A COMPARISON OF LOWER CASE AND CAPITAL LETTERS FOR HIGHWAY SIGNS

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SYNOPSIS

During the last two years the California Division of Highways has experimented with the development and use of lower case letters for overhead destination signs on freeways. Recognition of word patterns is known to be fundamental in close reading of ordinary printed material and it was thought that habit and pattern factors might also make this form of letter desirable for highway signs. Opinion as to their effectiveness has been varied, however. The problem therefore was to measure the distance at which lower case signs could be read as compared to rounded capital letters.

Experiments were undertaken jointly by the California Division of Highways and the University of California Institute of Transportation and Traffic Engineering, to determine the distances at which signs of each kind of alphabet could be read. Letters from 5 in. to 18 in. in height were mounted on a bridge 17 ft. above the ground and a total of 75 observers made 3939 individual observations under daylight and artificial illumination.

White on black, series E capital letters and lower case letters of approximately the same average width-height ratio were used. These letters represented the development of this form of letter for freeway signs by the California Division of Highways. The stroke of the series "E" capital was widened slightly, also to correspond to the letters used by the California Division of Highways. By means of a prearranged series of positions, each size and form of letter was presented an equal number of times on right and left and at top and bottom of the sign background to balance out errors due to position on the sign bridge.

In order to approximate the effects of word pattern (as opposed to letter legibility) and word familiarity, three sets of measurements were made: (1) using scrambled letters; (2) using California place names, being viewed for the first time; and (3) using California place names, being viewed for the second time.

The "scrambled" groups gave control of guessing and equalized familiarity between observers. The familiar place names, unknown to the observers ahead of time, should involve pattern recognition similar to that by drivers somewhat familiar to the territory. The familiar names known ahead of time to the observers might correspond to the reading of signs by drivers who drive the same highway every day—for example, commuters on freeways.

As was expected, for both kinds of alphabet the distances increased with the size of letters and with the degree of familiarity. The increase due to increasing familiarity was greater for lower case letters than for capitals.

The comparison of lower case and capital letters can be stated in several ways. If recognition distance (and legibility distance) is expressed in terms of letter height using the total height of the "risers" of the lower case letters, these letters appeared at some disadvantage, presumably because they were narrower.

On the basis of width, the lower case words could be seen farther than the capital words, presumably because they were higher. Thus where length of sign is the controlling factor, which is often the case, these lower case letters would have the advantage.

On the basis of sign area, the advantage of one type of alphabet over the other depends upon the vertical spacing or margins. Due to the open area between the stems of lower case letters in a word, it would be expected that the margins or space between lines can be less than for capital letters without loss of legibility. Further observations are needed to determine these factors for the two forms of letter.

The California Division of Highways has been using for some time on its new freeways large size destination signs mounted overhead on special standards. For about two years a lower case alphabet has been in the process of development and use on these large size overhead signs, as illustrated in Figure 1.

Experiments with type forms for the ordinary printed page have shown that lower case printing gives more rapid reading than solid block printing with capital letters. This advantage has been at least in part attributed to more definite pattern characteristics of the lower case words. It has therefore been suggested that the lower case form of letter might be of advantage on highway signs.[1, 2]

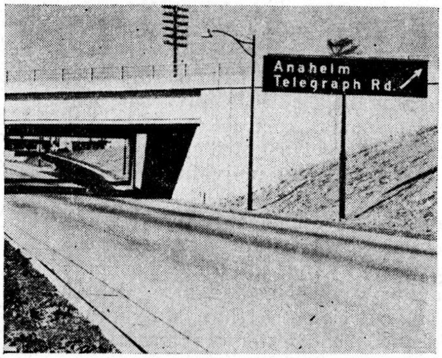


Figure 1

However, the factors which produce rapid reading at close range may not be the same as the factors which allow the reading of large signs at maximum distance, since a different combination of psychological and optical functions is involved. Moreover, as a result of the use of lower case signs on the highways, differences of opinion as to their effectiveness were reported by different individuals.

It thus seemed desirable to compare the distances at which the two forms of letters could be seen when used for highway signs. "Distance seen" was analyzed on the basis of known psychological factors into (1) recognition by overall word pattern and (2) actual discrimination of letters, as the two extremes. Since there were indications that letters may have a different effect in small size than when presented at full scale against an outdoor background, measurements were carried out in full scale.

OBSERVATION METHOD

Types of Observation—It would be expected that any advantage from the use of lower case letters would arise from a greater variety of overall word patterns as compared with the same words in capital letters. For this reason, test material consisting of familiar names would be expected to show the greatest advantage. However, if the test material is too familiar to the observer, reliable measurements will not be obtained since the observers may "recognize" the signs far beyond the point where they can see the letter at all. In contrast, the "scrambled letter" technique used in previous studies[3, 4] allows the control of such psychological factors as guessing on the part of the observer and also equalizes the familiarity of the test material to all observers.

In order to obtain the best control possible and still obtain a comparison of lower case and capitals with familiar material as well as with unfamiliar, observations of three types of test material were used. These three types were (1) six letter "scrambled" combinations, (2) place names, "without knowledge", and (3) place names "with knowledge".

The "scrambled" letter combinations were designed to give legibility distances comparable to those obtained in a previous study[4] with black on white standard series rectangular letters. The place names were of California cities and counties presumably known to the observers. Although an attempt was made to

[1] Tinker, Miles A., and Paterson, Donald G. "Typography and Legibility in Reading," Handbook of Applied Psychology, (Fryer, D. H. and Henry, E. R. Editors) Rinehart & Co., N. Y., 1950, Vol. 1, p. 57 and 59.

[2] Information received by letter indicates that the suggestion has been acted upon by New Jersey and Ohio as well as California. Lower case has apparently been used for highway signs by the former and given consideration by the latter.

[3] Forbes, T. W. "A Method for Analysis of the Effectiveness of Highway Signs." *Jour. Appl. Psychol.* 1939, XXIII, 669–684.

[4] Forbes, T. W. and Holmes, Robert S. "Legibility Distances of Highway Destination Signs in Relation to Letter Height, Letter Width and Reflectorization." *Proc. Highway Research Board*, 1939, Vol. 19, 321–335.

select names having the same number of letters, this was found to be impractical and those finally used ranged from six to nine letters in length. However, comparisons should not be affected since they were between observations of the same words in the two different forms of letter.

Twelve place names "without knowledge" were presented first. The observers were told only that certain well-known California place names would be used. The same twelve words were then used again, the observers being told that the same names would be used but in different combinations and locations. These latter were the observations "with knowledge". Thus the former observations might be similar to the reading of signs by drivers who are familiar with the territory in general. The latter might represent the performance of drivers, such as commuters on freeways, who go over the same highway every day and therefore are very familiar with all place names and signs.

Procedure by Observers—Distance from the sign bridge was marked by stakes at 25-ft. intervals up to 1500 ft. and at 100-ft. intervals from 1500 to 2000 ft. The observers started at a distance where none could identify the test words and approached on foot until they could read the first word. Each observer made his own record of the distance at which he thought he could read the word and the exact spelling of the word as he "read" it. The observers were instructed to make their own independent observations, scanning each of the six words which were presented at the same time, stopping and recording the next distance marker ahead each time that a word was identified, then proceeding to the next. In case the observer later found that the word had been "seen" incorrectly, his instructions required him to cross out the original record and put in the correct spelling and the distance. By this method, each individual could advance at his own pace and could also correct any error in observation, giving a new and correct record (See Fig. 2a and 2b).

In order to increase the speed of the observations and to reduce fatigue, the observers were returned to the starting positions in automobiles. Each trip of the observers for one set of six observations consumed about 15 minutes. This included the time for assembling and setting the next group of test signs.

