

STATE OF CALIFORNIA
SACRAMENTO 7

Inter-Departmental Communication

To:

Honorable Karl Warren
Governor of California
State Capitol
Sacramento, California

File No. 400-22

Date: January 12, 1951

Subject:

From: Director of Public Works

Attached, for your information and files, are two copies of a paper on "A Comparison of Lower Case and Capital Letters for Highway Signs", by T. W. Forbes of the Institute of Transportation and Traffic Engineering, University of California, and Karl Moskowitz and Glen Morgan of the Division of Highways.

This paper is the result of a cooperative research project of the Division of Highways and the Institute for which the field work was done last summer. The experiments were planned by a committee including Professor Forbes, Traffic Engineer J. C. Young, staff members of the Traffic Department and Materials and Research Department of the Division of Highways, and Photographer M. R. Nickerson. Also, employees of all the Headquarters Office participated in the observations.

The principal burden of preparation of this report fell upon Professor Forbes, and in response to an invitation from the Highway Research Board, he plans to read it to them at their 30th annual meeting this month.

C. H. FURCELL
Director of Public Works

By Original Signed Frank B. Durker

R. M. Shillito
Special Assistant to Director

kw

Attach.

cc/Mr. G. T. McCoy - 2
cross reference



Rm I says
FBD signed this.
~~Frank B. Durker~~
~~for signature~~
M.P.

STATE OF CALIFORNIA
SACRAMENTO 7

RECEIVED-SACRAMENTO
DIRECTOR'S OFFICE
DEPT OF PUBLIC WORKS

Inter-Departmental Communication

1951 JAN 10 PM 4 25

To: Mr. C. H. Purcell
Director of Public Works

File No.

Date: January 9, 1951

Subject:

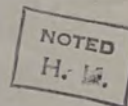
From: Division of Highways

Attached are three copies of a paper on "A Comparison of Lower Case and Capital Letters for Highway Signs", by T. W. Forbes of the Institute of Transportation and Traffic Engineering, University of California, and Karl Moskowitz and Glen Morgan of the Division of Highways.

This paper is the result of a cooperative research project of the Division and the Institute for which the field work was done last summer. Professor Forbes is a nationally recognized authority on sign legibility, having published results of previous investigations in the Journal of Applied Psychology (1939, XXIII, 669-684); Proceedings of the Highway Research Board (1939, 19, 321-335); and Transactions of the American Society of Civil Engineers (1943, 108, p. 233). The experiments were planned by a committee including Professor Forbes, Traffic Engineer J. C. Young, and staff members of the Traffic Department and Materials and Research Department of the Division. The Photographic Laboratory of M. R. Nickerson reproduced large quantities of letters of various sizes, and employees of all the Headquarters Office participated in the observations. The principal burden of preparation of the report fell upon Professor Forbes, and in response to an invitation from the Highway Research Board, he plans to read it to them at their 30th annual meeting this month.

G. T. McCOY
State Highway Engineer

Attachments



Read by
R. M. S.

NOT FOR PUBLICATION

A COMPARISON OF LOWER CASE
AND CAPITAL LETTERS FOR
HIGHWAY SIGNS

by

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For Presentation at the Annual Meeting of the
Highway Research Board, Washington, D. C., January 9-12, 1951

A COMPARISON OF
LOWER CASE AND CAPITAL LETTERS
FOR HIGHWAY SIGNS

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The Problem

The California Division of Highways has been using on its new freeways for some time 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}

*Visiting Associate Professor, on leave from University of Hawaii

**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.

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

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

However, the factors which produce rapid reading at close range may not be the same as the factors which allow the reading of large sized 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 letters" 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 with black on white standard series rectangular letters. The place names were of California cities and counties presumably known to the observers. Although an original attempt was made to 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

³Forbes, T. W. A method for analysis of the effectiveness of highway signs. Jour. Appl. Psychol. 1939, XXIII, 669-684.

⁴Forbes, 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, 19, 321-335.

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 free-ways, 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 feet and at 100 ft. intervals from 1500 to 2000 feet. 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 on 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 Figures 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 on each trip, on a given afternoon or evening. Observations were carried on during two afternoons and on two evenings starting at about 1:45 p.m. and as soon as darkness had fallen. Observations were carried on during the latter part of the month of July, 1950.

All observers were drawn from office staff of other departments than Traffic and 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 resulting 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

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widened to correspond to that deemed most satisfactory from experience of the Highway Division as shown in the Table.

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 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 care⁵ to insure the correct size and undistorted letter form after the photographic paper dried. Each of the letters so made was then mounted on a piece of 1/8 inch masonite which was cut to include a margin allowance for each letter as shown in Tables 1 and 2. The photographic letter was mounted on the masonite by means of dry mounting tissue.

Thus three sizes of each form of alphabet were made up, each letter being reproduced by enlargement from the same original. The 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 available⁷ but a similar approach was used. Margins on each side of the letter on the rectangular

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

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

⁷Spacings from printing and even from lower case display advertising signs but 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.

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Sign Bridge, Assembly and Mounting

This sign bridge was erected on the California State Fair Grounds at a location where a clear distance of over 2,000 feet was available. The observers faced in an easterly direction so that afternoon observations could be made with the sun directly on the sign boards but out of the direct field of vision.

