	2	Optional	Optional	1/2	CW/WW	Fluorescent Green
2215	Olive Green	Olive	Chartreuse	High	6	OK	OK	2/3	CW/WW	Fluorescent Green
2324	Aqua	Green/ Turquoise	Green/ Turquoise	Good	16	OK	OK	2/3	DA/CW	Fluorescent Green
2050	Blue	Dk. Blue	Vivid Primary Blue	Good	1	OK	OK	1/2	DA/CW	Not Recom'd
2051	Blue	Medium Dk. Blue	Pastel Light Blue	Low	19	Optional	Optional	1/1	DA/CW	Fluorescent Green
2114	Blue	Dk. Blue	Vivid Blue	Good	2	Optional	OK	2/3	DA/CW	Fluorescent Blue
2308	Turquoise	Turquoise	Turquoise/ Aqua	High	6	OK	OK	1/2	DA/CW	Fluorescent Green
2648	Blue	Primary Blue	Richer Blue	High	5	Optional	OK	1/2	CW/WW	Fluorescent Green
2329	Light Blue	Pastel Blue	Pastel Blue	High	13	OK	OK	2/3	DA/CW	Fluorescent Green

TABLE 24 (Continued)

Plexi glas Color No.	Color Name	Reflected Light Hue	Transmitted Light Hue	Diffusion Qualities	Light Trans-mission %	Formed Flat Face Letters	Formed Curved Face Letters	Minimum Distance Ratio	Type of Tube	Best Neon Color
2146	Ivory	Milk White	Ivory/ Yellow	Medium	35	Optional	OK	2/3	CW/WW	Fluorescent Green
2287	Violet	Dk. Purple	Deep Violet	Medium	6	Not Recom'd	Optional	1/1	CW/WW	Green/Red
2461	Red	Pastel Red	Pastel Red	Good	6	Optional	OK	1/2	WW/CW	Clear Red
2380	Rust	Brownish Red	Tan	Good	4	OK	OK	1/2	WW/CW	Clear Red

(from Rohm and Haas, 1969, p. 41)

Rohm and Haas also completed extensive research in other various aspects of such signs, and has formulated the following important conclusions about methods used to obtain proper and uniform illumination. It was found that the most influential factor in obtaining uniform lighting is the depth of the sign box enclosure. The straight back sign box has been found to be the most effective; specially shaped boxes with elliptical, sloping, or parabolic backs make no improvement in the light distribution. Light distribution can be improved, however, by the use of special reflectors, such as a parabolic reflector troffer, which allows sign boxes of given heights to be shallower than usual. Also, although brightness of the sign face cannot be expected to be totally uniform for all parts of the sign face since some parts are farther from the light source than others, there is a defined range of allowable variation. Rohm and Haas calculated the ratio of uniformity of brightness of the sign face to be the ratio of foot lamberts near the light source to foot lamberts at the point farthest from the light source. Naturally, a ratio of 1 would be optimum; but ratios of 1.3 to 1.5 provide satisfactory results in most signs. A ratio of 2 is considered the maximum allowable ratio.

"Powergroove" fluorescent lamps were found to be just as efficient as "aperture" bulbs in the uniform distribution of light. For a sign up to four feet high, Rohm and Haas recommends a straight back sign box, interior painted with high reflectance white paint; equipped with one or two Powergroove tubes; and shielded with a light baffle and egg crate grid. Listed in Table 25 are the various outputs for the principle types of fluorescent lamps.

TABLE 25

FLUORESCENT LAMPS FOR OUTDOOR SIGNS — LUMENS PER FOOT

		Total Lumen Output			Lumens per Foot		
		WW	CW	SW	WW	CW	SW
Slimline T6 and T8	300 milliampere						
F42T6		2065	2060		635	615	
F64T6		3275	3175		655	635	
F72T8		3313	3187		576	554	
F96T8		4563	4413		589	569	
Slimline T12	430 milliampere						
F48T12		2700	2600		720	693	
F72T12		4200	4100		730	713	
F96T12		5700	5600		735	723	
High Output	800 milliampere						
F48T12		4000	4000	3000	1067	1067	800
F60T12		5250	5250	3900	1105	1105	821
F72T12		6300	6450	4800	1096	1122	835
F84T12			7600	5700		1126	844
F96T12		8900	9000	6600	1148	1161	852
Extra High Output	1500 milliampere						
F48T17		6900	6900		1840	1840	
F72T17		10,900	10,900		1896	1896	
F96T17		15,000	15,000		1935	2000	

(Rohm and Haas, 1969, p. 46)

OTHER FACTORS AFFECTING LEGIBILITY OF ILLUMINATED LETTERS

In the evaluation of the relationship between different colors, such as a letter of one color on a background of another color, several factors complicate the matter. One of these is the fact that different colors produce different contrasts as their distances from the observer vary. Another is that all values change as their letter shape changes, so we are back to the relative differences in legibility of different letters, but with added factors resulting from the various colors. Actually, an accurate evaluation of a color contrast can only be evaluated when a single unchanging letter is used for a fixed period (or flash) of observation at a prescribed distance.

Any veil of atmospheric haze reduces the legibility of all distant letters by decreasing their apparent contrast, so in this case the apparent contrast to any observer depends on the distance he happens to be from the sign. When there is competitive lighting or daylight, the apparent luminance of any distant sign is governed by two things. The first is that the light from the sign is gradually scattered and partially absorbed by the atmosphere, and the second is that surrounding light or daylight is scattered towards the observer all along the path of sight. The relationship between the amount of light reaching the observer's eye from the sign, and the scattered light from around it, determines the apparent luminance of the sign. In daylight, the apparent luminance of the sign changes with distance until the light from surrounding spaces matches it, and then it virtually disappears. At night, the result is the same because of atmospheric absorption.

IRRADIATION

A major factor influencing the legibility of illuminated signs is irradiation. As has been mentioned in other contexts, irradiation is a phenomenon in which white or light-colored letters appear to be wider than they actually are on a black or another dark background. The consequence of this for printed material has been that the strokewidth of white figures on a black background should be thinner than for black letters on a white background. For illuminated signs, the problem is one which occurs primarily at night when the eye is adapted to the dark. As has been indicated (p. 57), the effects of irradiation vary greatly with the age and ocular condition of the observer. When letters are dark, irradiation from the background (illuminated panel) has less effect than when the letters are light and the background dark. This is because a light letter irradiates over the dark spaces between strokes, and reduces contrast. The background is the adapting medium for the human eye and when it is a light color, it stimulates a large area of the retina for its adaptation, and

the degree of contrast possible is finite. White letters on a dark background, however, can produce infinite contrast because the adapting background is dark. However, when this occurs, irradiation fogs the letters, so that the letters must be larger in comparison to be legible.

When irradiation reduces contrast when bright letters are used on a dark background, a reduction of illumination in the letters frequently improves legibility. The effect of the irradiation is greater on smaller signs, or when the surroundings are very dark. Competitive lighting reduces the effect of irradiation. Therefore, dark surroundings will permit reduced illumination, while competitive lighting will demand more. Competitive lighting actually stimulates the readability of any panel under observation.

Based on the previous findings, the following generalizations can be made. First, light letters on a dark background are more subject to irradiation, which reduces legibility. Second, the lighting in a panel with dark letters can be increased to a very large extent before the effects of halation or irradiation interfere with legibility. Third, the contrast of the letters with their background is the most important factor in legibility; irradiation reduces this contrast for dark letters on a light background, and fills in the letters for light letters on a dark background. A panel in which the letters are lighter than the background is said to have *positive contrast*; one in which the letters are darker than the background, *negative contrast*. Negative contrast can never exceed unity, whereas positive contrast has no upper limit. Both are affected by surrounding light and both are equally visible in theory when the contrasts are equal.

At first glance, there appear to be only two ways to reduce irradiation around neon letters: to reduce the illumination level, or to produce narrower tubing. The latter measure invokes new problems of structure and strength, while the former can probably not be accomplished in a practical manner with present equipment. In fact, it is quite undesirable, because while reducing brightness often produces greater legibility beyond certain distances, brighter illumination has greater attention-getting power.

Assuming that brightness must be kept at a maximum, there are presently three ways we can accomplish this. One of these is producing a narrower stroke relative to the overall letter size, by reducing the tube thickness. A second is increasing the size of the letters while still using conventional tubes. Experiments were made with a metallic tube encasing the gas-filled glass tube with the light from the glass tube showing through slits in the metal tube and not irradiating in all directions.[62] However, these tests showed no

[62] NESA, 1960.

improvement over the metal channel letters now used.

The *neutralization* of the neon irradiation by light of a complementary color from a different source is another and better idea. If all irradiated light can be absorbed, or by an additive process rendered invisible, we may have an improved method of presenting neon letters more effectively.

One method of doing this is to mount the neon letters against a background of back-lighted plastic transmitting light of a wavelength capable of neutralizing the irradiation from the neon light, but not the neon light itself. This solution is limited since there are only a few available colors of light which will neutralize each other, and at the same time act as a contrasting background for each other. Such colors must also be aesthetically acceptable.

To test out this idea, NESA used plastic panels for internally illuminated signs in a selected set of wavelengths, together with neon letters. Their experiments showed that in fact neon irradiation and reflection can be eliminated in certain colors by this method of placing the letters in front of illuminated panels transmitting certain complementary wavelengths. It was also found that some neon colors themselves changed considerably by this technique. Finally, it was found that certain combinations of neon letters and illuminated plastic panels produce a high contrast which is both aesthetically pleasing and very legible.

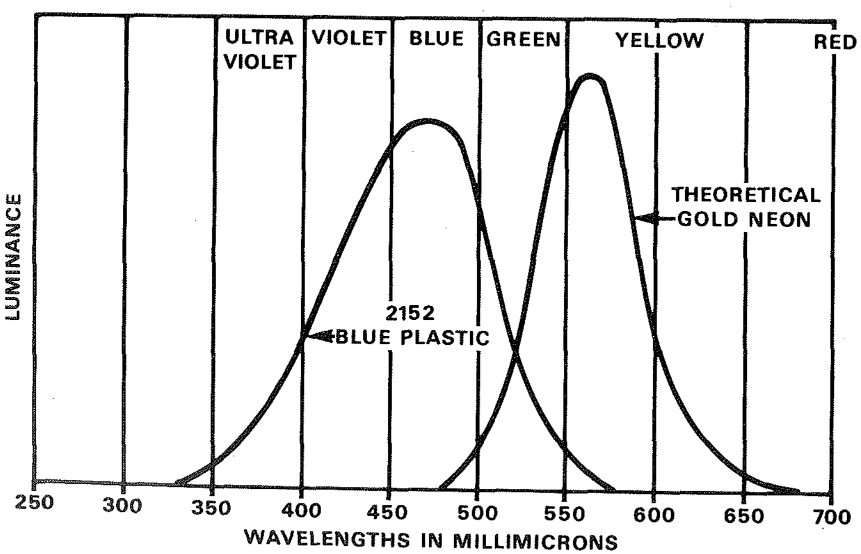


FIGURE 22
(NESA, 1960, p. 47)

If the two peaks of the neon light and the plastic material were well overlapped, it would mean that the two were similar in color, and naturally there would be an absence of contrast. Curves well separated and of complementary colors, as shown in the graph, can produce high contrast. (See Figure 22) When examining the combinations of illuminated plastic and superimposed neon listed in Table 26, it will be seen that some of the most highly contrasting combinations are plastic materials which have spectral transmission peaks between 450 and 480 millimicrons, and noviol-gold neon contrasted against them, or vice versa. A number of combinations which were excellent as far as legibility and aesthetic qualities are concerned are not practical because of the lasting qualities of those specific plastics over long testing periods. Others were not used because their density made them useful only for daylight viewing. An almost endless amount of research can be carried out on these combinations to produce useful ideas.

TABLE 26

REVIEWING PLASTIC COLORS WITH VARIOUS COLORS OF NEON LETTERS

Plastic Color	Availability	Color Fast	Color Peak (Millimicrons)	Best Illum. with Neon (Ft.-Lamberts)	Neon Letters Color
2045 transparent blue with white	stock	very good	450-455	800	noviol gold
2186 transparent amber with white	custom	very good	575-700	wide range	cobalt
2092 transparent green with white	stock	very good	525-530		noviol gold (some irradiation)
2108 translucent green	stock	very good		500	noviol gold
2108					rose
2152 transparent blue with white	custom	very good	470-480	600	noviol gold
2264 transparent blue with white	custom	best	470-480	wide range	noviol gold
2057 translucent green	custom	very good		300	noviol gold
2162 transparent amber with white	custom	fair	400-500 & 600-700		cobalt

TABLE 26
(Continued)

REVIEWING PLASTIC COLORS WITH VARIOUS COLORS OF NEON LETTERS

Plastic Color	Availability	Color Fast	Color Peak (Millimicrons)	Best Illum. with Neon (Ft.-Lamberts)	Neon Letters Color
white translucent	stock	very good		400	uncoated cobalt & ruby
2071 Transparent red with white	custom	very good	650-700		green (some irradiation)
2030 translucent green	stock	very good	520-540	900	noviol gold
2114 translucent blue	stock	very good	dense 464-472	700	noviol gold
2444 transparent red with white	stock	fair	dense 660-700	wide range	green
2415 translucent red	stock	very good	640-700	300-900	white and turquoise
2283 translucent red	stock	not known	630-700	300	white and turquoise
2037 translucent yellow	stock	very good		600-700 450	uncoated cobalt ruby

Another obvious conclusion is that it is not always desirable to flood the panel with maximum back lighting, especially at night, because this frequently encourages irradiation. Table 26 indicates the most effective levels of panel illumination when used with neon lighting. The backs of the neon letters must be blocked out, otherwise in certain color combinations their back brightness reflects from the surface of the illuminated panel and so reduces legibility by partial duplication of the letters. The backs of neon letters will also change the quality of the panel color to some extent, if the panel is not very brightly illuminated. During the daytime, a few of the panel colors shown in the table will present good contrast to the neon letters, even if they are not illuminated because in some cases their transmission qualities are more effective than their reflectance. It seems highly probable that no more panel illumination need be used during the day than at night. Building an actual sign will be necessary to test all levels of daylight against the internal illumination.

Further observations of the effects of some color combinations in the above table show that a white panel with a surface illumination of 400 f.l. and either ruby or uncoated cobalt neon letters silhouetted against it produces a striking, irradiation-free, highly legible neon letter. A slight toning of the white background by the red neon is noticeable upon closer examination. This can be eliminated with more illumination behind the panel, which does not in any way affect the legibility or contrast. Probably the next most striking combination with good contrast, excellent legibility, and complete absence of irradiation will be found with transparent blue (2142) plastic backed with translucent white plastic, illuminated with 600 f.l. fluorescent light behind, and noviol-gold neon letters in front.

The contrast can be increased by using translucent blue (2114) plastic illuminated with 700 f.l. and using noviol-gold letters. The reduced background illumination due to the density of the plastic permits a faint trace of irradiation. The use of transparent blue (2045) acrylic backed with translucent white, and illumination of 800 f.l. with noviol-gold letters, will show slightly less contrast, but an entire absence of irradiation. Not all blues are as satisfactory as these. Those having their spectral transmission peaks nearer the red show more irradiation.

By using translucent yellow (2037) with 600-700 f.l. of illumination and letters of uncoated cobalt or ruby, a legible contrasting and fairly attractive combination results. However, with the backs of the letters not blocked out, two details show up. A white reflection of the cobalt letter on the yellow panel is visible, and a deepening of the yellow panel to an orange where the ruby letter is located. The ruby letter does not show the white reflection, because of the relative

wavelengths, and the deepening of the panel can be eliminated by using a yellow panel with a spectral transmission peak slightly nearer the green band.

SIGN PLACEMENT ANGLE

An important factor which must be considered when discussing the legibility and readability of signs available to viewers and to the motorist in particular is the angle and height of the sign. Any sign which is at an angle suffers a distortion to the eyes of the viewer. This distortion is related both to the speed of approach and the angle of the sign: the closer the viewer comes to the object, the greater the effect of the distortion. Professor Prince suggests that an eye-level highway advertising sign should not be angled more than 20 degrees from the normal position of facing on-coming viewers; when the angle must be greater than 20 degrees, the widths of the letters should be increased accordingly.[63]

For signs that are above eye level, such as those on the tops of buildings, will shrink in apparent height when viewed from below, and those which are to one side of a building and at an angle will seem narrower. Dr. Prince uses Figure 23 to explain this.[64]

[63] J. H. Prince. "Height of Sign and Speed of Approach Affect Visibility." Signs of the Times, March, 1958, p. 79.
[64] Ibid., p. 78.