Number of Observations—A total of 3,939 observations were made by an average of 55 observers for each condition. An additional number of observations was obtained, but some of these had to be discarded due to incompleteness. Each observer made six observation trips "reading" six different signs

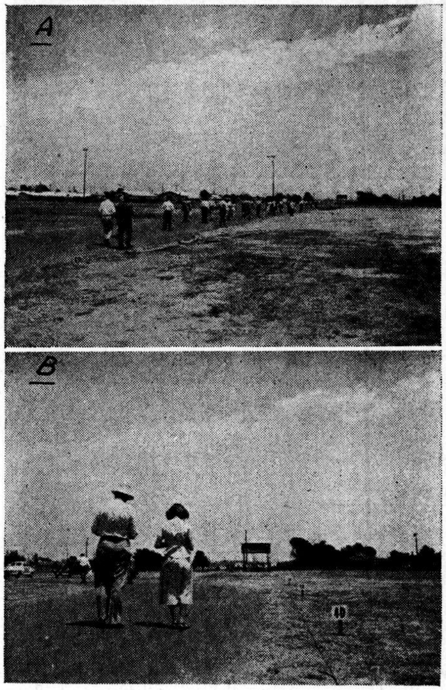


Figure 2

on each trip, on a given afternoon or evening. Observations were carried on during two afternoons and two evenings during the latter part of the month of July, 1950, starting at about 1:45 p.m. and as soon as darkness had fallen.

All observers were drawn from office staff of other departments than Traffic, and included a number of secretaries and wives. Thus both male and female observers took part. Ages ranged from 18 to 70 years. In order to eliminate any possible bias, all observations by Traffic Department personnel, and by others professionally interested in traffic signing, were excluded from the analysis.

CONSTRUCTION OF TEST SIGNS

The test signs consisted of white letters on a black background and represented the designs of lower case and capital letters result-

Figure 3

TABLE 1
WIDTH AND SPACING OF CAPITAL LETTERS

U. S. Standard Series E Rounded Capitals with Stroke Thickened From 0.172 to 0.20 In. per Inch of Letter Height

	Width in Inches per Inch of Letter Height			
	Neat Letter	Right plus Left Margin	Added Constant	Total of Width plus Spacing
A	1.02	0.08	0.15	1.25
B	0.81	0.22	0.15	1.18
C	0.80	0.11	0.15	1.06
D	0.81	0.20	0.15	1.16
E	0.77	0.21	0.15	1.13
F	0.74	0.17	0.15	1.06
G	0.80	0.11	0.15	1.06
H	0.82	0.30	0.15	1.27
I	0.20	0.30	0.15	0.65
J	0.77	0.16	0.15	1.08
K	0.84	0.16	0.15	1.15
L	0.77	0.16	0.15	1.08
M	1.04	0.30	0.15	1.49
N	0.84	0.30	0.15	1.29
O	0.84	0.10	0.15	1 09
P	0.82	0.25	0.15	1.22
Q	0.84	0.10	0.15	1.09
R	0.82	0.20	0.15	1.17
S	0.82	0.08	0.15	1.05
T	0.75	0.04	0.15	0.94
U	0.83	0.30	0.15	1.28
V	0.92	0.08	0.15	1.15
W	1.08	0.08	0.15	1.31
X	1.01	0 08	0.15	1.24
Y	1.01	0.06	0.15	1.22
Z	0.82	0.26	0.15	1.23

Average width weighted for occurrence in California place names:
Neat letters = 0.81
Letter plus spacing = 1.13

ing from the experience of the California Division of Highways. The lower case alphabet is shown in Figure 3 and the proportions are given in Table 2. The capital letter alphabet was a standard Series "E" rounded letter alphabet, but with the stroke widened to correspond to that deemed most satisfactory from experience of the Highway Division as shown in Table 1.

For purposes of greatest economy and versatility individual letters were constructed from which the various names and scrambled combinations were assembled. This allowed preliminary tests of spacing between letters for selection of the value to be used during the

TABLE 2
WIDTH AND SPACING OF LOWER CASE LETTERS

Vertical Strokes 0.22–0.25, Horizontal Strokes 0.20–0.22-in. per Inch of "Loop" Height, Depending on Letter. Stem Height of "b", "d", "k" = 1.415 In. per Inch of "Loop" Height.

	Width in Inches Per Inch of "Loop" Height			
	Neat Letter	Right plus Left Margin	Added Constant	Total of Width plus Spacing
a	0.85	0.23	0.17	1.25
b	0.86	0.23	0.17	1.26
c	0.85	0.14	0.17	1.16
d	0.84	0.23	0.17	1.24
e	0.85	0.14	0.17	1.16
f	0.55	0.10	0.17	0.82
g	0.85	0.23	0.17	1.25
h	0.84	0.34	0.17	1.35
i	0.25	0.34	0.17	0.76
j	0.47	0.12	0.17	0.76
k	0.83	0.23	0.17	1.23
l	0.25	0.34	0.17	0.76
m	1.42	0.34	0.17	1.93
n	0.85	0.34	0.17	1.36
o	0.88	0.12	0.17	1.17
p	0.84	0.23	0.17	1.24
q	0.86	0.23	0.17	1.26
r	0.65	0.20	0.17	1.02
s	0.83	0.09	0.17	1.09
t	0.67	0.10	0.17	0.94
u	0.85	0.34	0.17	1.36
v	1.01	0.06	0.17	1.24
w	1.32	0.08	0.17	1.57
x	1.03	0.10	0.17	1.30
y	1.07	0.08	0.17	1.32
z	0.87	0.14	0.17	1.18

Average width weight for occurrence in California place names:
Neat letters = 0.77
Letter plus spacing = 1.15

tests. Furthermore, the same group of letters could be used to form a variety of test words. And finally, the letters could be made by photographic enlargement to insure that letter proportions would be the same for different sized letters.

Each letter for the two alphabet forms was drawn and carefully photographed. From this film original the three sizes of letter and the different individual letters required were made by photographic enlargement on double weight, semi-matte, white photographic paper. This process required considerable care[5] to insure the correct size and undistorted letter form after the photographic paper dried. Each of the letters so made was then mounted by means of dry mounting tissue on a piece of ¼-in. masonite which was cut to include a margin allowance for each letter as shown in Tables 1 and 2. The resulting signs gave much the same appearance as the matte finish porcelain enamel signs used on California freeways.

Letter Spacing—Each of the 26 letters was provided with its own individual spacing by mounting it on its masonite backing so as to allow varying margins. A further spacing (constant for each letter size) was added to this as shown in Tables 1 and 2. In assembling a word this spacing was made uniform by use of a spacing block for each size of letter. In this way, an attempt was made to obtain a fairly good looking letter spacing which took due account of spacing areas produced by different letter forms.

For the capital letters, the spacing was originally similar to that described by the Texas Highway Department,[6] modified for California use and with the added proportion. For the lower case letters very little precedent was available[7] but a similar approach was used. Margins on each side of the letter on the rectangular block were worked out in an attempt to equalize the spacing area produced by the different forms of adjacent letter strokes. Here again a constant proportion was added.

Sign Bridge, Assembly and Mounting—An experimental sign bridge was designed[8] consisting of two telephone poles as uprights to which were bolted a wooden background 24 ft. wide by 6 ft. high, the bottom edge being 17 ft. above the ground. A catwalk was provided along the bottom and in front of this black background.

This sign bridge was erected on the California State Fair Grounds at a location where a clear distance of over two thousand ft. was available. The observers faced in an easterly direction so that afternoon observations could be made with the sun directly on the sign boards and out of the direct field of vision.

Figure 4

The individual sign letters were assembled to form a test word by pinning them to a mounting board (cellotex for the small letters and wood for the largest). In the case of the smaller letters, two words were mounted on each of these mounting boards whereas only one was possible in the case of the large size letters. Four of these mounting boards could be attached to the sign bridge background by means of suitable cleats, thus presenting six test words.

One board at a time could be removed, lowered and replaced by another assembly which had been prepared in the meantime. One set of test signs was assembled and mounted before the first observation trip began and during each trip by the observers, the sign crew assembled the next set of words

[5] Special acknowledgement is due to the personnel of the Photographic Laboratory of the Division of Highways for their careful preparation of the photographic letters.