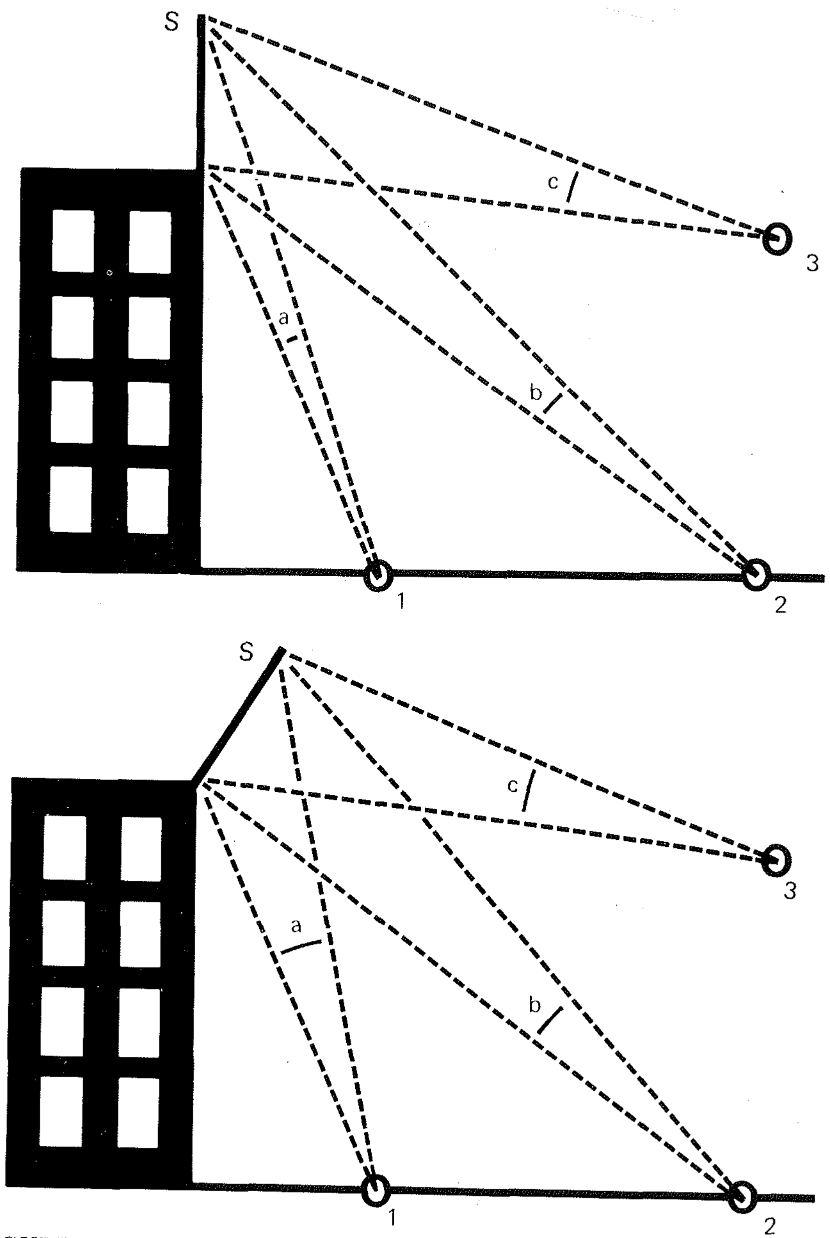


FIGURE 23. The sign "S" on top of the building is being viewed by three people, 0_1, 0_2, and 0_3, and (a), (b) and (c) are the angles subtended to their eyes by the sign. If the sign is tilted forward 27 degrees as shown in the lower illustration, all the angles increase in size, and the amounts of improvement of view to the three observers are 66 percent for 0_1, 37 percent for 0_2 and 3.4 percent for 0_3. While construction problems will not often make it practical to tilt a sign forward on the roof of a building, this does demonstrate a legibility problem confronting artists and designers preparing copy for displays high on roofs.

The placement angle of a sign plays an important role in determining the maximum distance from which the sign will be readable. It is noted in the *660' Janesville Survey* that for a sign set back 660 feet from the road, an angle of 30° from a line parallel to the highway seems to offer optimum legibility.[65] Stating that this was only conjecture and that further studies should be done on the subject, the authors suggested that for such a 660 foot setback, the placement angle should be between 0° and 45°, and definitely not over 45°.

The 1960 NESA results indicate that for a sign directly facing the viewer (no setback), maximum legibility was achieved for a sign at right angles to the observer. Because of the fore-shortening of the letters, legibility will decrease as the angle becomes progressively smaller. (See Figure 24)

[65] National Advertising Company, 660' Janesville Survey, Bedford Park, Ill., 1966.

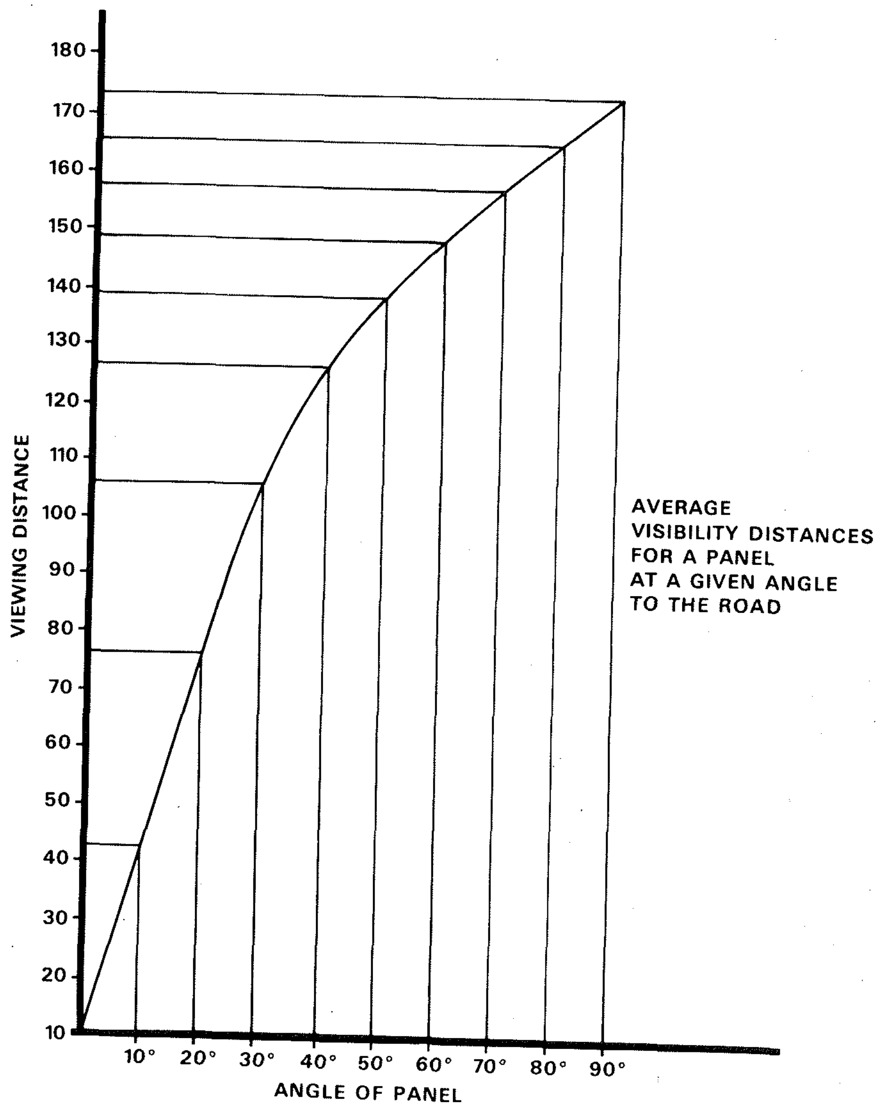


FIGURE 24
RELATIONSHIP OF PLACEMENT ANGLE TO LEGIBILITY
(NESA, 1960, p. 37)

Loss of legibility is not greatly marked, however, until the angle is reduced to 50°, at which point there is a 25 percent loss. At 30°, there is a 45 percent loss of legibility. These results were obtained experimentally by having observers view a sign with numerals on it at varying angles.

The same experiment was repeated using letters instead of numbers, and produced similar results; however, the legibility distances were somewhat shorter for the letters, and the maximum and minimum ranges of response were wider. One can calculate mathematically the apparent reduction in width of a letter with a change in angle. However, it must be emphasized that the figure obtained seldom bears any relation to the actual legibility of the letter at that angle unless it is a simple straight horizontal line letter like E. L, or H. Changing a panel angle from 90° to 60° reduces the apparent width of the letters and their vertical strokes by 50 percent. This may reduce the legibility of some letters by no more than 10 percent, and others by as much as 45 percent, depending on their shapes. After this degree of angling is passed, the drop in legibility becomes more precipitous. When letters are closely spaced, the reduction in legibility becomes even greater.

COMPETING PANELS

Ordinarily, as the number of signs increases in an available area, the total amount that can actually be read on them in a given time becomes reduced. For instance where there is one panel alone, almost all of it may be read in about 2 seconds. But if another panel of approximately the same size appears directly above, and if the new panel is easily viewed, the upper panel will probably be given 75 percent of the viewer's attention time and the lower one only 25 percent. Should there be three panels each above the other, then the attention times may well be divided into 55 percent for the top, 40 percent for the second, and 5 percent for the bottom. The top panel is always the most valuable if it does not enforce anatomical strain.

If the panels are viewed from an angle of 60°, the top one alone of the three is likely to receive adequate attention, whereas with only two panels, each could well be given almost equal chances. All this presupposes an equal amount of copy on each panel and an equal illumination and color attraction. As soon as this balance is upset, other factors come into play.

Tests have been made where subjects view panels at angles which become progressively more oblique to the line of sight. They first lose the ability to identify objects, and then the ability to identify words. But they are impressed by colors at almost any angle. Backgrounds and borders are also noticed more as legibility drops under these conditions. If there is only a limited time available for reading, such as when driving past a sign, the largest print on the panel will be read before the rest, no matter in what position this may be, and the same criterion can be assumed in competing signs. The sign with the more legible type will receive the maximum attention.

When two panels side by side are competing with each other, both are likely to suffer, although the left one may suffer less than the right. If they are one above the other, the lower one will be the less effective as already mentioned, but it will be more effective than if it were in a horizontal line with the other. All this presupposes approximately equal material on the two signs.

When experiments are made from moving vehicles, we find that when several signs are adjacent to each other, the choice of which one to look at is much more difficult than when the observer is stationary. Then the things which arrest attention are boldness of print and brightness of color, so long as the color is not psychologically repellent. All things being equal however, once more we find the top and left-hand panels most effective.

If a panel is likely to be partially obstructed by another, it may be desirable to map out the area and find just where it will be completely visible from the average observer's likely position (and for how long at a given speed from vehicles.) If this produces a hypothetical short viewing time, the sign should be planned with just the right amount of reading material for comfortable reading. For instance in Figure 25, the sign "C" has unlimited legibility approach distance, but sign "A" has a very limited one, and sign "B" an even more limited one. All the signs are the same size, but their effectiveness can only be equalized by giving "A" less reading material than "C", and "B" even less than "A". Another factor to be considered in the short approach distance of panel "B" is its height. The top of a car windshield, as shown in Figure 26, will cut off the view of a sign earlier when that sign is placed higher and the accompanying Figure 27 gives some idea of this.

Assuming there is no impediment to view when panels are competing with each other, and that the panels are all reasonably similar, we can, on the basis of past experience and organized experiments, suggest that they might have the following individual values for gaining attention.

1. Four panels in an approximate box formation; to left 50 percent, top right, bottom left and bottom right, 16.6 percent each.
2. Two panels vertically situated; top 66.5 percent, bottom 33.5 percent.
3. Two panels horizontally situated; left 66.5 percent, right 33.5 percent.

4. Three panels vertically situated; top 48.5 percent, center 32.25 percent, bottom 19.25 percent, or say 50, 30 and 20 percent.
5. Three panels horizontally situated; left 48.5 percent, center 32.25 percent, right 19.25 percent.
6. Four panels vertically situated; top 45.5 percent, second 27.5 percent, third, 13.5 percent, bottom 13.5 percent.
7. Four panels horizontally situated; left 45.5 percent, second 27.5 percent, third and fourth 13.5 percent each.

These figures will all be affected by each individual's decision to read which one first or most attentively. So we can assume that unless viewers have more time than is usually available, panels grouped near to each other will always be less effective than single ones, except when competitive lighting acts as a stimulant to reading when lighting conditions and contrast permit this.

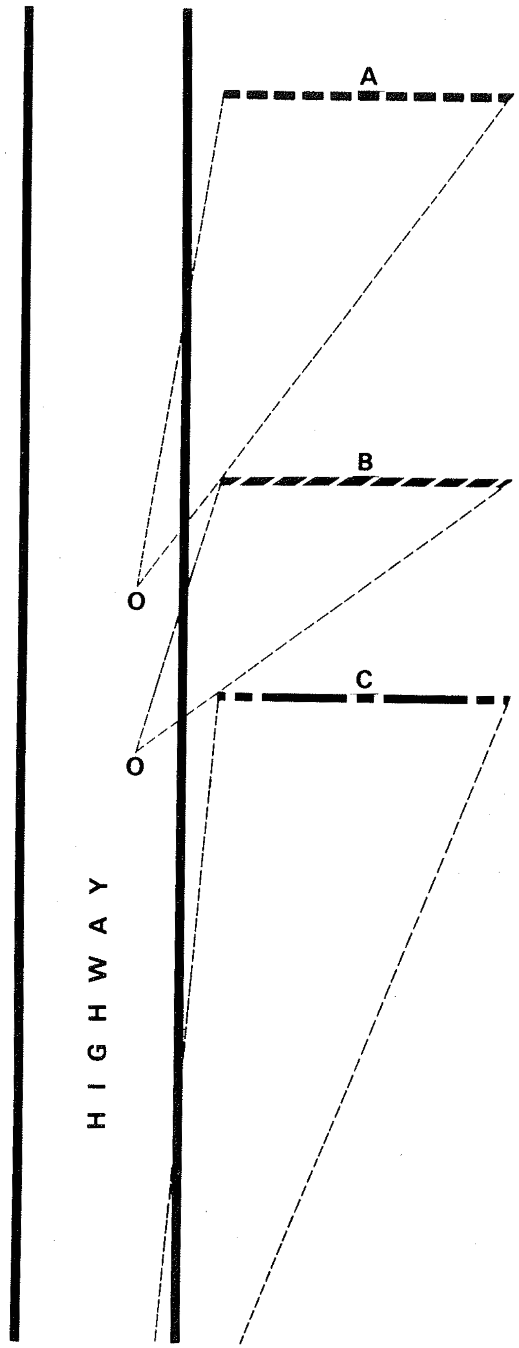


FIGURE 25
(NESA, 1960, p. 40)

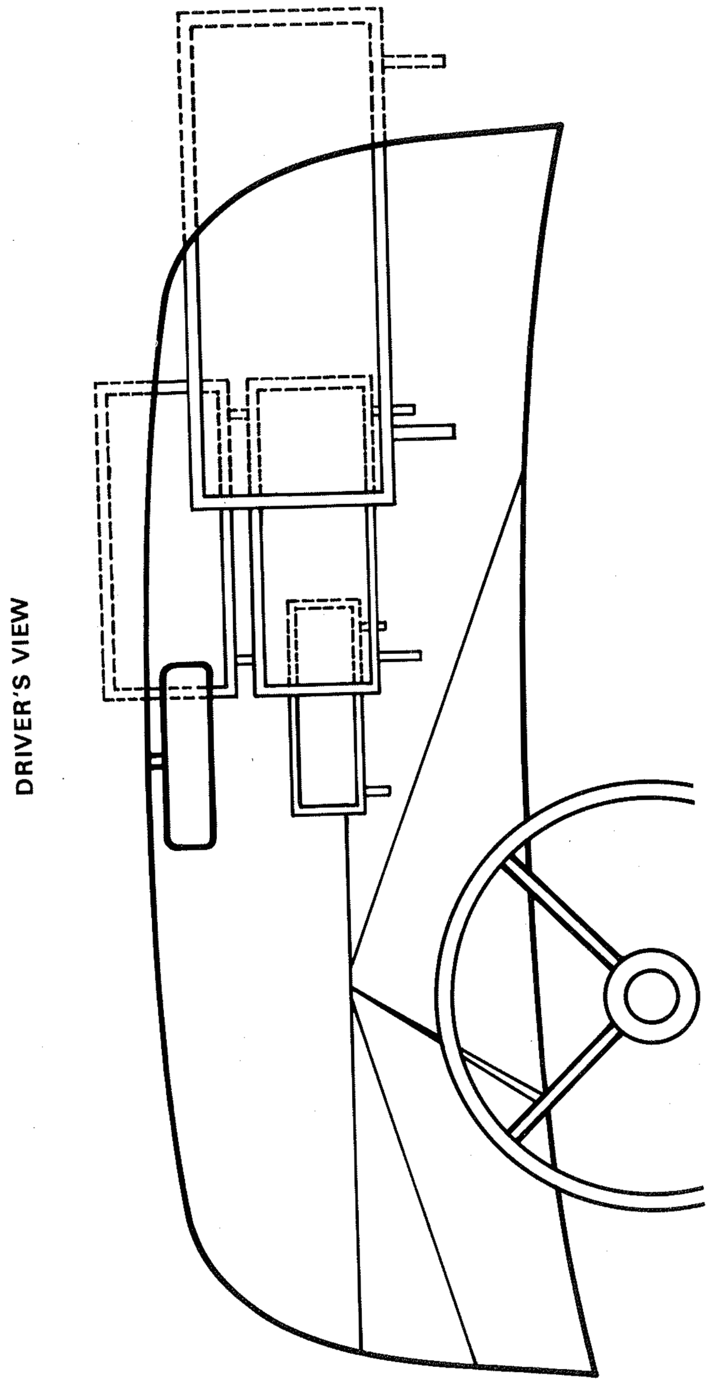


FIGURE 26
(NESA, 1960, p.41)