[6] Texas Highway Department, "Standard Alphabet and Numerals." 1945, mimeographed.

[7] Spacings from printing and from lower case display advertising signs designed for relatively close reading were not satisfactory. We wish to acknowledge the co-operation of Messrs. J. T. Penton and E. E. Radek of the California Metal Enameling Co. in making available results of their experience with both forms of letter on highway and other signs.

[8] By Mr. Caroll Dunham of the State Traffic Engineers office.

following the careful schedule which is described below. Figure 4 shows operations in progress.

PRESENTATION SCHEDULE

Enough individual letters were made up to form eight different words in each letter size. The same words were available in both forms of letter for each size. Thus there were eight words available for lower case and for capitals in the small size, the medium size, and the large size.

In order to make a valid comparison, it was necessary that observations of the same words be made in lower case and in capital letters. But at the same time, in order to preserve the "unknown" character of the names to be used, it was necessary for half of the observers to see the words for the first time in lower case and the other half to see them for the first time in capitals.

Therefore of four words of each size used for the day observations, two of the words occurred in lower case first and the other two in capitals for the first day's observers. However these words appeared first in the other form of letter for the second day's group of observers.

Four of the words were reserved for the night observations and were similarly reversed as to form of letter presented first to the two night groups.

In order to control guessing as much as possible in the observations "with knowledge" it was also necessary to work out carefully a previously prepared series of positions for each of the test words so as to present a different combination each time. This series also equalized the number of times each word and form of letter occurred on the right and left or on the top and bottom of the sign bridge. The purpose of this was to eliminate well known factors which might tend to favor words in certain of these positions.

Each afternoon or evening observation series included two six-word combinations of "scrambled" letters in which the same type of position schedule had been worked out. The scrambled letter combinations for each letter size were different but were designed to include 24 of the 26 letters of the alphabet.

Thus each group of six signs presented a different combination. The same "familiar names" were used but reversed as to letter form and presented in different combinations and positions on the second afternoon as compared to the first, and similarly for the two night series.

In order to be sure that the presentation series was actually followed without error by the sign crew, a photograph was taken of each six-word presentation on the sign bridge while the observers were making their observations. Examples are shown in Figure 5.

Figure 5

METHOD OF ANALYSIS

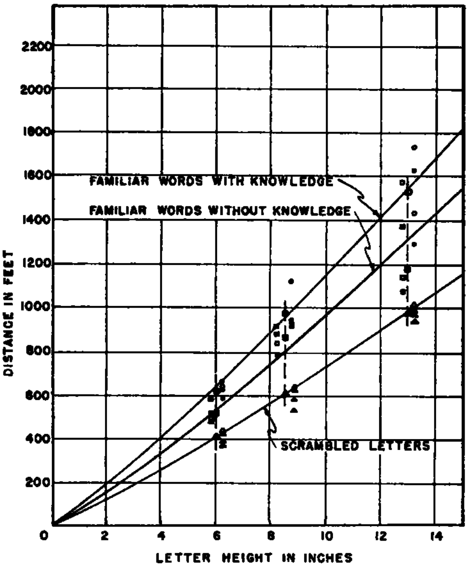
As has been pointed out, the various series of test words had been set up first to furnish three conditions of familiarity, i.e. (1) scrambled, (2) familiar names "without knowledge", and (3) familiar names "with knowledge" and, second, to furnish observations of the same familiar names in both forms of letter and in different letter sizes. The general aim of the analysis was to obtain the relationship of "distance seen" to letter size for each type of observation, and each form of letter under day and under night conditions.

Tabulations were made to give a distribution of "distances seen", first for each test word under each condition of size and letter form and, second, for the total observations of the four test words of a given size, letter form and familiarity type for day and for night observations separately.

From the first set of distributions, median values and standard deviations were computed. Graphs of letter height and width plotted against distance were made showing the medians for each word and also the median values from the four word totals. Although least squares lines of best fit were also calculated, trend lines were finally fitted by inspection since linearity and equal weighting of deviations in long and short distance observations could not be assumed with validity. A simple analysis of variance was carried out to see whether the place names were sufficiently different to represent more than chance. Plots of sign area per letter as against distance seen were carried out with a view toward practical applications.

of the capital letters including spacing. Although the resulting letters did not prove to be exactly of the same width and height, comparisons can be made by plotting these variables against distances seen.

In previous studies,[3,4] it was shown that observations of legibility distances of highway signs resulted in a rather symmetrical frequency distribution of distance values, and here again similar distributions were obtained. As a measure of group tendency for such a distribution, either the arithmetic mean or the median value can be used. In this case the median was chosen since it is less affected



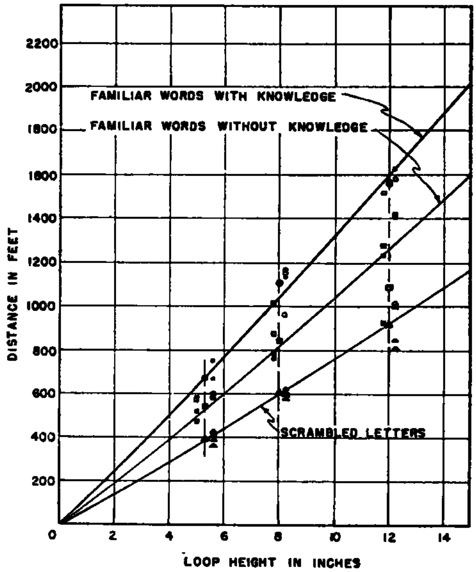


Figure 6

RESULTS

In the development of the lower case alphabet it was found that the stem height of various letters and the length of the descending strokes all varied somewhat, so that the "loop" height of the lower case letters was the only constant value which could be used in constructing the letters. It was not known ahead of time whether "loop" height and letter height would be of the same significance, while it was known that the average width of the letters is of importance in determining the amount of sign area necessary; thus lower case letters were chosen whose average width including spacing would be very close to that

by a few very high or very low values which were thought to represent extreme cases or unreliable judgments.

Letter Height vs. Distance "Seen"—Figures 6 and 7 show the relationship of letter height and "loop" height of capitals and lower case letters to distance at which the signs were recognized or read. Each plotted point represents the median of about 27 observations for a single test word or for the total of about 110 observations of four words of a given form and size of letter as indicated by the legend. It will be noted that there is a much closer grouping of the single word medians in the case of the true legibility measurement (scrambled test letters) and a much wider spread word total observations appear to fall more definitely on a line of relationship.

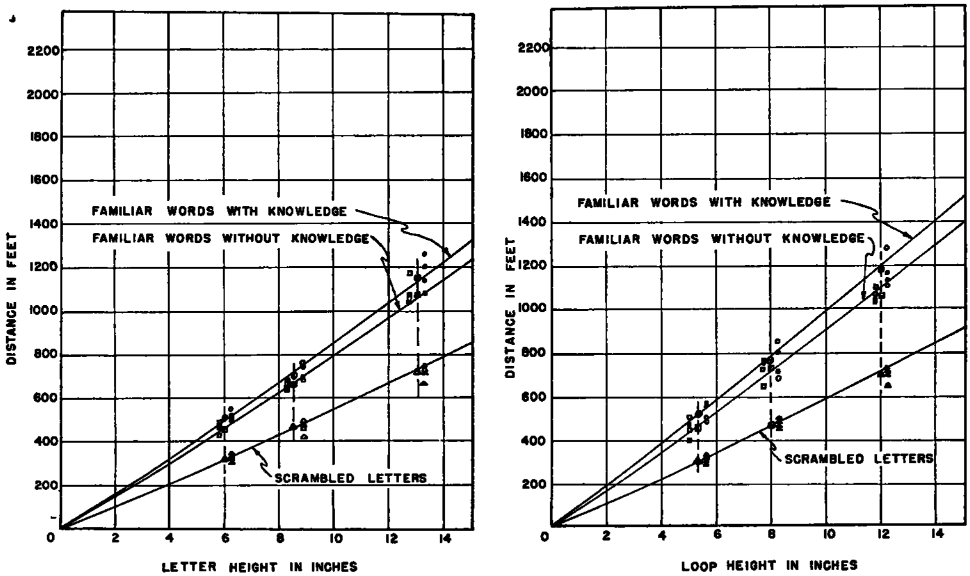


Figure 7

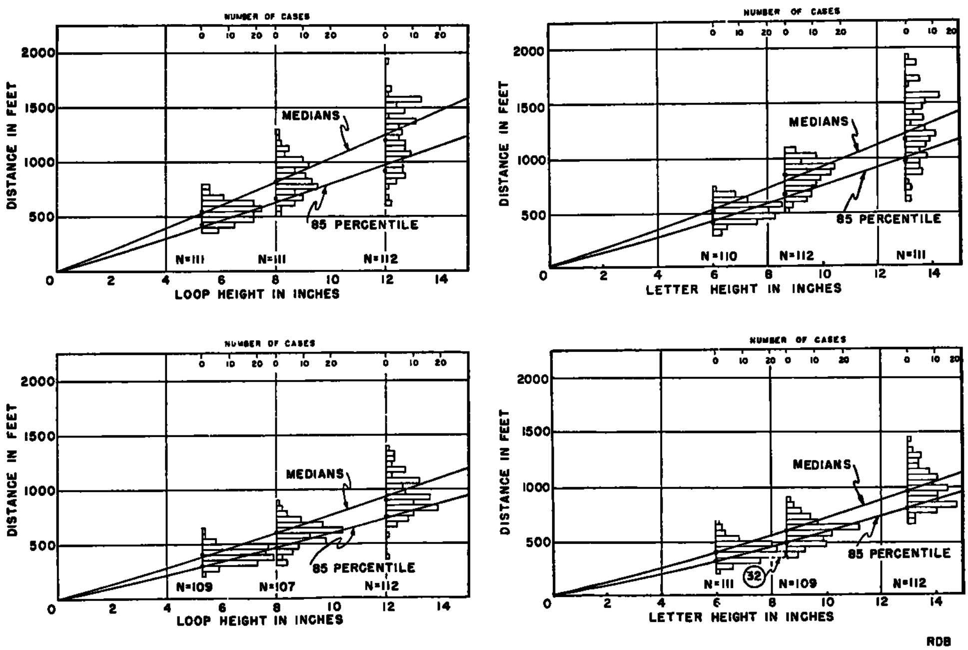


Figure 8

of the individual word medians in the case of place names (both "with" and "without knowledge"). Also the medians for the four

Figures 6 and 7 also show that the median distances were shortest for "scrambled" letters, longer for familiar names "without knowledge" and still longer for familiar names "with knowledge". This relationship held for both lower case and capital letters.

Figure 8 is an illustration of the distribution of distance values obtained when all observations on the four test words of a given size, form and familiarity were thrown together. The distributions shown are for scrambled letter determinations and for familiar names "without knowledge". The lines of median values shown correspond to the lower two trend lines of Figures 6 and 7.

These distributions illustrate the increased variability of observation which occurs with greater distance "seen". Again the greater variation of the more familiar test material as compared to the scrambled letter material is illustrated.

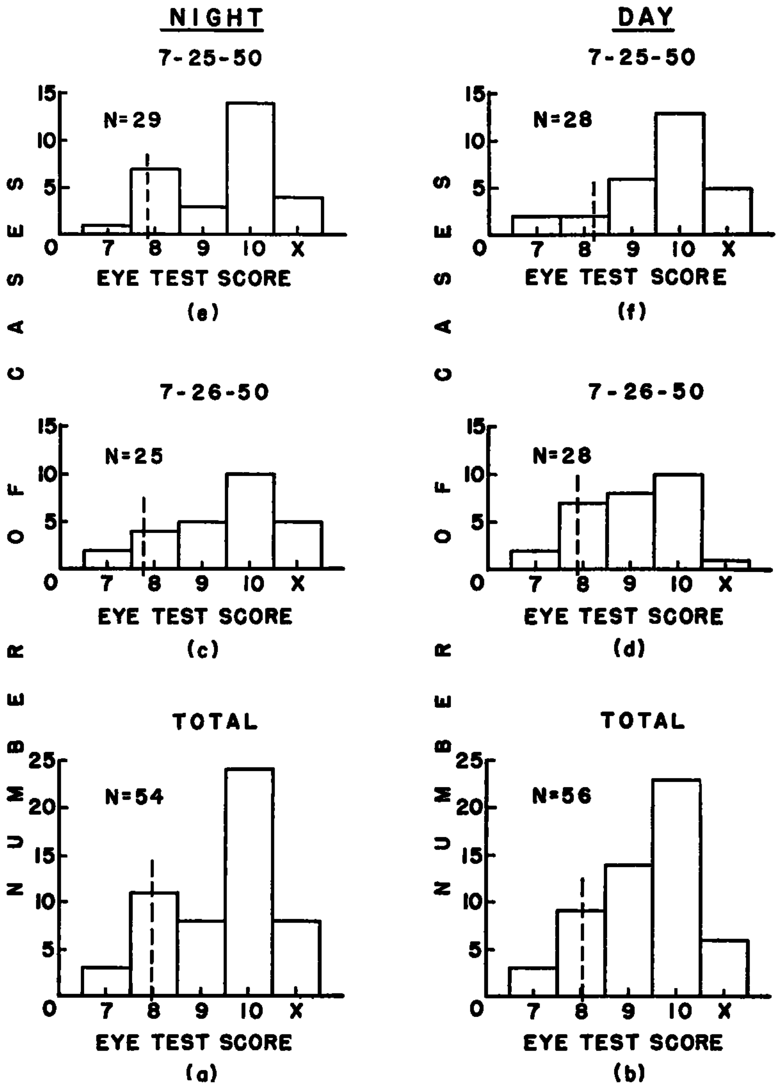


Figure 9

Visual Acuity of Observers—It is important for the purpose of comparison with results from other studies to know the range of visual acuity of the observers. Eye tests were given, therefore, by means of the usual Snellen Eye Charts, to the majority of observers. Figure 9 shows the distribution of eye test scores. A score of 8 represents so-called "normal" or 20/20 vision and "x" indicates those on whom no test was obtained due to their not being available when the eye tests were given. Tests were given with the subject wearing glasses if these were habitually worn and were worn during the time of the sign observations. Figure 9 shows that the majority of the group had better than normal vision and that the 85 percentile represents about 20/20 or "normal" vision.

Distances for Normal Vision—This result indicates that the 85 percentile line shown in Figure 8 should be used for comparing the

TABLE 3
ACTUAL MEDIANS AND 85 PERCENTILE VALUES FOR "SCRAMBLED" LETTER OBSERVATIONS BASED ON TOTAL DISTRIBUTION FOR FOUR WORDS OF EACH SIZE

Capitals			Lower Case		
Letter Height	Distances		"Loop" Height	Distances	
	Median	85 Percentile		Median	85 Percentile
Daylight Observations			N = 109 to 112		
in.	*ft.*	*ft.*	*in.*	*ft.*	*ft.*
6.0	401	327	5.3	399	325
8.5	604	469	8.0	607	470
13.0	958	802	12.0	912	762
Night Observations			N = 100 to 110		
6.0	327	256	5.3	306	231
8.5	482	369	8.0	468	354
13.0	731	575	12.0	708	542

distance values obtained with those for 20/20 vision in previous studies. It will be noted that these 85 percentile values from Figure 8 give us approximately 55 ft. per inch of letter height for scrambled letter legibility distance and approximately 75 ft. per inch of letter height for recognition of familiar names "without knowledge" for the white on black rounded capital letters.

Actual median and 85 percentile values are shown in Table 3 for scrambled letters. Actual distance values are not shown in the table for familiar names because, as seen in Figures 6 and 7, the medians of the summed observations may not be entirely accurate. An estimate, however, can be obtained from the trend lines. (See Table 4.)