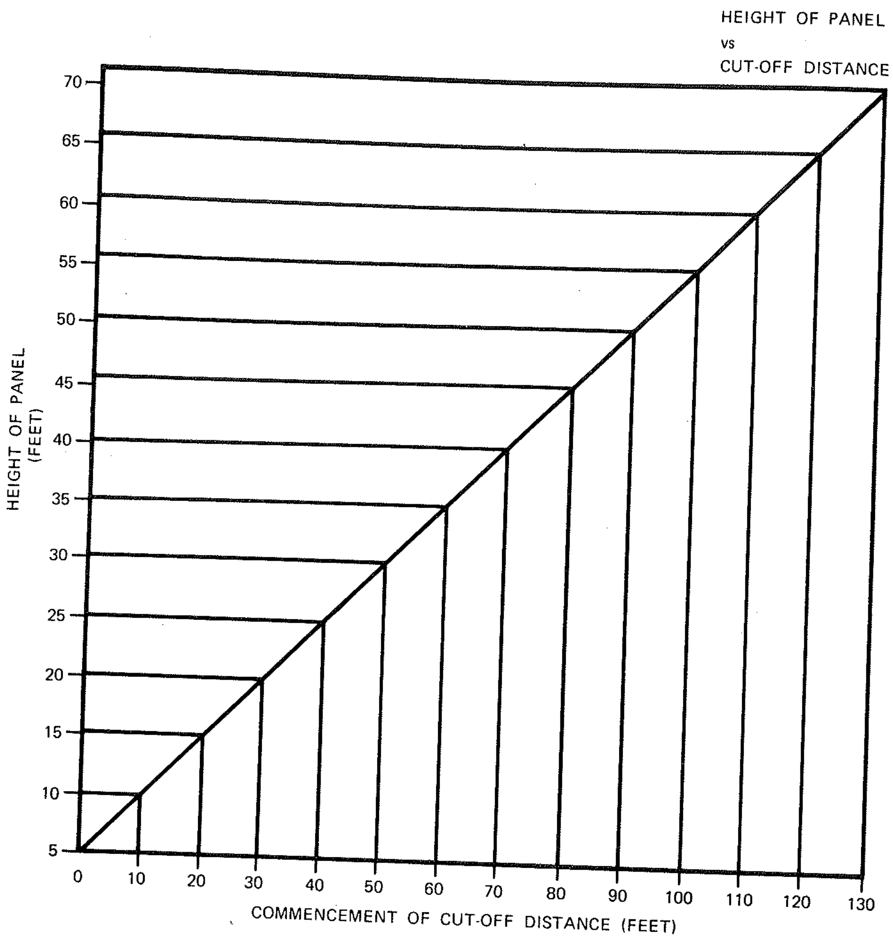


FIGURE 27
(NESA, 1960, p. 42)

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CHAPTER 2
VISUAL INFORMATION PROCESSING AND THE DRIVER

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CHAPTER 2
VISUAL INFORMATION PROCESSING AND THE DRIVER

Most of the information that comes to us through our senses comes through our eyes. The complex processes involved in seeing and in making sense of what we see are of special interest to researchers in several scientific disciplines. It is possible to investigate seeing from many points of view, so to speak. Experiments are conducted to probe diverse but related questions pertinent to the problems of what we do when we see.

Anything that we see is produced by energy, light energy in particular, which stimulates cells in our eyes. Physicists study the properties of light, trying to understand what distinguishes its many diverse forms, only a fraction of which are visible to human eyes. These scientists can be thought of as exterior-oriented: they describe light in terms of its physical properties, independent of anyone's view. Physiologists, on the other hand, are internally-oriented. They study the minute results of seeing light that take place inside the organism; this means careful analysis of the activity of receptors such as cells and nerves. Psychologists, because they study the behavior of entire organisms (as opposed to cells) concentrate on the visual experience of the person in his environment. The result of this interaction, their special area of interest, is what we know as visual experience.

It is important for the psychologist to understand the properties of light well enough to control and measure it for purposes of experimentation. Moreover, he needs some understanding of the neurology and physiology of the visual system so that his results will be meaningful to him. It is obvious, then, that he must make use of other sciences, but his main task is to find those aspects of visual experience that are invariant.

If an organism is to maintain a satisfactory visual awareness of its environs, it must make countless adjustments almost continually. One knows from experience that eye, head, and body movements help in making these adjustments. The processes that tell us when and how to make these changes are only beginning to be investigated. Visual perception can be made less formidable for our purposes if we consider it in the context of visual tasks. Driving an automobile is a behavior that combines many actions that we might consider independent of each other. Because it is so familiar an experience and relevant to problems of viewing signage we shall treat it closely in the second part of this chapter. First we will survey some of the research on visual tasks (visual search in particular) that typify the perceptual activities of the driver, is, there can be visual noise such as the array of incomplete letters which Sperling used to distract subjects and key them from "seeing' the display for a brief interval after the stimulus display was terminated.

The rate at which subjects scanned brief printed displays was found to be one letter per 100 msec. This rate was constant even when subjects were shown visual noise prior to the exposure to the stimulus. By using a pre-exposure field that was 100 times brighter than the field on which the stimuli were displayed, Sperling was able to delay the onset of scanning by 100 msec. The noise was effective in that it delayed the beginning of scanning activity, but it could not retard its rate. In this and other experiments[4] Sperling found that for the subject, the visual display persists for a few tenths of a second after the stimulus has in fact been turned off. He refers to this phenomenon as visual information storage. By asking subjects to report what they have seen immediately after the stimulus is turned off, he is asking them to "scan" or "read out" from this visual storage system. As Sperling found in his experiment, the rate at which scanning can be done is quite high.

To understand the results of this experiment, one must view them in some perspective. It is well to keep in mind that this rate of scanning is only valid for up to three or four letters. Also, it is significant that the stimuli used were displays of letters, as opposed to words. Therefore, this scanning must not in any way be confused with reading, such as when a driver momentarily takes his eyes off the road to read a sign. Later in the chapter we shall mention some of the influences of reading on perceptual tasks.

There are also some technical limitations of this research which Sperling himself points out in reporting the data. For example, it is virtually impossible to be sure that retinal locations on which letters fall will regain their sensitivity at the same rate. Many questions about scanning rate are raised by these data and cannot be answered before more research is done. It was noted, for example, that the intensity (brightness) of a stimulus could be reduced to 1/100 of its prior brightness and the scanning rate was only slightly reduced. One wonders, then, whether other variables such as the shape and size of the stimulus or its contrast with the background would have a similar effect.

In a more recent experiment, Sperling and colleagues investigated the scanning rate when more than three or four letters

[4] Sperling, G. Information retrieval from two rapidly consecutive stimuli: A new analysis. Perception and Psychosis. 1971 (Jan) 9 (1-B) 89-91.

though the research does not necessarily treat them in that frame of reference.

The driver, one can assume, is always trying to see something: he has a perceptual goal. If one thinks of the driver as receiving information as he looks at his surroundings, then the purpose of this behavior is to control the input that he receives. There are several options available to him: he can look in different directions, he can pay close attention to a selected part of the entire field of view, or he can close his eyes. All of these things are different strategies for reaching his perceptual goal. Because perception is a process, an interaction, the organism sees and, as we shall discover, changes his environment in the act of seeing. But that same environment influences him. The environment demonstrates its importance when he has already perceived his surroundings. Another set of factors exists that influence the perceptual behavior of the driver or viewer that cannot be accounted for as coming from his surroundings. These are the influences that come from within him and determine what he will do to achieve his perceptual goal. These factors are more difficult to isolate than are environmental influences. There is no way to observe them directly. They have to be inferred from the behavior of individuals.

Probably the most reliable way to control the environment so as to make valid observations about particular behavior is in laboratory conditions. But, as has been observed, experiments rarely make critical discoveries. It does not commonly happen that the results of an experiment allow one to make a choice between two theories or two predictions based on two theories.[1] Nevertheless, a survey of research points to the particular questions that are of interest to perceptual psychologists and indicates which approaches to visual perception will be used in future research. We shall concentrate on those aspects of research that treat problems related to the application of visual information to a perceptual task. We will repeatedly consider various experiments involving visual search and brief visual displays for reasons that will become clear.

REVIEW OF RESEARCH

In dealing with questions of visual information processing, an appropriate first step is to define what we mean by visual information. We know that it is not merely the light that excites

[1] Haber, R.N. (Ed.) Contemporary and research in visual perception. New York: Holt, Rinehart and Winston, 1968, p. (Introduction).

the receptor cells, nor is it the pattern of stimulation that the light produces. Visual information exists as the result of the operation of the eye and brain on the stimuli available in the environment. Psychologists use the term coding to describe the compression and transformation of information into the form in which it is stored. Many everyday tasks involve using visual information that we have stored. One looks for a telephone number in the directory and then mentally keeps that number in sight before he dials it.

Because psychologists infer that visual information is stored and that it is retrieved, a practicable question that can be studied by experimentation and measurement is at what rate can visual information be put into a form that is storable.

One situation that is often studied in this context is the viewing of a brief visual display. Superficially one might expect this to be for pragmatic reasons only: a brief display can be constructed and controlled (by using a tachistoscope) more easily than a complex one. But there is also a theoretical reason for studying this situation: many normal visual activities are characterized by brief stops between eye movements. Reading comes to mind immediately as an example of this type of activity. Javal, who first noticed these movements in the 19th century, named them *saccads* (the French word for "jerk"). We still use the term today to describe eye movements. Our eyes move in saccades and only during the pauses do they take in information. It has been noted that many other activities such as viewing stationary objects and even tracking moving objects also involve this pattern of saccades and rests. [2] Investigations of extremely short exposures to visual stimuli have an important place in our understanding of how visual information is acquired and used.

A researcher who has carefully and consistently investigated the viewing of brief visual displays is George Sperling. His study of scanning tasks led to the evolution of a theory of visual memory. [3] Sperling was able to determine the rate at which scanning takes place by precise control of the moment at which the scanning activity began and ended. This is not the same as control of the onset of the stimulus. He used a standard experimental technique known as masking - interference with the subject's perception of a stimulus by an intruding stimulus either before the main stimulus or after it. The name given to the material used to mask the stimulus is conventionally called noise, regardless of its mode. That

[2] Sperling G. Information A model for visual memory tasks. In Haber, R.M. (Ed.). Information - processing approaches to visual perception. N.Y.: Holt, Rinehart and Winston, 1969, 18-31.
[3] Ibid p. 18

appear in the display.[5] This was done by requiring subjects to do a visual search task. After viewing a fixation field for one second, they then saw a series of nine-letter arrays. One display in every sequence of from six to twelve arrays would be critical; it would contain a numeral. The subject's task was to name the numeral that he saw and to indicate its location (for instance, "six, upper right").

The fastest rate at which any subject was able to scan was from 75 to 125 letters per second or one letter every 8 to 10 msec.

The time between displays, or inter-stimulus interval (ISI), was measured from the beginning of one display to the beginning of the next. This interval was controlled so as to be extremely brief; briefer in fact than the normal amount of time separating eye fixations or saccades. Normally the time between our eye movements is from 200 to 250 msec. This means that we fixate our eyes on a stimulus four or five times in every second. But the interval that made possible the fastest scanning rate was only 40-50 msec. This result indicates that in this particular task, eye movement limits the speed of visual search. There is an implied possibility here that in other tasks which also seem to be limited by eye movement (such tasks as reading) the manipulation of the sequence of stimuli may be able to replace eye movements to enhance the processing of visual information.

In this same experiment another element of the search task was manipulated. In some instances subjects knew only that they were trying to locate a number in the visual display. But at other times subjects were told what the particular number was which they were looking for. The rate of scanning was apparently unaffected by the change.

The concept of visual information storage which Sperling investigated in earlier writings has been deduced by other researchers in altogether dissimilar contexts. It has been found that when a pattern is moved behind a stationary slit so that its parts appear to the viewer successively in the same place, the pattern can be "seen" in its entirety. This may be interpreted as evidence of the existence of visual storage. In one experiment, it was referred to as post-retinal visual storage.[6]

It is possible to object to this conclusion, given the results of the experiment. Conceivably one might agree that no visual

[5] Sperling G. Budiansky, Jr., Spivak, J.G., and Johnson, M.C. Extremely rapid visual search: The maximum rate of scanning letters for the presence of a number. Science 174, (1971), 307-311.
[6] Parks, T. Post-retinal visual storage. American Journal of Psychology, 78 (1965) 145-147

information has been stored, rather, that the phenomenon is the result of eye movements. It could be supposed that through eye movements the entire pattern is spread over areas of the retina so near to each other that the effect would be one of parallel stimulations. Similar phenomena are known to exist and to evidence what is known as sensory integration time. But this is probably inappropriate as an explanation of post-retinal visual storage.

One reviewer of the research objects to this argument, believing that it overlooks the whole point of the experiment,[7] that given the appropriate conditions, it is possible for the visual system over time to combine a set of incomplete displays that have fallen on one area of the retina and to make of them a coherent and simultaneous scene. It is even suggested that this kind of integration that is not bothered by the time lapse that separates the puzzle pieces, so to speak, is not uncommon in visual experience.

RECOGNITION

From the point of view of perceptual tasks, particularly with respect to the special task of the driver, recognition is a fundamental ability. The phenomenon of recognition is the activity that allows a person to see an object, situation, or another person, and immediately "understand" what or who it is. Because this process is not satisfactorily understood, there is a diversity of opinion and vocabulary in the literature on recognition.

According to one possible explanation, recognition can be accounted for if one imagines a set of stored models in our heads corresponding to all the familiar patterns that we encounter daily.[8] Every time we see a pattern we compare it to our assortment of models until we find the one that it matches. We then know what it is that we are seeing. The stored models are called templates and the operation is known as template matching. In another version of how recognition is possible, one assumes we make a lightning-fast set of analyses of the irreducible elements of a visual scene and then identify the object as the composite of its various parts. The elements might be angle of a line, or size and orientation of an

[7] Hochberg, Julian. In the mind's eye. In Haber, R.N. (Ed.) Contemporary theory and research in visual perception. New York: Holt, Rinehart and Winston, 1968, 309-332.

[8] "Pattern" is recognized as a loaded word here but seems unavoidable. Any reader prepared to grapple with the abstruse topic of pattern is encouraged to seek out Peter Dodwell's Pattern recognition. New York: Holt, Rinehart and Winston, 1970.

object. This process is referred to as feature extraction. Of course, neither of these explanations is adequate or even particularly satisfying. We know that of a class of objects, some are more characteristic than others of that class. (Advertisers exploit this fact: "It's the peanuttiest peanut butter," and so forth.)

Studies of recognition commonly entail the use of visual search tasks, as did investigation of the storage of visual information. Ostensibly the experiments we shall now discuss are very reminiscent of those done by Sperling, but we must bear in mind that they are posing different questions. In one experiment, subjects were asked to report whether a display of symbols contained any one of a series of symbols that they had memorized prior to the test.[9] (Theoretically, this task is very much like template matching.) The purpose of the experiment was to find out more about the process by which internal comparisons are made. Data showed that increases in the list of symbols that had to be memorized before the test resulted in an increase in time needed for recognition. There was speculation that part of the time between the presentation of the test array and the response was used to make a series of comparisons. This process by which the information was retrieved from memory was mathematically expressed in such a way that it was thought to be a step by step comparison.

Other experiments have been reported that describe recognition in extremely different terms. According to one account, when a letter is presented through a tachistoscope the chances of its being accurately reported depend in part on the relation between where it is located on the retina and the length of delay before it is scanned.[10] In an actual experiment, this means that the amount of information that a letter contains for the viewer depends on where it is located on his retina. The reason for this is that the retinal location also determines how quickly the letter will start to fade out. A letter falling on a relatively acute area of the retina will be more memorable to the viewer than will a weaker impression (that is, one falling on a less acute area). The test that led to this position was combinations of letters that were not words ("nonsense arrays") as is common in recognition tests. When words are used the results bear little resemblance to tests of letter

[9] Sternberg, Saul. High-speed scanning in human memory. In Haber, R.N. (Ed.) Contemporary theory and research in visual perception.

[10] Fudin, Robert and Kenney, John T. Some factors in the recognition of tachistoscopically presented in alphabetical arrays. Perceptual and Motor Skills, 35 (1972), 951-959.

recognition.

Factors which influence the rate at which letters can be recognized have long been studied experimentally. In 1942 there was already evidence that previous knowledge or experience with letters, presumably through familiarity with reading, could influence recognition time. At that time Henle used legible letters and their mirror images and found that the recognition threshold for legible letters was somewhat lower than was that of the reversed ones.[11] This has later been interpreted as a suggestion that having learned to read may be influential in recognition tasks.