Comparison of Lower Case and Capitals—Since median values are in general more reliable statistically than 85 percentile values, medians were used for comparisons between lower case and capital letter determinations; but it should be borne in mind that the dis-

TABLE 4
APPROXIMATE MEDIANS AND 85 PERCENTILE VALUES FOR THE THREE TYPES OF OBSERVATIONS
(Estimates read from trend lines on original plots)

DAYLIGHT

Letter or "Loop" Height	Distance in Feet			
	Capitals		Lower Case	
	Median	85 Percentile	Median	85 Percentile
Scrambled				
in.				
6	405	320	445	370
8	560	450	595	500
12	885	700	910	755
Place Names "Without Knowledge"				
6	530	445	610	480
8	745	605	830	640
12	1190	950	1280	960
Place Names "With Knowledge"				
6	620	500	760	635
8	870	720	1030	850
12	1390	1150	1590	1255
NIGHT				
Scrambled				
in.				
6	340	250	330	255
8	450	350	450	355
12	675	530	685	545
Place Names "Without Knowledge"				
6	465	360	505	420
8	635	510	690	560
12	990	800	1065	855
Place Names "With Knowledge"				
6	510	400	555	480
8	690	560	755	640
12	1060	900	1165	960

tances are longer than those representing "normal vision" performance. Figures 10 and 11 give a comparison of lower case and capital letter determinations in terms of median distance values, Figure 10 representing day observations and Figure 11 representing night observations. Again "loop" height and letter height were used for lower case and capital letters respectively. In Figure 10 the two lower curves represent legibility distances determined from the scrambled letter observations. Thus for daylight the lower case letters showed a slightly greater median distance than did capitals. This advantage increased somewhat for familiar names "without knowledge", as shown by the middle pair of trend lines, and became considerably greater for familiar names "with knowledge" as shown by the upper pair of lines.

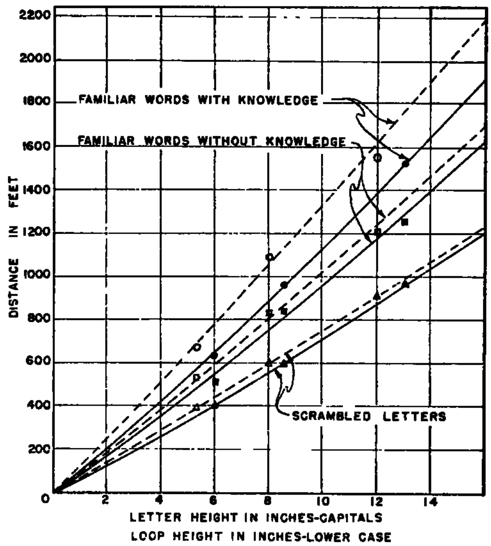


Figure 10

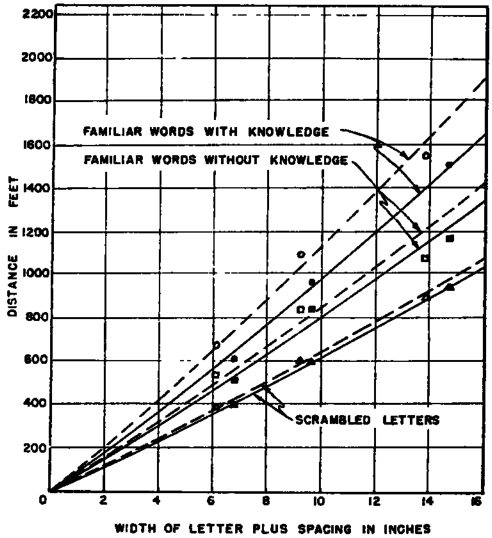


Figure 12

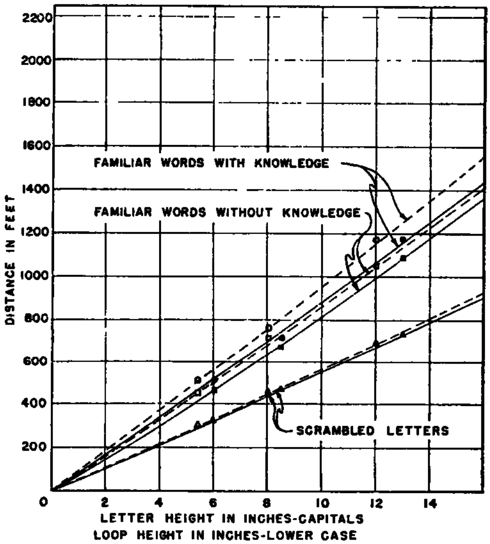


Figure 11

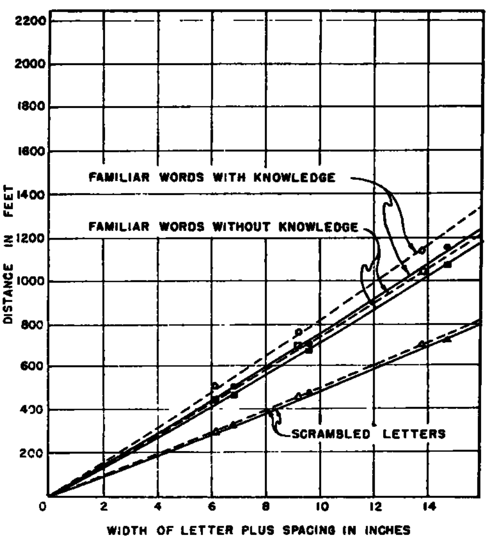


Figure 13

A similar increase of advantage with familiarity was shown (Figure 11) for the night observations. However, it will be noted that at night the distance advantage of the observations "with knowledge" over those "without knowledge" was very much reduced for both lower case and capital letters.

When plotted against width of letter plus spacing (weighted for frequency of occurrence), a somewhat similar relationship was found (Figure 12 and 13). Since the width of the different letters varies considerably it was necessary to use an average value for width. Looking toward application to highway signs, the letter widths were weighted by their frequency of occurrence in California place names. However, an unweighted average, computed for the neat letter width, did not change the relationship markedly.

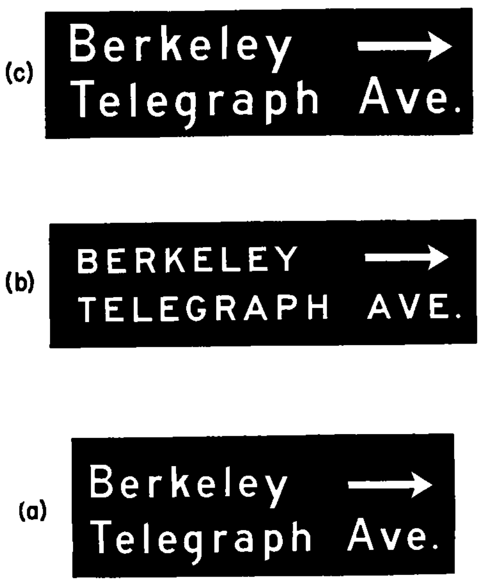


Figure 14

Distance "Seen" and Sign Area—Where large numbers of porcelain enamel signs are involved, the amount of sign area required per letter is of importance in determining cost. An analysis was therefore desired of median "distance seen" in terms of sign area required per letter.

In order to make such a determination, assumptions as to minimum vertical spacing between words and vertical spacing for margins were necessary. In the case of capital letters, California experience seemed to indicate that a border width equal to the letter height above and below each word is satisfactory to eliminate blur from the brightness of the sky or fusion between two words when arranged one above the other. For a two line sign, this gives a vertical spacing of 2.5 letter heights per line as illustrated in the middle example in Figure 14 (b).

For the lower case letters, however, the vertical spacing required to obtain an equivalent isolation of words was not clear. If the same factor were used on the basis of stem height of the letters, it would result in a greater effective area of vertical spacing for the lower case words, since only a relatively few of the letters involve rising stems or descending strokes.

Two alternative assumptions were therefore made for exploratory purposes. The first assumption was that an average vertical spacing of 2.5 "loop" heights per line on the sign would be sufficient. The top example of Figure 14 illustrates such spacing. The second assumption was that an average of 2.25 "stem" heights per line for the vertical spacing would be required. This spacing is illustrated by the bottom example of Figure 14 for the same total area of sign.

The sign area required per letter is shown in Figures 15 and 16. Average width (neat letter plus spacing, weighted for occurrence) was multiplied by the two vertical dimensions resulting from the two assumptions. Figure 15 indicates that a considerable advantage resulted for the place names "with knowledge" when the assumption of a vertical spacing of 2.5 times the "loop" height was made. However, on this basis there was very little difference between lower case and capital letters for the scrambled letter legibility distances.

On the other hand, the assumption of a vertical spacing of 2.25 times the "stem" height made the lower case and capital letters about equally effective in the case of the most familiar test material and showed the lower case at some disadvantage in the names "without knowledge" and the scrambled letter determinations.

The effects of the two assumptions were similar for day and night conditions except that differences obtained were smaller for the latter (see Figure 16).

DISCUSSION

It is known from psychological studies of ordinary reading that rapid reading of familiar printed material involves, to a considerable degree, recognition of words by their overall pattern. On the other hand, reading of scrambled letters requires the actual discrimination of each letter and therefore depends more directly on the legibility of the different forms of letter design. Observations of familiar names esses and therefore to result in recognition distances somewhere between those for the other two. (However, it should be noted that studies of printing involve close reading of a mass of material whereas our signs consisted of separate words "read" at long distance.)

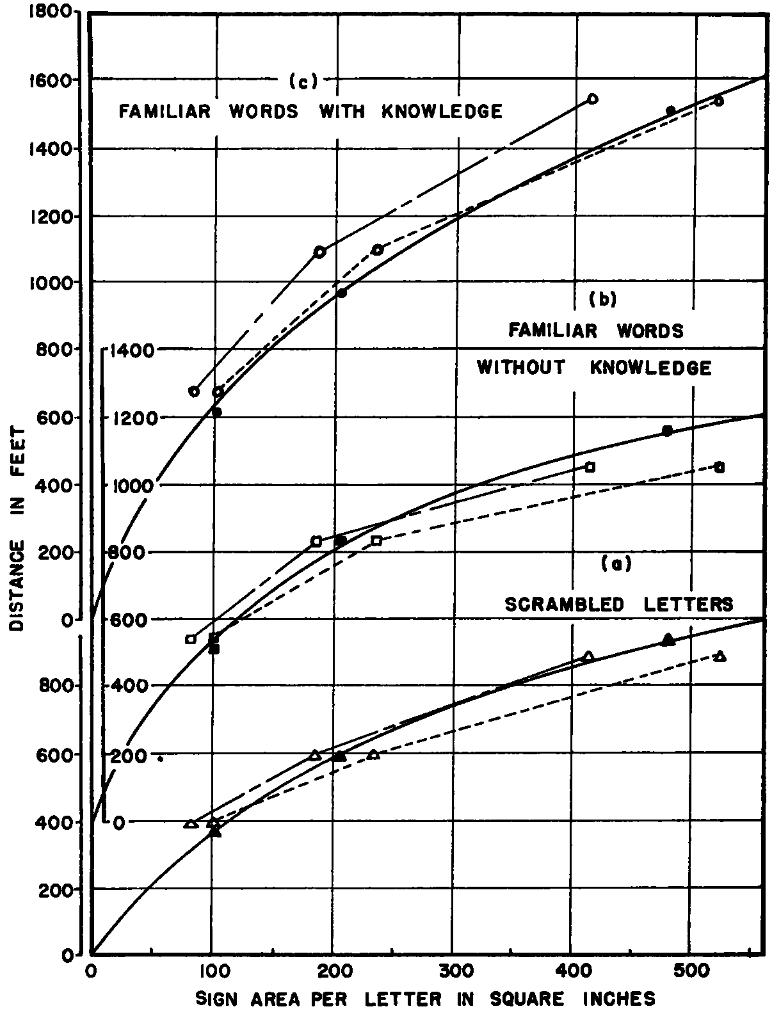


Figure 15

"with knowledge" should be very largely a matter of recognizing the overall word pattern and therefore it is preferable to speak of recognition distance rather than legibility distances in this case. The observations of familiar words "without knowledge" would be expected to involve some degree of both proc-

The results indicated that this was the case and that recognition of word patterns probably entered in the "distance seen" of place names in both the lower case and the capital letters.

The advantage in recognition distance of the familiar names "with knowledge" over those "without knowledge" was much greater for day observations than for night observations. This may indicate that the extreme recognition distances obtained when the observers were familiar with the list of test words depended upon very slight visual cues which could not be seen as far at night. Some extremely long individual observations were obtained which were correct but other extremely long ones were obviously wild guesses, a fact which agrees with this interpretation

The relationship between the median distance values for the familiar words "without knowledge" and the scrambled letters was similar for both lower case and capital letters and was not markedly changed under night conditions. Approximate median values for scrambled capitals as compared to names "without knowledge" were 70 and 95 ft. per inch respectively for day observations and 55 and 80 respectively for night observations (See Figures 10 and 11 and Table 4.)

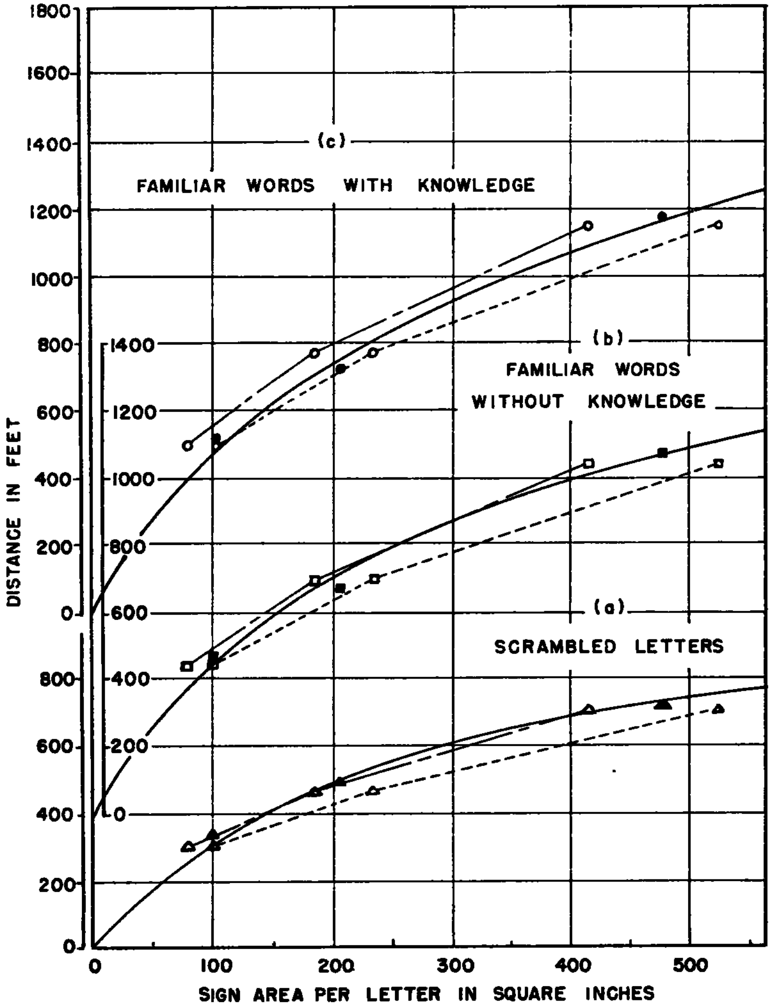


Figure 16

It seems preferable to give approximate values rather than expressing relationships in terms of an equation since the results suggest a slightly curvilinear relationship between distance "seen" and letter height, especially for the capital letter material. Such a curvilinear characteristic was also found in a previous study.[9] This slight non-linearity is of no practical importance if full scale determinations are made but would cause a substantial error if determinations were made on small scale signs and then "blown up" on the assumption of a linear relationship.