More recent observers have found more compelling evidence that learning is a part of perception. A provocative question emerges from this observation: what exactly is changed by learning?[12] One can conceive of at least two plausible alternatives. Perhaps the way that we see words is influenced by knowledge of reading. That is, perhaps there is some subtle change in the way that we see the form of letters. It may be, however, that our seeing is unchanged but that we acquire different ways of remembering words. As Julian Hochberg has articulated these alternatives: "(1) The basic receptive processes themselves might alter, and thereby the nature of what will be an adequate visual stimulus might change . . . or (2) The receptive processes, and at least some associated perceptual phenomena, remain untouched by perceptual learning."[13]

Hochberg goes on to argue for the second alternative, maintaining that the available research evidence supports this view. According to his understanding, what a person can and does see in any momentary glance is not changed by perceptual learning. What does change is where a person looks and for how long he will remember what he saw. When we discuss the difference between novice and experienced drivers in reference to eye movement studies, we will see corroboration of this argument.

SELECTIVE ATTENTION

If we return for a moment to the problem of the driver and the adjustments that he can make to control incoming visual information, you will recall that one option we mentioned was selecting one part of the visual field and effectively excluding all else. We do this every day in various sensory modes. The classic

11 Henle, M. The experimental investigation of past experience as a determinant of visual form perception. Journal of Experimental Psychology, 30 (1942), 1-22.

12 Hochberg, Julian, op. cit.

13 Ibid.

example is the aptly-named cocktail party phenomenon. We have little trouble listening to just one conversation (whether or not it happens to be the one we are engaged in) in a room buzzing with many "intimate" conversations.

We do the same thing visually when, for instance, we look for, say, a particular car in a parking lot; we do not even see the cars that we scan over rapidly. There are nearly as many explanations of this phenomenon as there are psychologists engaged in investigating it. One area of disagreement centers on the problem of how much we know of the unattended stimuli. On what grounds do we make the decision not to take a "good" look at these subjects? As with other questions that we have considered, visual search tasks can create a context in which the process can be studied rather conveniently.

In a particular experiment a fairly easy task was assigned in order to study the movements that direct the eye to areas that the subject considers important.[14] Mackworth chose an easy matching task because it involved the activity of peripheral matching which he considered a common experience that functions to guide eye movements. He maintained that recognition of a familiar pattern commonly takes place through a process of comparing information from peripheral visual areas. In non-psychological terms, one knows that looking around is a process of moving from one area that one wants to see to another desired area. The background remains unwanted and unnoticed.

In previous discussion of the subject of optics, you will recall that the fovea is the central part of the eye on which fall the stimuli in the center of the visual field. When a person consciously chooses to attend a particular visual stimulus, he will move the fovea, as Mackworth phrases it, "from one rich source of data to another." This means that the fovea is engaged in this searching task a great deal of the time; it has to scout, as it were, to find the data that it considers essential. The purpose of this scouting is to avoid meaningless eye movements. If the fovea did not transmit its preview to the rest of the eye, it is conceivable that eye movements would tend to be random. It is important to keep this in mind to understand the main premise that is drawn from the research described below: that noise (irrelevant information) acquired by the peripheral retina can interfere with recognition. This occurs, the argument goes, because peripheral matching cannot take place. The peripheral retina is impaired because of the similarities between the information in the fovea that the eye "wants" and the many peripheral distractions. It is thought that

14 Mackworth, Norman H. Visual noise causes tunnel vision. Psychonomic Science, 3 (1965), 67-68.

the peripheral items cannot be recognized adequately. This means that ultimately the fovea has to be used more often.

In the test under discussion, subjects were first dark adapted for 10 minutes. They were then asked to fixate on a small dot in the center of the screen at which they were looking. They were asked, however, to attend to the entire width of the screen, and required to report yes when they observed that the letter in the center of the screen was on both sides of the center as well. The conditions under which this letter was presented differed in terms of the content of the peripheral field. But in every case the letters had the same relation to the fixed point. In the condition described as having "no noise," there was a total of only three letters visible on the entire screen. When this condition was manipulated so that a contiguous line of 17 letters appeared (an instance of noise), the accuracy of reporting was severely impaired. A somewhat drastic variation was tried in which the whole display area was covered with 22 lines of print, a total of 374 letters. As would be expected, peripheral matching was most difficult under this condition, which was described as information overload.

The important concept which explains these data is the useful field of view. This is the area immediately around the fixation point. It is the source of the information that the fovea scouts; the information in this field is very briefly stored and read, in a way, in many visual tasks. This field can be conceived of as analogous to the pupil. When a stimulus contains excessive light the pupil contracts; similarly, when an excess of visual information is made available in one field, the useful field contracts to rescue the visual system from being overloaded. This does not mean that the visual system can never, in effect, be overloaded. In extreme cases where potential overload is severe the useful field will not even expand to a size that could be considered normal given the average physiological limits of the visual system with normal visual acuity.[15] In cases of massive overload (for example, the page of letters that Mackworth used) the confused and generally unsuccessful attempts at matching are thought to be caused by the subject's not having sufficient time to form a visual image.

[15] For a more detailed discussion of information-overload see: Mackworth, N.H. and Mackworth, J.F. Remembering advanced cues during searching. British Jour. of Psychology, 50 (1959), 207-222; Kaplan, I. T. and Carvellas, T. Scanning for multiple targets. Perceptual and Motor Skills, 1965; and Sanders, A. F. The selective process in the functional visual field. From Institute for Perception. RVO-TNO. Nat. Res. Organiz. Soesterberg, The Netherlands, 1963, 37.

Attractive as these conclusions may appear, they are not the only version of selective attention in visual scanning that may be found in the research literature. In a series of experiments that antedated Mackworth's, Ulric Neisser made some useful finds, with which Mackworth's later conclusions are not everywhere consistent. The tasks were similar insofar as both involved visual scanning. Neisser asked subjects to scan lists of letters (made up of pairs of letters or of arrays of six letters) and to indicate whether a particular letter(s) appeared or did not appear. First, he noted that it takes less time to find a letter in a list than it takes to scan a list and report that the letter is not present. This is explained as involving two different levels of information processing. Unlike Mackworth, he found that the horizontal distance separating the letters was irrelevant to the speed with which the task could be performed. He also found that tasks requiring subjects to find two in a display could be performed just as quickly and accurately as a search for one letter. He noted that scanning an array of six letters takes longer than scanning pairs of letters, but that it never takes three times as long.

The same tasks were repeated with slight variations to investigate to what extent scanning could be manipulated. The number of letters to be scanned was significant, as we have said, but so was their shape. A round letter such as Q was easier to distinguish when it was in a field of angular letters (E, I, M, V, W, X) than when it was viewed with rounded letters (C, D, G, O, R, U). He also found that if subjects were given the opportunity to practice scanning tasks, they could increase their rate. After about three weeks of practice, subjects were able to scan for two or even four letters at approximately the same rate. This means that separate targets do not have to be looked for in separate operations. It is quite possible to look for several items at the same time.

Recent research has shown that scanning can be extremely rapid when a "category effect" is present.[16] If, for instance, a particular letter has to be found, it is more conspicuous in an array of numbers than in an array of other letters. This is not particularly surprising in view of other research. But it was also noted that with a category in mind a subject could overcome a visually ambiguous situation. To wit, the numeral zero and the letter o were not represented by the identical character. When zero was the target in an array of letters it could be found as rapidly as any

[16] Jonides, John and Gleitman, Henry. A conceptual category effect in visual research: O as letter or as digit. Perception and Psychophysics, 12 (1972), 457-460.

nonambiguous number. This means that the category that the subject had in mind was a stronger influence than the configuration of the target itself.

This sampling of research raises many questions about how these various data fit together in the living, seeing human. A big problem is to determine what hierarchy of operations characterizes visual perception. Models of how the steps follow one another are being developed almost daily. A notion that has recently been articulated is that the grammar of natural (human) languages may be ideally suited as a model of these operations. A recent dissertation suggests that the concept of "picture grammars" is pertinent to an understanding of visual information processing.[17] The ramifications of this association of concepts go far beyond the scope of this chapter. Stated simply, the idea is based on a position that psychologists have noted before: that grammar with its careful structure, well-defined relationships and functions, is a paradigm of nearly every cognitive activity.

Writing in 1956, George A. Miller presented this notion in seminal form: "Language has a hierarchical structure of units — sounds, words, phrases, sentences, and narratives — and it is there that one should seek evidence for a similar hierarchy of cognitive units."[18]Because he had this awareness in advance of many of his colleagues, Miller was able to participate in work that likely was one of the influences that led to the notion of "picture grammars."[19] Now computers with television cameras for eyes are being used in experiments that attempt to penetrate more deeply into the difficult questions of visual perception.

THE DRIVER AND VISUAL INFORMATION

The association of the driver and his vehicle is so basic that many people do not conceive of the man and the machine as two discrete elements. Rather, it is becoming popular to refer to the totality of automobile, plus driver, plus the visual environment in which they function (highway, signs, and traffic) as a

[17] Ein-Dor, Phillip. Elements of theory of visual information-processing. Ph.D. dissertation. Carnegie-Mellon University, 1971.
[18] Miller, G.A. Information and memory. In Perception: Mechanisms and models Readings from Scientific American. (Article reproduced from August, 1956)
[19] Miller, George A. Some psychological studies of grammar. American Psychologist. 17 (1962), 748-765.

man-machine-environment system. The concept of system is widely used but is nevertheless elusive. It has been defined as "a set of objects together with relationships between the objects and between their attributes." Any man-machine-environment system consists of one or more individuals and one or more physical components working together with particular inputs to produce certain outputs given the limitations of some environment. Probably the most important faculty that the driver depends on in dealing with inputs, in making decisions, is vision. We shall discuss the role of vision in this sytem from the point of view of the particular nature of the driving task and its dependence on visual information.[20]

The responsibility of the driver to process visual information is unrelenting. Inputs from the environment must be continually attended, interpreted, and acted upon. The dynamic quality of the driver's tasks derives from the nature of his visual environment: it is continually changing. Essentially, driving is a twofold task consisting of tracking some objects and avoiding others. While the driver's visual milieu is in constant flux it is at the same time spatially limited. The area that is clearly visible to the driver has been described as a fan-shaped envelope[21](see illustrations).

At any moment a driver is in the act of committing himself, as it were, to occupy a subportion of the fan-shaped zone within the next few seconds that are about to transpire. The information that guides the driver in deciding where to place himself comes from visual inputs. Some of the factors that he must consider are the design of the highway, the road surface, the amount and speed of traffic, the speed at which he himself is moving, weather conditions, particularly insofar as they affect visibility and time of day.

THE DRIVING TASK

While driving involves vehicle control and obstacle avoidance, it should rightfully be acknowledged to be much more. Attention, the perennially controversial topic among psychologists, is basic to the skill and judgment that are the *sine qua non* of safe driving. The driver has to sample information from an environment that is evanescent; he has to do a great deal of decision making. If anyone doubts that driving is a complicated task, he need only be reminded how unpredictable it is. Some specific behaviors such as

[20] DeGreen, K.B. (ed.). Systems psychology, New York, McGraw-Hill, p. 6.
[21] Hulbert, Slade F. and Burg, Albert. Human factors in transportation systems. In De Greene, K.B. (ed.), op. cit., pp. 471-509.

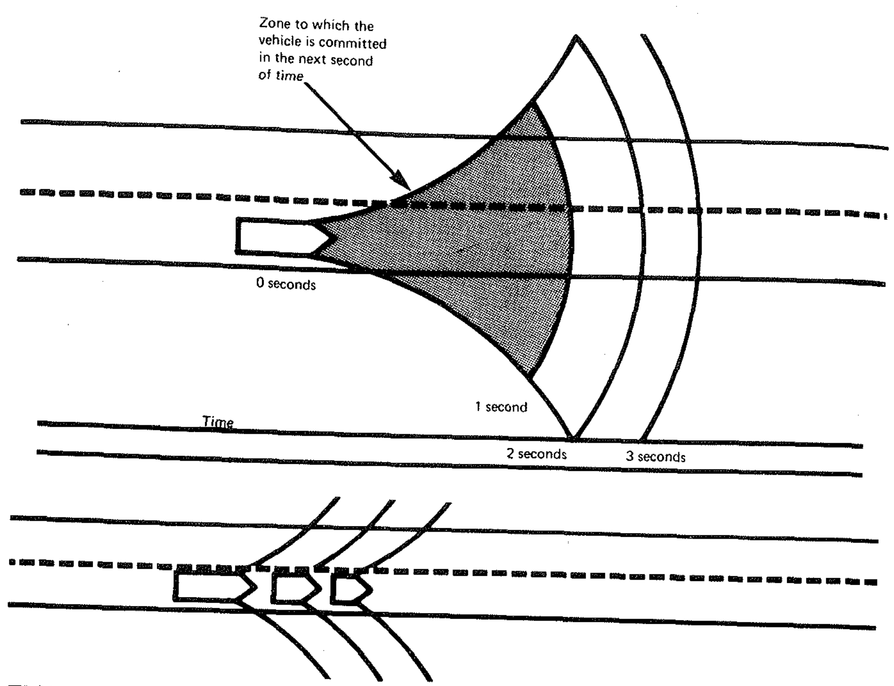

FIGURE 1. The exact configuration of this fan-shaped zone will depend upon the vehicle speed, turning radius, and stopping distance as they interact with the driver's reaction time. As each driver proceeds, the fan-shaped zone extends in front of his path and changes shape as velocity and pavement conditions vary (Hulbert and Burg, 1970).

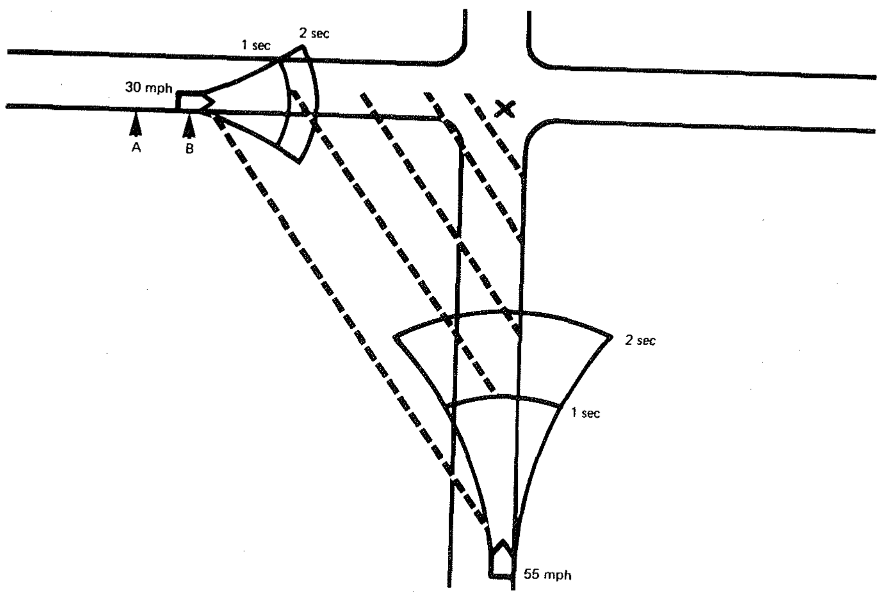

FIGURE 2. "Committed zones" for two vehicles approaching an intersection.

acceleration and deceleration have been studied as functions of car-following dynamics (Rockwell, Ernst, and Hanken, 1968), but usually the sources of driver inputs are impossible to trace.

No one seems to understand the total picture of how the driver does all the attending and instantaneous filtering necessary to the execution of his complex task. Perhaps when scientists are able to understand how the driver goes about his business of acquiring information, they will have some insight into how he uses that information. For the moment, both subjects remain puzzlements.

HUMAN FACTORS

The particular case of the automobile driver demonstrates special problems of information processing. The driver is in a complex relationship with the machine he operates and with the visual environment. The machine enhances his mobility, but the fact of being in motion influences the functioning of the operator's sensory abilities. Because driving involves the interaction of human behavior and the use of physical objects, it has come within the province of *human factors engineering* (also called *engineering psychology* and, in Europe, *ergonomics*). This interdisciplinary effort utilizes at times the inputs of behavioral and physical scientists (psychologists, sociologists, anthropologists, biologists) and engineers of every description (civil, electrical, design, traffic, mechanical). Generally, this polyscience deals with the designs of things people use and the manner in which they are used by applying pertinent knowledge of how people behave. In theory, human factors engineering aims at finding more efficient ways for people to use the physical objects, the man-made resources of their environment and to preserve certain positive human values (such as safety and satisfaction) into the bargain. In the past twenty years or so, there has been a spate of excellent reference works in human factors engineering (McCormick, 1957, 1970; Chapanis et al., 1949; Fitts, 1951; the Tufts College Handbook, 1952; Morgan et al., 1963; Woodson, 1954; Woodson and Conover, 1964; and DeGreene, 1970).

DRIVING AS A TRANSPORTATION SYSTEM

In broad terms, driving is an example of a transportation system: it is a set of objects (some of them human beings) that have relationships to each other and to each other's attributes that function to promote transportation efficiency. Because this is true, we are able to make use of research on other instances of man's behavior as machine operator. The rationale for studies across the entire spectrum of man-vehicle systems has repeatedly been that the design of any transportation system must take into account certain fairly consistent human characteristics. One knows, for example, that people usually have a fairly short attention span, that repetitive tasks tend to produce boredom, or at least a waning of interest. One also recognizes that absolute levels of stimulation are less important than differences in level of stimulation. And in perception of the environment in which any system functions, people are tremendously influenced by their past experience, so that in some instances they can be counted on to anticipate a particular stimulus.

In the context of transportation systems, the man-automobile-highway relation is thought by some to be unique. Hulbert (1968) points out that in virtually no other system is one able to find two fundamental constituents (namely roads and vehicles) being designed by two disparate groups of engineers. In fact, design engineers and traffic engineers have close to no common ground. On the one hand there is a group that functions entirely in the private sector and on the other hand, a group that operates exclusively in the public sector. To complicate matters further, the task of operating the system falls to two other groups, traffic engineers and law enforcers, who do not share in the responsibility for the original design. The fragmented picture of responsibility for the transportation system is obvious when one thinks of the discontinuity in traffic control devices that can be observed during interstate travel. Ideally, with the help of human factors specialists, the system will approach more efficient operation by simply doing a better job of serving its primary function: to move people from an outset to a destination.

SENSORY CAPABILITY AND DRIVING

People operate vehicles efficiently within the limits of their own sensory capabilities. Since this chapter is concerned with the driver's use of visual input, it is appropriate to mention the limits that may exist on his visual capacities. The way in which the driver reacts to his environment depends on the acuity of his visual senses.

If facility and efficiency in operating a vehicle depended simply on the driver's vision as defined by physiological characteristics, matters would be far less complicated than they are. In fact, many variables influence visual efficiency. For a person with normal eyesight, visual efficiency in driving is contingent on: visual acuity; ability to perceive color; contrast present among various stimuli and between stimulus and background; glare interference; level of luminance; state of visual fatigue; time available for perception and recognition; deterioration of acuity with increasing age. Each of these influences will now be considered more carefully.

VISUAL ACUITY

The primary purpose of most eye tests is to evalate a person's visual acuity, which is also referred to as minimum separable acuity. When we say that a person has normal (20/20) vision, we mean that he can discriminate an object that occupies only one minute (1/60 of a degree) of his visual field. Stated another way, this equals about .35 inches from a distance of 100 feet. This criterion describes the smallest letter or other character (figure or symbol) that can be discriminated at a given distance. Of course, this assumes that conditions are optimal: that the person has normal vision, that there is sufficient light to see the stimulus and that enough time is available to form a clear image on the retina's central part, the fovea. The normal range of conditions in the environment of the vehicle operator make it necessary to raise the size of the minimum discriminable letter. It is important to in some way allow for such factors as an individual's vision being below 20/20, a low lumination level, insufficient time for fixation, and poor general visibility.

COLOR VISION

The ability to perceive color implies that at certain luminance levels, sensitivity to spectral colors varies. It was found, for instance, that the colors that provoke response most effectively are those whose wavelengths are near the center of the visible spectrum (Bartley, 1951). Those with wavelengths at either end of the visible spectrum are less able to elicit responses. In practical terms, this means that yellows and greens will be preferred over reds and blues. As the luminance level varies, so does color sensitivity. There is evidence for individual differences in color sensitivity, and for some connection with variations in light intensity or brightness (Mount et al., 1956). When illumination is decreased, color sensitivity deteriorates proportionately until at very low lumination even the brightest of colors appears to be a shade of gray. For this reason, at very dim light levels, color differentiation is determined more by brightness than it is by hue (Hunt, 1952).

In a transportation system, a judicious use of color requires knowledge of the range of lighting conditions under which a color will be viewed. The effect of luminance level on color sensitivity ought to be a primary consideration. If, say, lower luminance will be commonplace, then a color in the yellow-green range will be more easily distinguished than a color nearer the red and blue ends of the spectrum (Forbes and Katz, 1957). Because diminishing luminance also makes brightness important, there may be times when brightness and hue differences will have to be used to complement each other.

Technically, colors are combinations of hue, saturation, and brightness. Therefore, it has been stated that theoretically millions of colors are possible, but in the visible spectrum only 150 wavelengths are discriminable, and from that range only about 12 colors can be consistently identified without error (Chapanis, 1965). This coincides with the number of colors suggested for highway signs by the National Joint Committee for Uniform Traffic Control Devices in 1968. Twelve specific colors were named and each was recommended for use in a particular situation. Because verbal designations of colors are so imprecise (ask any interior decorator!) a technical description of each color was provided by giving its Munsell notation. This uses the three criteria of hue, value (or brightness) and chroma (saturation) from the Munsell collection of 1,000 standard colors. One consideration made in selecting the twelve colors was that they were as distinguishable from one another as possible. This was determined not only by the appearance of the colors but also by comparison of their brightness and hue (wavelength).[22]

CONTRAST

When an object must be discriminated from its visual field, the contrast between the two is as important as the size of the object. Usually, an increase in contrast enhances an object's discriminability. Research has uncovered the exact opposite to result from extreme contrast. When, for example, contrast approaches a ratio of 50 to 1, one experiences an "unpleasant" effect rather than superior legibility (Richards, 1952). When lumination levels decrease, contrast is important because visual acuity deteriorates (Richards, 1952, 1958; Roper, 1962) as does form perception, and judgment of size, motion, and position (Richards, 1952). Hue differences must be thought of as operating hand in hand with contrast. In a transportation system, this means that background illumination must be considered in highway displays.

Driving at twilight is a situation which manifests several problems of contrast and low luminance: the brightness of the sky impedes the successful adjustment of the retina to road level conditions where relatively small amounts of light are available. It was found that letters visible under higher light levels may need to be made five times as large and have their contrast made 6 to 20

[22] This color coding system is described in detail in the Manual on uniform traffic control devices for streets and highways. Washington, D.C.: U.S. Department of Transportation, 1970.

times greater if they are to be visible under low luminance. (Richards, 1958).

GLARE

When an excessive amount of light suffuses the retina glare is perceived. In effect, this reduces the contrast between an object and its background which then diminishes the object's discriminiability (Blackwell, 1957). When glare is anticipated, as for example from either direct or reflected sunlight, it may be necessary to change the position of a sign. If this is not possible, other techniques must be used to increase contrast so that the glare will not make visibility impossible. In some cases the dulling of the finish on a sign may help reduce glare. Increasing contrast can be achieved by manipulating the colors used on a sign and by modifying the size and spacing of letters.

ILLUMINATION LEVEL

Everyone knows that increasing luminance levels tend to aid our visual functioning. Research has confirmed the fact that general visual acuity and color perception in particular benefit from raised luminance levels (Soar, 1955). But when luminance is too far past its optimal level, visual perception may suffer because normally glare will appear and, as noted above, contrast and discriminability will degenerate accordingly (Bartley, 1951). An optimal level of lighting demands some compromise or tradeoff between lighting that approaches daylight levels of brightness, that is at the same time economically sensible, and that is free of glare in outlandish proportions such as "islands of light." One transportation system that falls prey to such hazards is the air travel system. Not uncommonly, pilots tell of deadly runway approaches caused by peripheral lights in such extreme contrast with runways that the surface of the runway becomes nearly invisible.

VISUAL FATIGUE

Most of the time, the feeling of visual fatigue or "eyestrain" is a result of luminance levels in the environment. The problem is generally caused by having to make repeated adjustments to unsteady light, glare or flickering light (Richards, 1952; Blackwell, 1957). If eyestrain is to be curbed, every source of light to which the driver is subjected must be considered. This means not only the lights on the highway but even the lighting within the vehicle, the light given off by the dials on the dash of the automobile.

One knows, however, that varied stimuli are necessary to our staying alert. One of the criticisms of indoor windowless spaces is that they provide no change of illumination and no occasions for a change of visual focus (Heron, 1957; Davis et al., 1960). Commonly such spaces depend on fluorescent lighting which tends to distort color since it has a discontinuous spectrum. Some investigators believe that such lighting can contribute to other stress (Ott, 1966). Perhaps the variation in luminance experienced while driving is preferable to the sameness of the interiors of so many modern office buildings.

RESPONSE TIME

Knowing how much time it takes to read a printed display at a glance presupposes knowledge of the nature and number of the operations involved in reading. Thanks to the most up-to-date investigations, reading is acknowledged to be complex beyond belief. Psychologists and linguists recently compared their findings in a conference sponsored by the National Institute of Health and found an increasing number of internal processes being discovered as twenty years to find statements on rates of recognition time. They cite Forbes' (1953) statement that a glance to read a target outside a five degree arc requires from .6 to 1.0 seconds (DeGreene, p. 475). Sometimes one finds reference to the "four short familiar words per second" limit confirmed by Hurd in 1946 (Forbes, p. 103).
necessary to reading (Kavanagh and Mattingly, 1972). But these discoveries are not necessarily salutary. As one observer noted, present knowledge about reading is in a "crisis in theorizing" (Miller, 1972). Therefore, current human factors texts have to go back in time some

Because specialists now appreciate, even if they do not fully understand, the existence of many different kinds of reading (Gibson, 1972), there are now fewer investigators than heretofore who are willing to risk making an estimate of how long it takes to read any given material. Even in 1936 Essen understood that many studies of reaction time to visual stimuli produced underestimates of the true rate because lights were too near the observers. He found that as lights are placed farther from the observer they can be discerned more rapidly. Also, the vehicle operator, because he is in motion, directs his attention to an ever more distant portion of his course as vehicle speed accelerates.

We know, therefore, that distance and speed of travel influence reaction time. We also know that a message, particularly if it is a warning, should be concise, straightforward and clear. Extreme examples of unduly complicated signs are reproduced below. The problem of ascertaining the precise reaction time necessary in responding to a highway sign is even more difficult in view of the trend to use pictorial signs, similar to those used widely in places

like Europe where a multilingual sign would be the alternative. If the rate at which people read and comprehend words cannot be satisfactorily evaluated, where does one begin to measure how long it takes to read a picture?

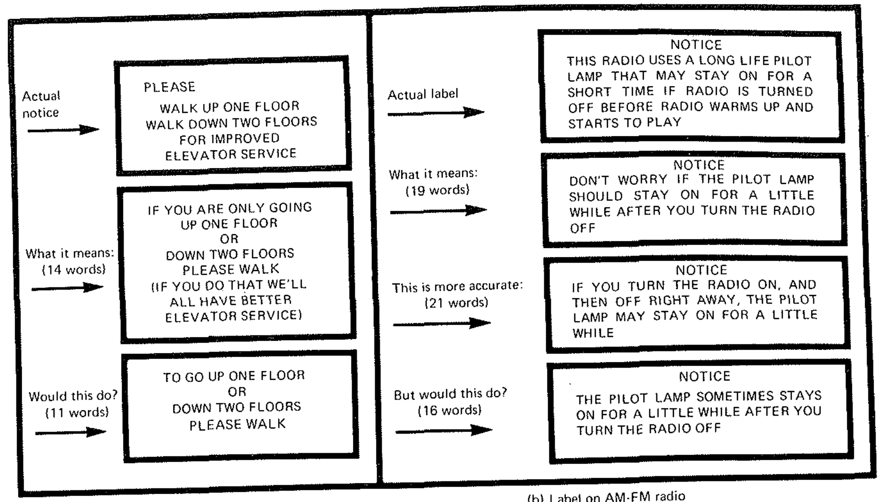

FIGURE 3. Examples of an elevator sign and of a label on a radio, and of suggested revisions. (Adapted from Chapanis, 14.)

EFFECTS OF AGE

In vehicle operation, the most important visual abilities are acuity, extent of visual field, sensitivity to glare, and visual adaption to low luminance (Burg, 1967a). There is good evidence that all of these capacities diminish as age increases (U.S. Department of Health, Education and Welfare, 1964; Allen and Lyle, 1963; Burg, 1966, 1967b, 1968). Various approaches have been recommended to the problems inherent in this steady loss of visual acuity. Richards (1958) thought that older drivers would be well served by having signs and traffic signals made larger and brighter. Rather than try to accommodate the elderly driver by changing the environment, Peckham and Hart (1959) suggested that these drivers be encouraged not to drive at night. Some states require annual eye tests before they will review driver's licenses of older individuals. But since poor eyesight is not exclusively a function of advancing age, it may be more practical to have all highways and signs designed to meet the needs of individuals with slightly less than 20/20 vision.

Even people who have physiologically good vision sometimes find themselves in situations that can detract from their normal abilities. Being tired, under stress, or in a state of emotional unrest may contribute to poor attention to driving. The use of alcohol or other drugs can also create an abnormal condition in the driver. And there will always be adverse weather conditions such as dense fog or heavy precipitation that cause problems for all drivers. For all these reasons, design of the system must allow for other than optimal conditions.

While one may choose to remain unconvinced by the generally negative findings of the study, several thought-provoking questions were raised. Environmental factors were tested as variables in affecting subjects' recording capacity. Road conditions, for instance, were assessed on a three-point scale. Clean dry asphalt was designated as grade 1, while grade 3 was an extremely slippery surface. The difference in recording capacity under these three conditions was nonsignificant, but worsening conditions were accompanied by a very slight increase in capacity. Visibility was likewise described on a three-point scale on which grade 1 was clear weather and grade 3 either fog or heavy snowfall. These conditions did not contribute to a significant change in recording capacity either. As one expects, poor visibility meant that signs could not be seen any better than the rest of the surroundings, so they were reported less efficiently under poor visibility conditions. Traffic density showed a tendency, albeit slight, to enhance the ability to recall signs.

Of course the driver's visual acuity is no guarantee that he will be receptive to all the information available on important signs. One must also consider the sign itself.

A Swedish study of road signs (Johansson and Backlund, 1970) concluded that to a great extent road signs do not achieve their communicative purpose. Tests indicated that the overall probability of a road sign's being noticed by a passing driver is no more than approximately 0.5. The results confirmed the findings of an earlier Swedish test (Johansson and Rumar, 1966).

INFORMATION ACQUISITION BY THE DRIVER

Much more is known about the effects of modifying the visual environment than about educating drivers to modify their style of looking at their environment. We know that there are good drivers and bad ones. Some drivers seem able to see more or perhaps see more effectively than others. But because safe drivers are failures (as are the psychological experts) in articulating exactly what accounts for their success, they cannot initiate anyone into the mysteries of an accident-free driving record.

But new methods of eye movement observations are being made available. The advantages of such studies are appreciable when a comparison is made to the alternatives: studies of response time, vehicle control, and car-following. In each of these instances the subject is fully aware of what constitutes a good performance. But special eye cameras allow scientists to observe behaviors so subtle and automatic that the subjects cannot be suspected of unwittingly modifying their actions because of the tests. The apparatus used may be a camera or a highly sophisticated system that will inevitably be made obsolete by an even more intricate one.[23] The eye marker camera, for instance, has been heralded as a breakthrough because it allows the subject to be practically instruction free and hardware is minimal.

A great deal of useful information has come from investigations of the eye movements of novice drivers. Experience in driving has been found to contribute to discernible changes in patterns of eye movements (Zell, 1969; Mourant and Rockwell. 1970). For the most part, the changes are characterized as affecting the areas looked at rather than the time spent looking. When individuals are learning to drive, they tend to make large and sometimes darting eye movements in their search for important information. Sometimes these are grand and sweeping movements, only to end in a fixation on some feature of the environment (such as a tree) that is extraneous to the informational needs of the driver. These individuals also tend to alternate between close-ups (fixations very close to the vehicle) with far away glances, zoom lens style. The distant fixations are suspected of being attempts to finding out about the relative distance of objects, and the close-ups are thought to be an attempt to evaluate lane position (See illustration).

[23] For a complete and detailed description of some of these machines see T. Rockwell, Skills, Judgment and Information Acquisition in Driving, in T.W. Forbes (ed.) Human factors in highway safety research, New York: John Wiley & Sons, 1972.