Although the lower case observation distances were consistently longer than those for the capital letters, when expressed in terms of distance "seen" for a given loop height or width of letter, the situation was reversed if average "stem" height was used. Since over half of the letters have neither a "riser" nor a "descender" it might be expected that an intermediate value between "loop" height and "stem" height could be derived to serve as an equivalent to letter height in the capitals.

In conformity with use on California highways, the lower case words began with a large capital letter. These were of series D and their height was 1.5 times loop height. The "scrambled" lower case, however, included no initial capitals.

Some advantage might accrue from these large capitals in the lower case place names. For instance, they might serve as a cue for recognition of the whole word when viewed "with knowledge". If this had occurred, 6-in. lower case words "with knowledge" should have given a distance equal to 9-in. capitals. Figure 10 shows that this was not the case. Therefore, although the initial capitals may have influenced the longest observations, apparently the remainder of the word in lower case had to be read by the majority.

The 85 percentile legibility distances obtained for the scrambled capital letters (corresponding to normal or 20/20 vision) were about 55 ft. per inch for day and 44 ft. per inch of letter height for night, as shown in Table 3. These compare with 50 ft. to the inch for day and a 15 per cent reduction for night conditions reported by Forbes and Holmes[10] for black and white series "D" letters. Since the present series "E" letters were somewhat wider such an increase of legibility distance is consistent.

Table 4 also gives 85 percentile legibility and recognition distances for capitals and lower case letters. These represent the distances for so-called normal vision, while many drivers on the road may have only 20/40 vision. It is suggested therefore that the 85 percentile values for names "without knowledge" should be used for practical purposes, rather than the longer median values or the longer recognition distances for the names "with knowledge".

A recent study[11] using rounded capital letters reported "legibility distances" of from 58 to 62 ft. per inch for series "E" (black on white and white on black) letters in daylight. These distances fall about halfway between our distances for "scrambled" and for names "without knowledge" in capital letters.

This difference, however, can be accounted for when it is noted that (1) simulated place names were used, (2) observers were in a car moving at 25 mph, and (3) observations were spoken and recorded by an observer, also riding in the car, who recorded the distance values. The distances, therefore, should be similar to our recognition distances for familiar names "without knowledge" but it should be noted that two perception reaction times were involved. The distance travelled in two 0.75-sec. reaction times at 25 mph. is 55 ft. if added to the distance values for their four inch letters, this will bring their 62 ft. per inch figure to about 76 ft. per inch. Thus we obtain a fair correspondence to our figure, if we correct for the reaction time variable introduced by the method of observation. This corrected figure, however, is still somewhat of a guess since distances were reported as average values and no eye test data for the observers was given.

It is felt that the method used in this study is advantageous in that it allows observers to correct errors, furnishes a record which shows exactly what the observer sees, and eliminates the reaction time variable were speed of a vehicle is involved. Once these basic determinations have been made, any effects of perception time, speed, and ad-

[9] Forbes, T. W. and Holmes, Robert S. op. cit. p. 332.

[10] Forbes, T. W. and Holmes, Robert S., op. cit., p. 334.

[11] Neal, Harry E. "The Legibility of Highway Signs." *Yearbook*, Amer. Assn. of State way Officials, 1944.

vanced placement of signs can be calculated as desired.[12]

The presentation of different combinations of six different words each time is desirable in order to control as much as possible the factor of guessing where familiar names are used. When wild guesses do occur they usually show up in the error column and if not corrected by the observer himself they can be thrown out in processing the data.

The occurrence of statistically significant differences between the medians for certain of the familiar names but not between those for scrambled combinations indicated greater differences in the pattern characteristics of familiar names. Such differences indicate that use of larger numbers of words and of observers is desirable where familiar names are used as the test material.

In order to compare the recognition distances of the two forms of letter for the familiar names "without knowledge" it was necessary to have half of the observers see one form of letter first and other half see the other form of letter first, and then to compare these results for the two halves of the group. This procedure would introduce an error unless the two groups of observers are equated as to visual acuity and familiarity with the region from which the names are selected. Equating of the two groups was fairly satisfactory as shown by the distributions of eye test scores (Fig. 9).

Unfortunately, it was not possible to have all of the individuals who acted as observers present for both the day and the night observations, but 36 out of 55 were present for both.

The level of illumination obtained from fluorescent tubes above and below the sign was reduced to give a brightness of 12 to 18 foot lamberts for night observations. This was the result of preliminary observations at 30 to 40 foot lamberts which gave definite blurring at longer distances.

It was possible to demonstrate that glare from headlights of a car facing the observers actually increased the distance at which the sign could be read under these conditions. This is explainable in terms of contraction of the pupil of the eye. Since it was not feasible, due to the discomfort involved, to conduct observations in the face of glare, the lower level of illumination was used as a compromise value. The demonstration indicated the need for a systematic study of highway sign illumination.

Calculation of sign area necessary per letter of sign text would require information on vertical spacing on which nothing definite was available. Since the alternate assumptions made with regard to such vertical spacing resulted in alternate conclusions as to which form of letter is most effective in terms of distance per unit of sign area, test observations should be conducted to obtain information on this point.

[12] Mitchell, A. and Forbes, T. W., "Design of Sign Letter Sizes." *Proc. Amer. Soc. Civil Engrs.* 1942, 68, pp. 95–104.

SUMMARY

1. A determination of legibility and recognition distances was carried out for the purpose of comparing lower case and capital letters for large-sized highway signs. White on black letters similar to those developed by the California Highway Department for large-sized overhead signs on freeways were used. The capital letters were rounded standard series "E" but with a slightly widened stroke. The lower case alphabet was one based on practical trial and development.

2. Observations were made of three types of test signs. These were: (1) scrambled letters in a six letter combination for determination of true legibility; (2) familiar California names "without knowledge" as to the names which would be used; and (3) familiar names "with knowledge." Both lower case and capital letters were used in all three types of observations and in different sizes of letter. The first type of observation would require actual discrimination of each letter, the second type probably involves some actual letter discrimination and some over-all word pattern recognition. The third type probably involves more over-all pattern recognition. The second type of observation might represent the driver generally familiar with the territory and the third, the person who drives the highway every day.

3. The simultaneous use of both scrambled and familiar test signs allowed better control of psychological factors. Thus the more reliable determinations with the scrambled material were used as a base and the observations of familiar signs were related to them. The

method was otherwise similar to that used previously by Forbes and Holmes[4] and is felt to be advantageous in controlling variables which may otherwise introduce errors.

4. For both lower case and capital letter signs, the median and 85 percentile distance increased as the degree of familiarity (represented by observation types (1), (2) and (3)) increased. The longest recognition distances (for the third type of observations) however, were reduced more nearly to those of the second type under night conditions.

5. The legibility distances from "scrambled" letters were in line with those obtained by Forbes and Holmes, and decreased at night for the capital letters in similar fashion to their study. Somewhat different distance values reported in another previous study can be accounted for by certain uncontrolled variables in the method of recording used in the study.

6. Median legibility distances from the scrambled material proved to be roughly three-fourths as great as the recognition distances determined with familiar names when observed "without knowledge" of the names to be used. This relationship was also approximately the same for night observations.

7. Letter height has been used rather generally as a basic index of capital letter size since it is constant for all letters of the alphabet. For lower case letters, however, stem height was found to be variable and therefore "loop" height was the only constant dimension. When distance "seen" was plotted against loop height, comparison of median distances showed an increasing advantage for lower case letters over capital letters as familiarity of test signs increased. However, when stem height was used the advantage was reversed.