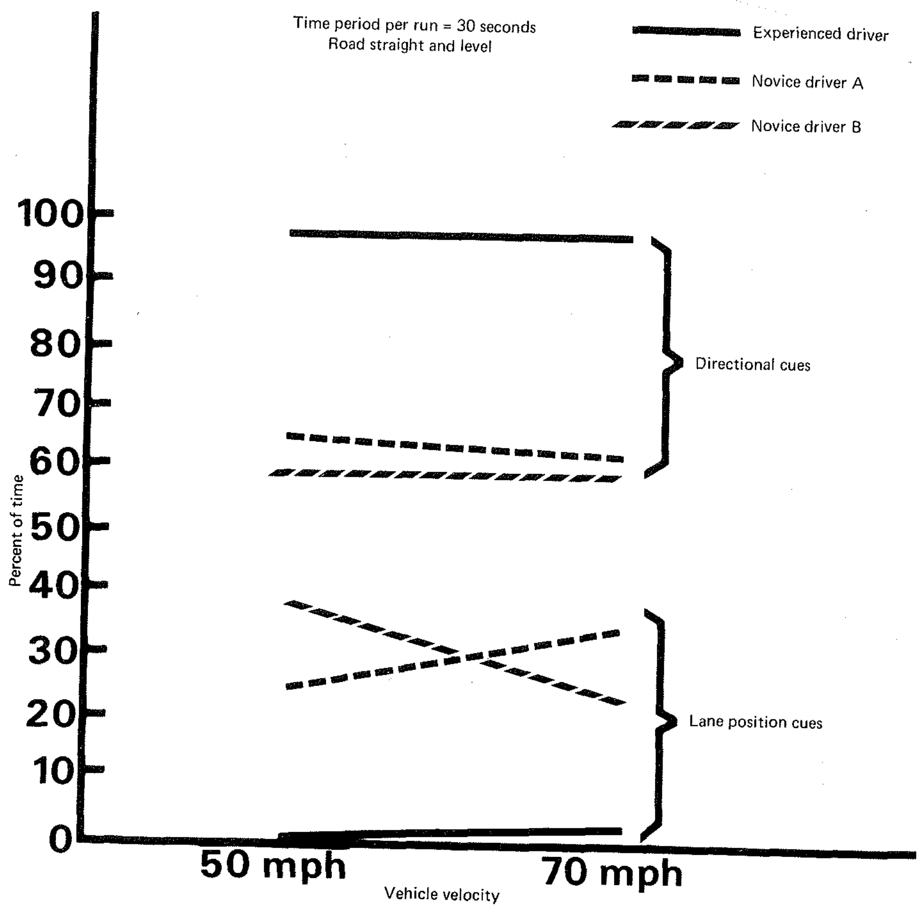

FIGURE 4. Percent of time sampling for directional and lane position cues as a function of vehicle velocity.

Generally, inexperienced drivers do not compensate for changes in velocity in their patterns of eye movements. They seem unable to use their abilities of peripheral vision and tend instead to look only close to the car for visual cues. With experience, drivers try to stay more ahead of themselves and usually keep between 2.5 to 3.5 seconds' time to preview what lies ahead when they change their speed of travel.

The same tendency to confine searching to an area relatively near the car is also characteristic of drivers suffering from fatigue (Kaluger and Smith, 1970). Drivers who had not slept in the previous 24 hours seemed to lose some of their powers of peripheral detection and presumably for this reason made many fixations close to their vehicle and to the right of the highway. Even when the testing equipment was in use, drivers in the fatigued state regularly dozed or closed their eyes for a few

seconds during the testing period. This is possibly an indication of the unobtrusiveness of the eye movement camera being used.

SUMMARY

In this chapter we have tried to point out basic driver-vehicle-environment interrelatedness. In particular we have been concerned with signs as a form of information visible in the environment. We have seen that a myriad of factors influence how well a sign may be observed by a passing motorist. Physical characteristics of the signs, the dynamic traffic flow of the larger environment, and the psychological disposition of the driver may all affect each other with the result that the information on the sign will be clear or obscure. We have shown driving to be a complex task that depends on visual information for the basis of continual decisions that are made. We have offered an overview of research and have described the direction of current systematic investigations of the driver as information processor.

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CHAPTER 3
HIGHWAY SAFETY

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CHAPTER 3
HIGHWAY SAFETY

In the visual environment of the highway, signs are the basic mode of communication. Information about routes, direction of travel, location of exits, and of necessary services is unavailable in any other form that approaches the accessibility of a sign. Maps are an alternate source of some of this information but in high-speed travel situations, the motorist who pulls off to the side of the road to consult his map may be placing himself and other drivers in grave danger. Signs also provide information about the availability of goods and services in nearby towns. Because major traffic arteries sometimes bypass what was once the commercial district (sometimes extending for only a few blocks on one main street) of a small town, the downtown merchants depend on signs to remind local drivers and possibly out-of-towners of the shopping opportunities that are available.

In this chapter we will look at the findings of research with respect to the necessary features of an effective sign. When highway signs are difficult to read because of their positioning or are ambiguous in conveying a message, accidents result. In hopes of improving the efficiency of signs, local and national governments have studied faulty signs. We will consider the recommendations that have been made as a result of these investigations. Finally we will examine technological innovations that promise to simplify situations that are beyond the scope of traditional signs.

From remarks made in the preceding chapter you will recall that highway safety insofar as it is affected by vehicle design, road design and other variable environmental features (e.g., level of illumination) is a concern of human factors engineering. This megaloscience combines the knowledge of human behavior with knowledge of the characteristics of objects that people use to arrive at more efficient ways of designing the man-made part of the environment. Ironically, human factors engineers research various problems of highway safety, but as recently as 1968 one finds an expert in the field professing under oath his ignorance of any highway department in the country whose regular staff includes an individual with any expertise in human factors engineering.[1]

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[1] U. S. Congress, Highway safety, design and operations: Freeway signing and related geometrics, Hearings Before the Special Subcommittee on Federal Aid Program of the Committee of Public Works, House of Representatives, Ninetieth Congress, Second Session, U. S. Government Printing Office, May and July 1968, p. 246. Testimony of Dr. Slade F. Hulbert.

THE BLATNIK COMMITTEE

The possibility that misleading highway signs contribute to serious traffic accidents became so suspect that a special subcommittee of the U.S. Congress Public Works Committee made an investigation into the matter. Under Representative John A. Blatnik of Minnesota, hearings were conducted from May 7 to July 18, 1968. The testimony of some twenty-five witnesses was recorded. From that testimony several explicit recommendations emerged concerning the requirements of effective freeway signs. The particular concern of the committee was to somehow rectify situations in which signs on busy parkway, expressway, thruway, and freeway systems did not give motorists adequate information in time to make critical decisions. In reading the record of these hearings, one finds illustrations of gores — places where a curbstone marks the divergence of an exit lane from the mainstream of traffic — that have been worn away by the countless motorists who had to correct their direction of travel when they were no longer able to make a safe maneuver to change lanes.

In its fact-finding operations, the committee consulted two experts in particular who had backgrounds in human factors engineering. These were Slade Hulbert and Albert Burg. Both testified to the inadequacies of the signage systems now common in this country. A written source of evidence that was found most useful was a 1960 study in which an interview technique was used to collect information from approximately 12,000 motorists.[2] In particular, subjects were questioned about their ability to find their way using the California freeway system. On the basis of these interviews, researchers concluded that in any ten trips made into regions unfamiliar to the motorist, one trip would involve getting lost and this was invariably attributed to not being able to follow sign directions. Basically, the suggestions made by the researchers can be expressed as several principles in sign planning.

CLARITY OF MEANING

When phrasing of sign messages is being considered, it is imperative to weigh all nuances in the language used. In the Blatnik hearings one finds reference to a disastrous incident in Texas.[3]

[2] Schoppert, D. W., Moskowitz, Burg A., and Hulbert, S. Some principles of freeway directional signing based on motorists' experiences. Highway Research Board Bulletin, 224, (1960), 30-87.
[3] Ibid., p. 3. The incident was previously reported in the Wall Street Journal on April 29, 1968.

An out-of-towner approached an intersection where he found a sign that said, "Advance Green When Flashing." His immediate reaction was to come to a screeching halt because of the utter confusion he experienced at reading the message. A resident of the town explained that what the sign was trying to say was that a left turn was allowed when the green light was blinking. Plans were made to replace the signs with a lighted green arrow when it was noticed that it even bewildered many locals.

Usually freeway signs are deficient in less obvious ways than the "Advance Green When Flashing" sign. When two alternative routes are offered, for instance, it is important to clarify the difference. It is desirable, according to the Schoppert group's data, to display alternate choices in uniform notation. That is, if a route number is used to designate one possibility, a number should be used for the alternate route. And it is always imperative to avoid an excess of information. Short term memory (STM) is very limited in capacity in terms of quantities of information.

This is just one reason why it is ill-advised to have apparently excessive information on signs. Lack of clarity can make related information seem disparate. Since the problem of getting lost suggests that motorists made erroneous decisions, it is basic that signs implement the decision making process by providing clear, concise and appropriate information.

Anticipating the ways in which a message can be confusing involves more than care in careful expression. Sometimes errors are reported because of the literal way in which motorists interpret signs. A strip of California highway became an eyesore and a health hazard because of this tendency to literalness. A sign that was meant to inform people about the location of a trash receptacle read "Deposit Refuse 500 Feet." Many people construed the sign to be announcing an anything goes (right out the window) policy on that 500 foot strip; they proceeded to throw all manner of litter to the side of the highway for the next few hundred feet after the sign. According to the Schoppert researchers, there are cases on record wherein drivers have made turns into alleys and driveways because of their excessively literal interpretations of signs on freeway on-ramps. This snag has to be allowed for before the sign is produced and its location decided upon.

CONTINUITY

Continuity in signs can be of positive value to motorists using freeways. The individual following signs for a particular exit may be misled if there is inconsistency in the signs directing him to it. Suppose, for example, that a person has been watching for several miles for an exit marked "Rowley" and at the crucial place where he must make a decision to turn off the main road, the sign pointing to his intended exit ramp is marked "Rowley--Ipswich". If this is the first time that these two names have appeared together, and if the motorist is unfamiliar with the area, he will likely experience some confusion. If this confusion leads to hesitation and if it is in a situation of dense, high speed traffic, the results could prove disastrous. The principle that Schoppert and the other researchers drew from this was that at a decision point no driver should be given previously unknown information about the through route or the exit.

PRIOR WARNING

One of the functions of proper signage is to offset the handicap of drivers who find themselves in unfamiliar territory. Certain errors of judgment are direct results of seeing the desired turnoff point a few seconds too late. When the Schoppert study investigated California freeway traffic, this was found to be a common problem. A driver would protest that he had seen no advance indication of the turnoff that he needed. Invariably signs announcing the upcoming exit did exist. Perhaps this difficulty is indicative of a defect in the location of the signs either with respect to the density of traffic or in the context of competing signs. If signs give warning and if the unwary motorist fails to notice the warning, he will be in trouble when his turnoff appears as a sudden surprise. But dealing with this problem is not simply a matter of placing a very large sign in a particularly conspicuous place. One of the complicating factors, though it has not been identified as such, is probably the rapid deterioration of short term memory. It is quite conceivable that a motorist could see a sign giving advance notice of his destination, and that he would forget the sign and its message by the time the turnoff appeared. Possibly, as Schoppert and his colleagues suggest, the advance notice sign would be most helpful if it informed the motorist of the relation of his present location to the desired destination. In this way he could prepare to make the necessary decisions and thereby be at less of a disadvantage compared to the motorist in familiar surroundings.

The Blatnik Committee heard other testimony that finding one's way from one place to another very often becomes complicated. John de Lorenzi, a managing director of a major travel service organization, the American Automobile Association (AAA), offered significant testimony in the matter of motorists' problems.[4] At the time of the hearings it was reported that members of AAA were

[4] Hearings, pp. 5-28.

taking an estimated 13 million vacation trips annually. Very often these trips entailed venturing into unfamiliar parts. For this reason AAA offers many services such as routings, tour information, maps and guide books to millions of people. The maps they dispense are the most up-to-date available anywhere; besides these, members also receive reports on road conditions as part of the trip planning procedures. Nevertheless, approximately 70 per cent of AAA members later report problems in finding the places they set out for. De Lorenzi very appropriately remarked that the experience of travelers who do not have access to such planning services is undoubtedly even more disheartening. This testimony is not cited as proof of the efficiency or inefficiency of signs; it represents no systematic investigation nor any analysis of data. It does, however, intimate the need that motorists have for clear communication while they are traveling.

RELATABILITY

For convenience and clarity signs should offer information in a form that is consistent with other sources of information that a motorist is reasonably expected to be using. For example, once beyond the high traffic density of a metropolitan area, it is possible for signs to resemble the format in which information is offered on state road maps. The Schoppert study suggested that if the engineers who design signs use maps of a corresponding scale to that of touring maps, they would insure some similarity.

A special problem of freeways is the need of informing the motorist about the kind of interchange that lies ahead. This is another situation in which the driver who is unfamiliar with the area is at a disadvantage. At the time of the Blatnik Committee's hearings Mr. De Lorenzi stated that AA's Cartographic Department was at work trying to develop a satisfactory way of representing various types of cloverleaf interchanges on maps. On small scale maps they were already representing the geometric shape of various interchanges, but some innovations were needed for larger scale maps. Once such a system of representation is settled upon and is widely used, a need will probably be felt for the use of a related representation on road signs.

In 1970 Eberhard and Berger were already at work on the problem of pictorial cues about interchanges for use on freeway signs.[5] They studied many different types of off-ramp patterns. Their goal was the invention of a system of graphic symbols that

[5] Eberhard, J. W. and Berger, W. G., Empirically Derived Criteria for Graphic Highway Guide Signs. (Washington, D. C.: Serendipity, 1970)

would give the motorist an accurate preview of the type of interchange that he was about to enter. This forewarning would presumably reduce the surprise of the motorist having to make critical decisions in an unfamiliar setting.

PROMINENCE

In positioning signs and inducing redundancy by having the same message reappear at set intervals, one must keep in mind the total picture of the visual surroundings involved. Competition in some areas is so intense that an otherwise conspicuous sign might go unnoticed. The factor that Schoppert and his colleagues call prominence is, as you recall, what Forbes (1939) labelled "attention value."[6] This is distinct from legibility which Forbes considered equivalent to discriminability. It is a special type of visibility that Forbes breaks down into "target value" and "priority value." Target value refers to the characteristics that make a sign very distinct against its background. Priority value is more complex and depends on where a sign is mounted with respect to the highway, the number and types of signs around it, the order in which signs will likely be read and certain psychological variables such as the search procedure and reading style of the motorist. Indeed all these variables that Forbes has so conveniently classified do contribute to the prominence of a sign and must realistically be considered.

Uniformity in design is one device that aims at making highway signs conspicuous. In many situations motorists are able to anticipate signs detected with peripheral glances long before the sign's message is truly legible. But in metropolitan areas where increased activity and much more densely built-up panoramas contribute substantially to added confusion, there is likely to be heavy traffic and a special strategy must be used in positioning signs to insure that they will be effective.

UNUSUAL MANEUVERS

A highway landscape may be full of irregularities. Towns and cities have developed in patterns that are not always salutary to highway design. When a motorist is required to negotiate an unusual type of turn because of an unexpected or unnatural feature, he needs sufficient warning to prepare for the maneuver. Signs are the obvious candidate for this communications function. Using a far-side turnoff can be nearly impossible for the motorist who has not done the necessary preparatory jockeying for position.

[6] Forbes, T. W. A method for the analysis of the effectiveness of highway signs. Journal of Applied Psychology XXIII (1939), 669-684.

For safety reasons even more than for convenience, signs have to be strategically placed so that maneuvers are possible.

The principles suggested by the study of Schoppert et al. clearly reflect careful work by experts in human factors engineering. But as we said above, the practical problem is that few highway departments (as of 1968, reportedly none) employ human factors engineers. Even the design specialists who propose how signs should look occasionally find themselves frustrated because of communications problems. According to Dr. Slade F. Hulbert, effective execution of a plan has often been impeded when a community orders signs, having in mind a particular standard model.[7] The sign producers, however, with an older standard in mind operate in accordance with their outmoded idea. Because of such problems, expertise and technological advances could conceivably be wasted if they are not to be evidenced in the final product.

COMMERCIAL SIGNS – A SEPARATE CASE?

We can tell when highway signs are not effective: motorists make costly mistakes. Large signs on freeway on-ramps reading "WRONG WAY" are known to be effective since they have been found to reduce accidents in some instances by as much as two-thirds.[8] (Tamburri, 1969). When advertising signs are ineffective, lives are not lost and consequently in-depth studies or congressional hearings do not pursue the factors that contributed to the failure of the sign. Theoretically, there is no reason why the techniques used to study the effectiveness of traffic signs could not be applied to advertising signs as well. Eye movement cameras might be used in laboratory tests, or group testing techniques could be used to preview innovative commercial signs. Perhaps the application of human factors engineering will eventually reach that part of the sign industry that operates within the private sector.

SIGNS IN COMPETITION

In discussing the requirements of effective freeway signs we mentioned the importance of considering the totality of the visual context, particularly with respect to competing signs. The term "competing" suggests that some people recognize the possibility that an advertising sign might sometimes win out, as it were, over a road sign. If this were the case, sign companies would be in serious legal trouble. If there were reason to believe that advertising signs

[7] Hearings, p. 246.

[8] Tamburri, T. N. Wrong-way driving accidents are reduced. Highway Research Record, 299, (1969), 24-50.

contribute in any way to negligent driving or, what is much worse, to traffic accidents, legal restraints would be placed on this sector of the sign industry. Quite the contrary is true. Advertising signs have never been conclusively proven to contribute to highway accidents. The only time a claim was made that they were a factor in accident causation, an embarrassing and devastating rebuttal silenced it. The incident provides a lesson in the errors that arise from incomplete information.

THE MADIGAN-HYLAND REPORT

The document that was to become known as the Madigan-Hyland Report was in fact a letter from a member of the Madigan-Hyland consulting firm to the then chairman of the New York State Thruway Authority. According to this letter, the Thruway Authority had requested the firm to analyze certain data and to determine whether any relationship existed between the occurrence of accidents and the existence of advertising signs along the expressway. Accordingly, the firm was given access to the state's accident statistics and records for the two years preceding the study (1961-1962).

Information provided to the consultants included particulars about the type of each accident, the place where it occurred, and its probable cause. By previous inspection of the Thruway, Authority personnel had recorded exact locations where advertising signs and the like were visible to motorists. With these two sets of facts available (sign location and accident records) the consultants were able to correlate accident rates of various stretches of road. Thus, it was possible to compare the records of places where advertising signs could be seen with places where no advertising signs were visible.

In commenting in his letter on the method selected to analyze data, the company representative makes a statement that at the very least is unscientific: "In preparing the analysis set forth below, however, it was recognized that advertising devices are a factor in accidents principally because they distract the motorists' attention." (He then goes on to describe methodology, to which we shall return presently.) This introductory remark effectively negates the value of the study since it indicates that the conclusion of the research was assumed to be true from the beginning. Perhaps "it was recognized . . . " was merely a poor choice of words. Possibly there was some reason based in research to explain exactly how this recognition came about. Nevertheless, when one reads of the technique used, one is compelled to question the validity of the findings.

It seemed important, the letter continues, to eliminate accidents

attributed to certain causes when advertising signs clearly could not have been involved. The only category of accident considered relevant to the study was the class attributed to "driver inattention." The assignment of probable cause routinely takes place at the scene of the accident when the investigating member of the New York State Police classifies it.

In an attempt to derive accurate results, the consultants also eliminated from the study those driver inattention accidents that could be readily explained by some factor other than the distraction of an advertising sign. Thruway toll barriers and interchanges were noted as the locations of about 25 per cent of the driver inattention accidents. Since these areas offer better advertising exposure than other locations, they characteristically displayed a disproportionate number of advertising signs. But because other factors were likely to be responsible for inattention (such as searching for the money to pay the toll), accidents in these areas were excluded from the study even though advertising signs were visible and accidents were attributed to driver inattention.

These special allowances were made to avoid distorting figures to unrealistic proportions. With the exclusion of toll areas, it was found that on approximately 13 per cent of the Thruway's 1,118 miles of one-way roadway, motorists were exposed to some type of advertising device. According to the 1961-1962 data, there were 1,550 accidents whose probable cause was driver inattention. Of these accidents, it was found that 32.6 per cent took place in the roughly one eighth of the Thruway where advertising signs could be seen. Using another set of figures, it was noted that 0.5 driver inattention accidents per mile took place where no advertising devices were visible. In places where advertising devices were visible, however, accidents of the same type averaged 1.7 per mile. In other words, as is stated in the letter, accidents per mile were three times as numerous in the presence of advertising signs.

Traffic density was also considered. Where there was greatest density and the greatest concentration of advertising signs, there also was a higher number of accidents per mile.

The conclusion of the letter states that the analysis "clearly demonstrated a pattern of substantially more 'driver inattention' accidents in all areas where motorists were exposed to advertising devices than in the areas where no such devices existed."

Even without training in statistical techniques or in the finer points of mathematical logic one sees the shortcomings of the report. The procedure followed is akin to the following: Suppose that at a boxing match one observes more bald men sitting in the fourth row than in any other row. After a careful tally one is able to confirm that indeed there are quite a few more bald men in the fourth row than anywhere else. According to the Madigan-Hyland procedure this would suggest that sitting in the fourth row at boxing matches somehow contributes to baldness. The conclusion is absurd only because the technique was inadequate for the investigation. Soon after the Madigan-Hyland results were publicized, expert and eloquent critics took issue.

THE BLANCHE ANALYSIS

Dr. Ernest E. Blanche, a professional statistician, prepared a formal analysis of the Madigan-Hyland document. After looking at their report, he began collecting data for his own use in evaluation and analysis. Working under pressure because of limited time, Blanche acquired a list of driver inattention accidents on the New York Thruway in 1961, one of the two years covered by the Madigan-Hyland study. From this list he was able to locate within one tenth of a mile the place where each accident had occurred. He also acquired a list of all the advertising signs that were visible from the Thruway. Then he personally made an extensive inventory of road design features, roadside features and related characteristics for both sides of the Thruway for a distance of about 45 miles from where the Thruway begins at Yonkers to Harriman, New York.

After a careful examination of the Madigan-Hyland report and analysis of his own data, Blanche maintained that the conclusions of the report were in error. As a statistician he declared their findings to be unsound. First of all, the report had limited itself to the study of only one variable. This seemed indefensible to Blanche who knew that data on other variables were available to them at the time of the study. In light of his own research Blanche claimed that no relationship existed between accidents and advertising signs.

Blanche makes specific reference to the claim in the report that three times as many accidents per road mile take place on Thruway portions where advertising signs are visible than on portions where they are not visible. This statement, he points out, ignores such factors as the number of vehicles passing particular locations, the number of vehicle-miles covered, characteristics of the roadway including on-ramps and off-ramps, bridges, overpasses, service areas and several other features which other studies have proven to be major contributing factors to accidents.

With the omissions of the first report in mind, Blanche gathered facts that he thought would be helpful; he did a survey as a passenger in a passenger car. He covered the 45 miles from Yonkers to Harriman going north and the same segment in a return trip in the southbound direction. He used graph paper and represented increments of 1/10 of a mile as indicated by official roadside markers on the Thruway. He then plotted all road characteristics and roadside features for the duration of 45 miles. He used a Thruway Authority map as a guide. From a published report entitled "Accident Facts 1961" issued by the New York State Department of Motor Vehicles he had a list of 1961 accidents that occurred on the Thruway. He plotted the location of driver inattention accidents on the same chart that indicated the roadside features. Because of his training and professional experience as a statistician Blanche immediately perceived the close relationship between the recorded locations of accidents and the road characteristics and roadside features in his inventory. From this graph, Blanche learned that in the 45-mile section he surveyed, 72 per cent of accidents (in both directions) were within two-tenths of a mile of a ramp (on or off), an overpass, a bridge, a service area or toll plaza.

To evaluate the advertising sign variable Blanche obtained an inventory of Thruway signs from a representative of the Outdoor Advertising Association of America (O.A.A.A.). In his personal survey, he noted the exact location of each sign. He also made a distinction in recording their locations between on-premise (signs on the premises of the business owning or leasing the property where the sign stood) and off-premise signs. In plotting sign locations it was immediately clear that in both directions of travel there were a great many signs over the first three miles. But after that initial expanse, distribution was sporadic. For example, going north from the 2½ mile to the 16-mile point there were no signs. And going from the 18-mile point to the 31-mile point again there were none. Going south, he noted a sign at the 4.1 mile mark and not another before the 20.7 mark.

After this survey, Blanche did a correlation analysis of the precise data to discover the degree of mathematical relatedness (but not necessarily cause and effect relationship) between accidents and advertising signs. As Blanche candidly admits in his analysis, one should consider many other features as variables in performing such an analysis, but the necessary data were not available to him, given the limitations of time. From mathematical analysis he found the correlation between accidents and advertising signs to be negligible (0.15).

Because of the polarity of these two opinions, one tends to look to a third party to comment on the opposing positions. J. Carl McMonagle, experienced as Director of the Planning and Traffic Division of the Michigan State Highway Department, was able to put the Madigan-Hyland report and the analysis by Dr.

Blanche into perspective.[10] McMonagle pointed out that one of the sources used in the original study, the classification of accidents according to their probable cause, was questionable. It is, after all, only the opinion of the investigating member of the New York State Police. Further, driver inattention as recognized by traffic safety experts could, as McMonagle proposes, be caused in a variety of ways, not necessarily by an advertising sign. Though McMonagle did not go on to enumerate alternatives, one thinks of "highway hypnosis" or of a driver simply falling asleep at the wheel. (Indeed the Madigan-Hyland report expressed no consideration as to whether accidents had occurred during daylight or nighttime conditions.)

In looking at Dr. Blanche's analysis, McMonagle found a different situation. Many roadside features and other variables had been considered; McMonagle was able to express his concurrence with Blanche's findings. He speculated that if the Madigan-Hyland team had made a full investigation of roadside features and then done correlation analysis of these features that their conclusions would have been "quite different." Nevertheless, McMonagle explicitly disavows any attempt to discredit or find fault with the honesty or ability of the Madigan-Hyland firm. He sees the problem as stemming from the assignment as it was given by the New York State Thruway Authority. He is of the opinion that had the assignment been a comprehensive one, the Madigan-Hyland report would have confirmed what earlier studies had concluded: that outdoor advertising signs show practically no relation to accidents on any highway.

EARLIER RESEARCH

One knows of the importance of human factors engineering to efficient sign design and one knows of how rarely this engineering expertise is used by highway departments. The private or commercial sector of the sign industry has traditionally expressed interest in questions of human factors. Two investigations reported together in 1955 are evidence of this early interest.[11] In one of these studies data on advertising signs and traffic accidents emerged as peripheral to the primary subject of investigation: sign efficiency as determined by angle in the driver's field of vision.

This study was done in 1950 when the O.A.A.A. asked the Driving Research Laboratory of Iowa State College to cooperate. The laboratory had long been known for its interest in problems of

[10] McMonagle, Carl. Correspondence

[11] Lauer, A. R. and McMonagle, J. Carl, Do road signs affect accidents? Traffic Quarterly, 9, (1955) 322-329.

driving safety and the sign association considered its own concern to be germane to safety. Not only did they want information about sign efficiency; they proposed that the laboratory might incidentally try to find a relationship between positioning of signs and possible driver "distraction." The laboratory offered an ideal setting for such a probe since a simulated environment is able to be manipulated with no danger of a serious traffic accident. Moreover, it was known from prior research that laboratory results were reliable reflections of human reactions in real situations.

In this particular study it was noted that very rarely does a driver fix his eyes on the portion of road directly ahead of him. Rather, his looking around and sampling of different parts of the visual environment seemed to function to keep the driver alert, help him enjoy the driving task and carry out the eye movement patterns practiced since childhood. This behavior suggested to the researchers that perhaps an optimal degree of stimulation exists that could conceivably influence driver efficiency in a positive way. Accordingly, researchers set up an experiment to test this hypothesis.

A limited budget did not allow the purchase of all new customized equipment for use in the study. Rather, modifications were made on apparatus that had been used in earlier work.[12] The objective of the study was to find whether a significant difference exists between efficient observations of a landscape under two conditions: having a great many signs present or having no signs. In every other way the two landscapes were identical. In the variation in which signs were used their position was kept between 0 and 45 degrees to either side of the road. Fifty subjects participated in a pilot test prior to the main experiment. Reaction time to stimuli was used as a criterion of potential "differential efficiency effects." The results of this testing preview violated those intuitively expected: there was no difference between the two conditions.

In the main part of the testing that followed, a total of 120 subjects participated in groups of 30. Three different landscape conditions were used (see illustration). One displayed no signs at all; another showed signs placed between 15 and 30 degrees to the side; the third had signs in a 15 to 45 degree area to the sides. No evidence whatsoever could be found to suggest that signs impede a

[12] Apparatus is described in: Lauer, A. R., and Johnson, LaVerne, Effects of manual and inherent handicaps on motor performance of a complex nature. Journal of Applied Psychology, 21 (1937), 85-93; and Lauer, A. R. and Allgaier, Earl, A preliminary analysis of the psychophysical correlates of automotive manipulation. American Journal of Optometry, 18, (1941) 49-52.

driver's efficiency. Rather, there was some indication that their presence was beneficial to a limited extent. The difference between the various landscapes favored the condition with signs by about 10 per cent.

It was also noted that in the presence of signs, a driver would likely recall at least as many (sometimes more) features of the landscape as he would notice in the absence of signs. This finding counters the argument that signs detract from the natural beauty of the land. It seems that the stimuli in the landscape that are attractive and interesting to a person will be noticed and remembered despite the presence of signs. This holds true for the landscapes and distributions studied in the laboratory. When the same problem was studied on a real highway, the laboratory results held true. This was the Michigan State Highway Department's study that still serves as a paradigm of careful procedure.

THE MICHIGAN STUDY

The Michigan State Highway Department cooperated with the US Bureau of Public Roads to study the possible influence of highway design and roadside features on traffic accidents.[13] The representative sample of highway that they studied was a 100-mile portion that ran along US 24 from the Ohio border to its intersection with M50 south of Pontiac, and then M58 to its junction with US 10.

A careful inventory was made of design characteristics and roadside features and of their location. Accidents were also inventoried according to type and location. Statistics on accidents were used for the years 1947 through 1949. Data were organized for convenience on IBM cards. One card corresponded to each accident; one card also corresponded to each section of road of which 119 were intersection sections and 144 were nonintersection sections. In analysis these two types of road were consistently given separate treatment. In the actual study there was approximately equal concern for design features, roadside businesses, advertising signs, and private drives. Our emphasis in reporting is understandably on advertising signs.

Mathematically, a variety of approaches to the problem are available; several methods were used. The first involved calculating the accident rate per sign. This was only done with reference to large and very prominent signs. The number of accidents at each one of five sequential 100-foot intervals from the sign was computed. The second approach was to figure out accident and sign density. For each section of road studied, the sum of accidents over a given period of time (1947-1948) was divided by the size of the section as measured in hundreds of feet. The third

[13] Synopsized by A. R. Lauer and J. Carl McMonagle in "Do Road Signs Affect Accidents?" Traffic Quarterly, July 1955, pp. 322-329.

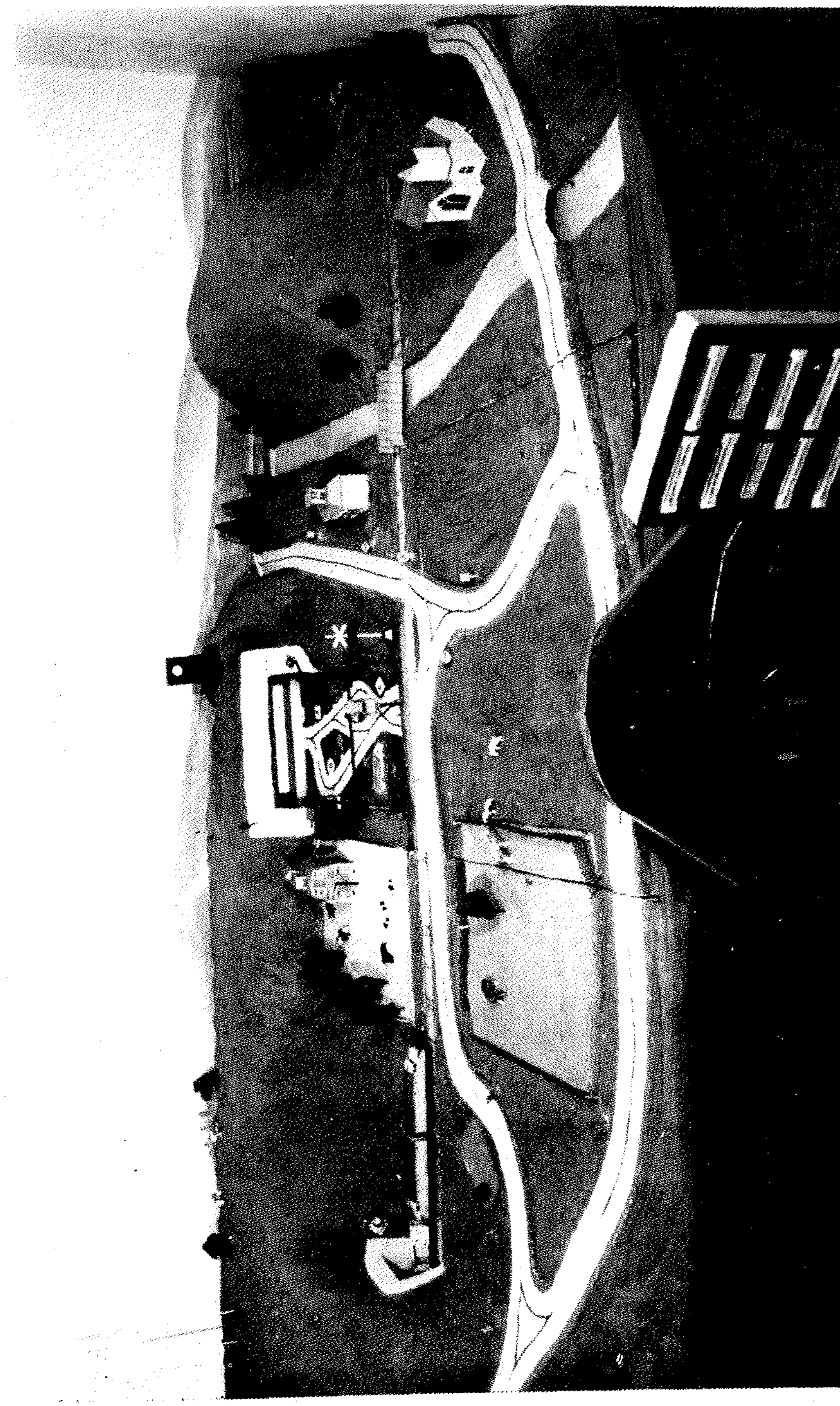


FIGURE 1. Landscape without signs of any kind. This was used as a control condition.