8. When median distances were plotted against sign area required per letter of sign text, alternate assumptions were necessary as to vertical spacing between words or margin to the edge of the sign. On the basis of one assumption, lower case showed an advantage for place names, while on the basis of the other, the two letter forms required about equal areas for place names "with knowledge", and the lower case showed a slight disadvantage for names "without knowledge" and "scrambled" letters. Since no experimental determinations of required vertical spacing have been reported, a series of observations should be carried out to determine the minimum vertical spacing necessary for the two forms of letter.

9. Approximate eighty-five percentile distances (representing 20/20 vision) for scrambled capitals and place names "without knowledge" were 55 and 75 ft. per inch of letter height. For lower case letters of equal "loop" height, these distances were about 10 per cent greater.

ACKNOWLEDGEMENT

The study could not have been successfully carried out without the assistance of many of the State Traffic Engineer's staff and of the Staff of the Materials and Research Department who assisted in the preparations and operations. To the officials of the California Highway Division and the Institute of Transportation and Traffic Engineering for their backing and to Mr. J. C. Young for his personal interest in the project, the success of the study is due.

DISCUSSION

D. W. Loutzenheiser, *Bureau of Public Roads*—Since first reading of the use of lower case letters on signs on California Freeways we have awaited some positive measure of the merits of this system when compared to the usual all-capital letters. The authors are to be commended for a thorough examination of this problem in which several tricky factors are involved. Their conclusions from the observed results seem deficient in one respect and this comment is offered to give emphasis to this missing point.

For immediate practical use a direct comparison is needed of "distance seen" values for the capital and lower case letters, as given in Figure 10. For practical examination the intermediate condition of "place names without knowledge" seems closest to the usual highway sign situation. It is most important to get the sign message to the driver not familiar with the highway or intersection. From Table 4 data for a range in letter height of 6 to 12 in. the difference in distance seen for the two types of letters for this condition was about 10 percent. The actual range in difference for both median and 85 percentile values is 1 to 13 percent for daylight and 7 to 14 percent for night observations. This compares the full height of the capitals to the loop height of the lower case letters. In each case the lower case letters were the better. In a broad sense this minor distinction of only 10 percent does not seem significant enough to warrant immediate widespread use of the lower case letters.

Direct comparison of capital letter height to the loop height of the lower case letters is not strictly correct. In usual use, the lower case letters for names involve a higher or capi'al initial letter, which requires more board space. Use of a larger initial letter in the all-capital names very likely could have stepped up the distance seen by about 10 percent. If such were the case the lower case letters have no advantage. Considered otherwise, it might be more logical to compare names with all-capital letters, say 9-inch height, to those with initial letters of the same height and lower case letters of about two-thirds that height, or 6 inches, roughly the proportion used in most printing. In such a comparison these data show that the all-capital letter names would be seen for distances 30 to 40 percent greater than those with lower case letters. Recognizing the controls of board size and space, a somewhat higher ratio than two-thirds may be in order for highway sign legends with lower case letters. This would reduce the percentage of difference but the advantage obtains for the all-capital letters, according to these data. It would be helpful if the authors brought out practical conclusions in these respects.

T. W. Forbes, *Closure*—Mr. Loutzenheiser is quite correct in pointing out that our results indicate about 10 percent advantage for lower case letters when medians or 85 percentible values of "scrambled" or "without knowledge" observations are compared in terms of capital letter height and of lower case "loop height".

However, the suggestion that this advantage could be due to the use of a large initial capital seems difficult to justify. As pointed out in our paper (see p. 369) if the lower case words were recognized by means of the initial large capital alone, 6-in. "loop height" lower case letters should have given the same results as 9-in. capitals. This did not occur. Therefore, discrimination of the remaining 5 or 6 (lower case) letters must have been required for recognition of the place names and these must have controlled the results

A second objection to the interpretation that the apparent advantage was due to an initial capital is that it occurred in the "scrambled" determinations also (see Table 4). There were no initial capitals in the "scrambled" letter test combinations.

Finally, the suggestion that lower case letters should be compared with capital letters as high as the rising lower case stems or more (the ratio of 9 to 6 inches is even greater) ignores the fact that a considerable spacing area above the word exists between irregularly occurring stems of lower case letters. The vertical spacing comparable to that between lines of print therefore enters and it is possible that lower case words can be spaced as shown in Figure 14C without loss of legibility. If so, comparisons on the basis of "loop" height as against capital letter height would be valid. However, since no observations were obtained as to the effect of vertical spacing, it was suggested in our conclusion No. 8 that a study of this factor should be carried out and alternative examples were given in terms of sign area required. Thus, we cannot merely assume that capitals fifty percent greater than lower case loop height can be used on the same area of sign, nor that a 30 to 40 percent advantage would accrue as suggested.

Another way of putting it is that if letters are used of such a size that the base and tops of the letters come to the edge of the sign (or to the next line, or word, above and below) there will be a loss of legibility. This loss is probably greater for capitals than for lower case, due to the space areas between stems of the latter and the solid characteristic of the former.

Pending experimental determination of such effects of vertical spacing, it was felt that practical conclusions must be limited to alternatives such as those of Figures 14, 15, and 16.

It should also be pointed out that if the tall capitals are used with the same actual width as the lower case, the capitals will be a narrower series letter. As shown in a previous paper such narrower letters will be legible for a shorter distance than the wider Series E letters used in our study. Thus, the claimed advantage would not be valid. The use of tall and wider capitals immediately involves a longer sign and greater area than required for the lower case, and therefore is not a fair comparison. Thus, the question of how to compare the two forms of letter is much more complex than it may appear at first glance.

PHOTOGRAMMETRY AND ITS USES IN HIGHWAY PLANNING AND DESIGN

CURTIS J. HOOPER, *Director of Traffic-Planning-Design, Connecticut State Highway Department*

SYNOPSIS

Photogrammetry might be described as the process of converting photographs into contoured topographic maps. Formerly ground survey methods were considered the only reliable means of obtaining accurate topographic information. It is now possible to develop topographic maps of specified accuracy by means of aerial photographs which are then subjected to a series of photogrammetric processes so that maps may be drawn at scales useful in highway location and design.

For location planning studies, Connecticut uses the Geological Survey topographic maps for the selection of the narrowest band containing all alternate routes considered for a highway relocation. If the alternative routes require a band one mile wide, photogrammetric maps to a scale of 1 in. = 200 ft. showing 5-ft. contours would be specified. Such maps produced on tracing cloth in sheets of 3 by 5 or 6 ft. provide the Location Planning Engineer with sufficiently precise information for the refinement of line and grade, the estimating of construction quantities and the determination of number of structures and acreage of land needed for right of way. The careful pricing of these quantities on the various alternatives will produce costs for comparison with the benefits each alternate line would produce. Study of the photogrammetric maps and the photographs permit evaluation in sufficient detail so that only one line need be surveyed for design purposes.

If all the alternates needing appraisal fall within a 2000-ft. band, Connecticut would specify that the photogrammetric maps be at a scale of 1 in. = 100 ft. showing 2-ft. contours. This scale permits more refinement in the selection of the location to be constructed.

The photogrammetric processes applied so convincingly at the 200 and 100 ft. to the inch scales in our location planning have recently been extended to the more detailed surveying used in the development of construction plans, namely, 40 ft. to the inch with 1-ft. contours. Such maps would have a maximum width of 1000 ft. but if the line determination on previous larger scale maps permits, a narrower width can be specified.

The accuracy of these photogrammetric maps is almost unbelievable. For planimetric detail on 40 ft. to the inch maps it has been found that buildings, fences and virtually everything which can be seen from the sky can be plotted at 40 ft. to the inch within the accuracy normally obtained by ground survey methods. Ninety percent of the contours will be accurate within one-half contour interval and the other 10 percent will be within a whole contour. In areas covered with evergreens or brush accuracy within double these tolerances is obtainable. Such accuracies have been obtained by the Connecticut State Highway Department on photogrammetric work in three contracts through the past three years. Advantages are the ability to supplement existing survey personnel, the shorter time required to obtain maps useful for design and costs no greater than slower ground surveys.