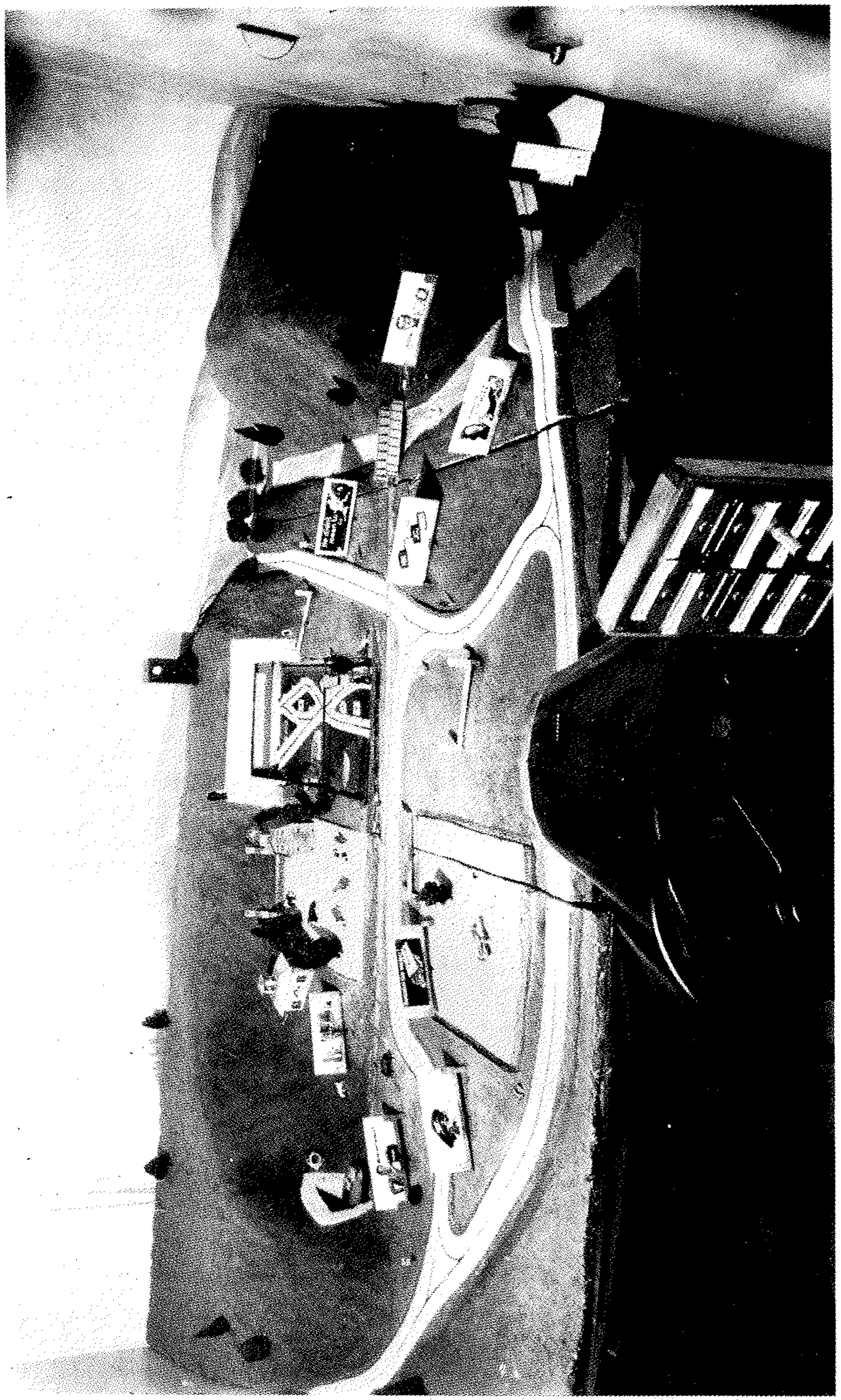


FIGURE 2. Landscape with signs shown within the limits of 15–30 degrees.

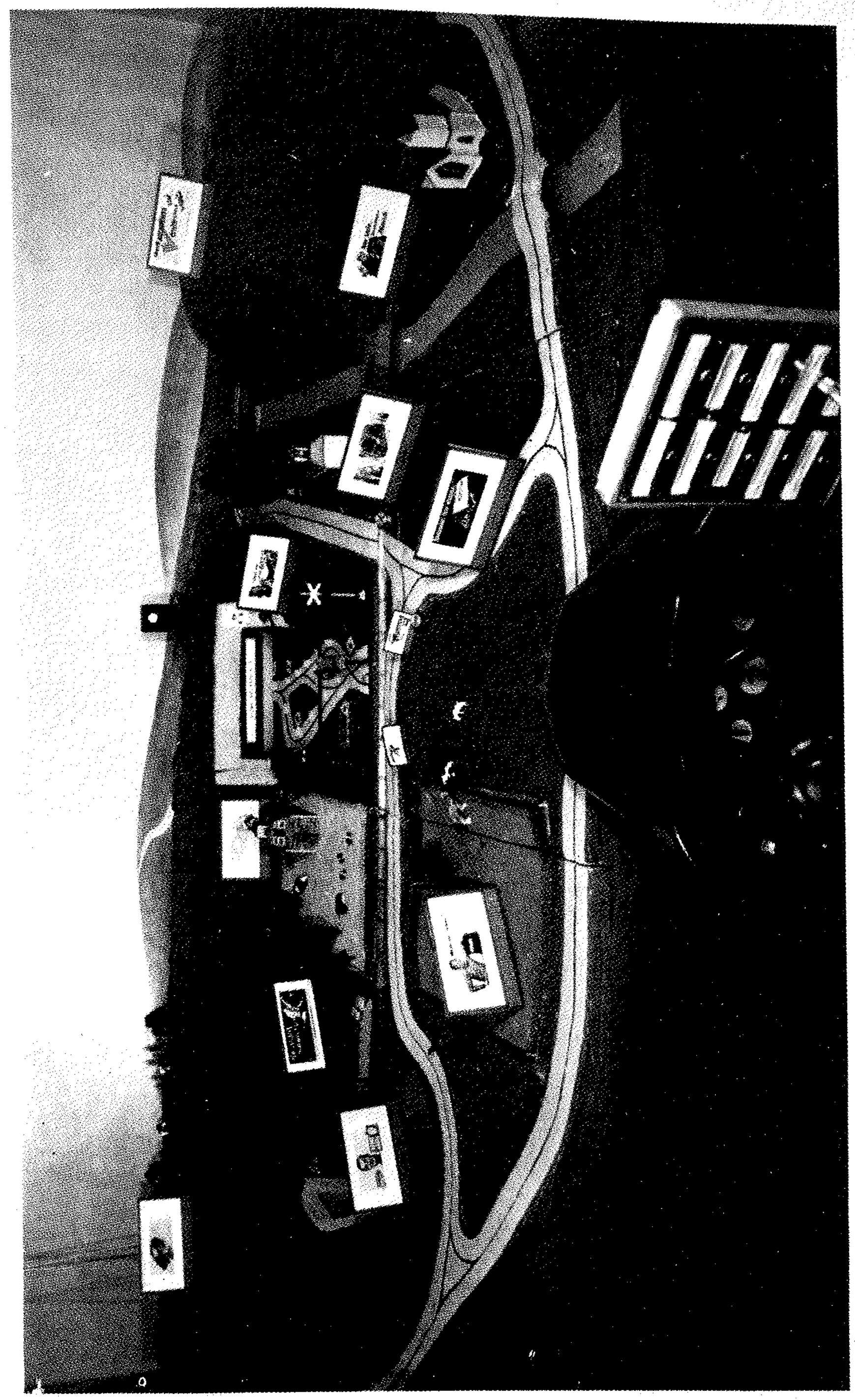


FIGURE 3. Landscape with signs placed from 15–45 degrees at the side.

method involved evaluating the relation between accidents and advertising signs by computing simple and multiple correlation coefficients. None of these methods yielded results that may be considered conclusive because they did not account for the influence of advertising signs and roadside features on each other. The correlation coefficients among these factors indicate that they are significantly interrelated. When partial correlation coefficients were computed, there was no basis for thinking that advertising signs contribute to accidents.

Other findings of the study suggest that carefully positioned roadside features can effectively alleviate the monotony of driving. In a report of this study reference was made to the New York Thruway whose designers had created otherwise functionless curves in the road merely to avoid visual monotony. The report went on to suggest a relation of lack of visual stimulation to a discovery of the Minnesota Highway Department: when sharp turns have to be made at the end of a long tangent they prove far more hazardous than when they come at the end of a short tangent.

According to the Michigan study, interference with driver attention is not a likely explanation of the accidents that occur on the road studied. Rather, the cause was thought to be "probably" friction on the road when entrance and exit ways to roadside businesses and private drives are uncontrolled. Traffic density and vehicle miles are also acknowledged as factors. In conclusion, advertising signs appear to have a positive effect on the highway landscape, since the "distraction" they afford keeps the driver alert.

Highways in the late 1940s and early 1950s were very different from today's roads in terms of design and of volume and speed of traffic; one wonders whether the Lauer/McMonagle methods are still applicable. Proof that their procedures are considered valid comes from the wide use still being made of them in modern studies. The validity of their findings is confirmed by the growing number of judicial decisions that acknowledge that advertising signs do not cause accidents. Recently, officials of the New Jersey Garden State Parkway made use of the methods developed by Lauer and McMonagle. This study is an important example of the complexity of a good highway study.

THE GARDEN STATE PARKWAY STUDY

Because of the detail and generally thorough investigative work contained in this survey, a summary would distort its excellence. The attitude of the researchers who worked under the direction of D. Louis Tonti, Executive Director of the Parkway, is realistic and

intelligent. Their intentions of avoiding a priori conclusions are stated several times at the beginning of the paper. They acknowledge the difficulty of the task being attempted.

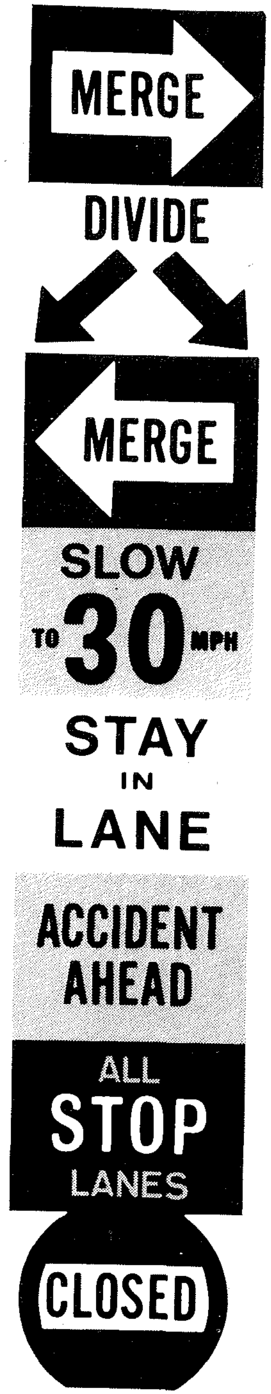
Basically data were collected in three groups: traffic volume statistics, accident data from the New Jersey Highway Authority, and an inventory of every stationary and unchanging feature along every arterial of the Parkway. As in previous studies no evidence could be found to link advertising signs with accidents. To gain some sense of the breadth and depth of subjects covered in this study one might read through the list of tables contained in the appendix of the report (see lists).

LIMITS OF SIGNAGE FUNCTIONS

After a look at research on what signs do not do, it is worth looking at what signs do. Because they are stationary features of the highway environment signs are able to give information about stable situations — a sharp curve, a blind drive, a steep hill. Some signs, not usually found on highways, offer changing messages. The most changeable conditions that we can conceive of, the time and the weather, are reported by special signs referred to as message centers. Surely in traffic there are occasionally changing situations of which the motorist deserves to be forewarned.

A system is now being developed that can help motorists who are indirectly involved in highway emergencies. In the aftermath of a severe highway mishap "creeper" accidents are commonplace. These are the lesser accidents that follow in the wake of a major traffic-stopping emergency. Usually the frustration and intermittent boredom of bumper-to-bumper traffic results in slow speed, rear end collisions. This situation shows the need for some medium to communicate information to drivers about which lanes are open, where they must merge and so on. Since these exigencies cause a *temporary* need for extra communication, it is logical to use a *temporary* sign. At long last designers are able to respond to this need. It has finally been realized that a temporary sign is a mobile sign.

At present signs that can be moved to the scene of an accident are being tested in Minnesota. These devices are about 52 inches high, 48 inches wide, and 6½ inches deep. They are mounted on the roofs of police cars, and are retractable so that when not in use they extend only eight inches above the roof of the vehicle. They can be raised to full height and the desired message can be displayed within 18 seconds. The models now being tested have changeable message scrolls, each one having a repertoire of eight different messages. A typical message scroll is reproduced below. There is a remote control unit within the vehicle that operates the



TYPICAL MESSAGE SCROLL

sign mechanisms. When one considers the alternative ways of dealing with special situations (not only accidents but athletic contests and construction or repair work) the benefits of this system become obvious. Manpower can be used more efficiently, particularly at the scene of an accident. Unsightly and unstable makeshift signs will not have to be used. (See illustration).

This is only one example of a technological advance that will create improved sign communications for highway situations and commercial advertising. Clearly human factors considerations made this new system a reality. One hopes that through future applications to signage problems, similar considerations will continue to expand our concepts of signage as a communication medium.

An aspect of the question of signs and traffic hazards which has not yet been dealt with by the courts is the traffic hazard involved in the use of a sign which is not clearly legible. Such a sign may cause a distraction to the motorist who attempts to interpret its message. An imperative attribute of signs designed to serve and direct the motorist is rapid and clear legibility.

The duty of the city, county or state to warn the motorist of conditions which are not obvious has been clearly established by the courts. When such signs are used, the city has an obligation to maintain them in a visible and readable condition. In *Suligowski v. State* (179 N.Y.S. 2d 55) the court held that the state has a duty to erect proper and adequate signs and can be held liable for its failure to do so. In *Wagshal v. District of Columbia* (216 A. 2d 172) and *Dudum v. City of San Mateo* (334 P. 2d 968) the courts held the district and the city, respectively, responsible for maintaining traffic signs in reasonable repair. A traffic sign becomes part of the physical appurtenances of the street and failure to maintain them is tantamount to the failure to maintain highways *O'Hare v. City of Detroit*, (106 N.W. 2d 538).

In *Fanning v. City of Laramie* (402 P. 2d 460) the court held that, once having erected a stop sign, the city was required to maintain its visibility and take care that shrubbery does not obscure the sign and prevent it from conveying its message. In *Resnik v. Michaels* (201 N.E. 2d 769), however, the court held that legal obligations do not begin until a traffic sign is erected.

Visibility is a major question when determining liability of a city. In *Christ v. State Through Dept. of Highways* (161 So. 2d 322) the court held that if a barricade or warning is necessary for protection of motorists, it should be of such size or nature as is commensurate with the danger. In this case, the court found the State Highway Department negligent for failing to set out signals at a reasonable distance in advance. And in *Hicks v. State* (171

N.Y.S. 2d 827, 4 N.Y. 2d 1, 148 N.E. 2d 885) the court ruled that warning signs must be reasonably adequate for the intended purpose. In *Gurecki v. State* (191 N.Y.S. 2d 32) the state was held negligent because a 6" by 7" sign was inadequate to alert the travelling public of the danger of a road sweeper ahead.

In *Strickfaden v. Green Creek Highway Dist.* (248 P. 456, 42 Idaho, 738 49 A.L.R. 1057), the court held that a jury, in determining the question of reasonable care with respect to warnings of excavation, should consider the kind of travel and probable speed of the vehicle, the same considerations that cities often overlook when setting size and distance specifications for on-premise signs and billboards.

Some national standards have been set to guide state highway departments in posting visible and legible warnings. In *Bovey v. State* (93 N.Y.S., 2d 560, 197 Misc. 302) the court held that the state has a duty to post adequate warnings of perilous road conditions and, as far as possible, these warnings should conform to nationally accepted standards. In *Radosevich v. County Comr's of Whatcom County* (476 P. 2d 705) the court held that the county was liable for accidents caused by nonconforming or unauthorized signs which mislead a traveler exercising reasonable care.

The study of size, shape and color of copy for signs for more efficient function under various conditions is only beginning to be undertaken on any significant scale. In the book, *Street Graphics* (Ewald and Mandexer, 1971) the author states that the largest sign necessary is 150 square feet. But the speed of the motorist, the distance from which the sign must be seen, the color and the letter stroke are all variables which affect the legibility of a sign. Because of the nascent state of this science, we have not yet seen cases where a sign manufacturer has asked to be allowed to erect a larger sign in the interest of public safety.

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