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

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, another for the medium size, and another eight for the large size.

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.

In order to control guessing as much as possible in the observations "with

Before the first observation trip began and during each trip by the observers, the team assembled the next set of words 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 four of these mounting boards could be attached to the sign bridge back, ground by means of suitable cleats, thus presenting six test words. One board at a time could be removed, lowered and replaced by another as assembly which had been prepared in the meantime. One set of test signs was as-sembled and mounted. 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 size). 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. ■ Back background. This sign bridge was erected on the California State Fair Grounds at a location 1 where a clear distance of over 2,000 feet was available. The observers faced in an easterly direction so that afternoon observations could be made with the sun directly on the sign boards but out of the direct field of vision. ■ LETTERS Sign Bridge. Assembly and Mounting ■ An experimental sign bridge was designed consisting of two telephone poles as uprights to which was bolted a wooden background 24 feet wide by 6 feet high, the bottom edge being 17 feet above the ground. A catwalk was provided along the bottom and in front of the board. ■ By 25 Age ■ to COLLEGE molévia yendh ■ OTI beduroo BLAT beffe asé Sulev ed to gold -5- 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. ■ LOWER CASE vs CAPITAL

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.

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.

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.

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.

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. Since it was not

known ahead of time whether "loop" height and letter height would be of the same significance, but the average width of the letters is of importance in determining the amount of sign area necessary, lower case letters were chosen whose average width including spacing would be very close to that 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 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 of the individual word medians in the case of place names (both "with" and "without knowledge"). Also the medians for the four word total observations appear to fall more definitely on a line of relationship.

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.

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 indicates therefore that the 85 percentile line shown in Figure 8 should be used for comparing the distance values obtained with values obtained 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 these distances 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.

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.

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.

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.

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 "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 processes and therefore to result in recognition distances

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 fits in with the above interpretation.

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 slightly non-linear characteristic 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.

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.

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

In terms of an equation since the results suggest a slightly curvilinear relationship between distance "seen" and letter height, especially for the capital Cues a curvilinear characteristic was also found in a previous letter study (see Figure 10). This slightly nonlinear characteristic is a nice practical example of how the visual system might be charged under night conditions. Approximate values for scrambled as compared to names "without knowledge" were 75 to 100 respectively for day observations and 55 to 80 respectively for night observa- tions (See Figures 10 and 11). It seems preferable to give approximate values rather than expressing rela- tionships correct but often extremely long ones were obviously wild guesses, a fact which fits in with the above interpreta- tion. However, the relationship between the median distance values for the familiar words "without knowledge" and the scrambled letters was similarly for both lower case and capital letters and was not markedly different from what we would expect if 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 low level observations were obtained which were capital letters. 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. The advantage in recognition distance of the familiar names "with knowledge" over those "without knowledge" was much greater for day than for night. In the case of the lower case letters, the difference between the two groups was about 10% for day and 20% for night. For the capital letters, the difference was about 10% for day and 20% for night. The difference between the two groups was about 10% for day and 20% for night. The difference between the two groups was about 10% for day and 20% for night.

The 85 percentile legibility distances obtained for the scrambled capital letters (corresponding to normal or 20/20 vision) were about 55 feet 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 percent reduction for night conditions reported by Forbes and Holmes¹⁰ for black and white series "D" letters. Since the present series "E" letters were somewhat wider such an increase of legibility distance is consistent.

A recent study¹¹ 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.

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 where speed of a vehicle is involved. Once these basic determinations have been made, any effects of perception time, speed, and advanced placement of signs can be calculated as desired.

¹⁰Forbes, T. W. and Holmes, Robert S., *Op. cit.*, p. 334.

Reference to the latter can be accounted for when it is noted that (1) Simulated plain names were used, (2) observers were in a car moving at 25 mph, and (3) observers were spoken and recorded by an observer, also riding in the car, who recorded the distance to the distances; therefore, should be similar to our own. However, a recent study using rounded capital letters reported "legibility distances" of 5 to 5.62 ft. per inch for series "E" (black on white and white on black) letters at night (daylight). These distances fall about halfway between our distances for "Scrambled" and for names without confusion shapes. This may be due to the fact that the names were on the road signs and still obtain a driver's license. It is suggested therefore that the present data for names with confusion shapes should be used for practical purposes, rather than the longer median values or the longer recognition distances for the names with 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 percent legibility and recognition distances for capitals and lower case letters. These represent the distances for so-called the 85 percent legibility distances obtained for the scrambled capital letters (corresponding to normal or 20/20 vision) were about 55 feet 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 percent reduction for night conditions reported OVER AS CIVILIAN and that has just used for 20/40 and 10 OVER CASE VS CAPITAL LETTERS - 10. Figure 10 shows that this was not the case. Therefore, although the initial capital may have influenced the longest observations, apparently the remainder of the word in lower case had to be read by the majority.

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 indicates 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 the 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. (Figure 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 the largest proportion of the group was present for both. (36 out of 55)

The level of illumination obtained from fluorescent tubes above and below was reduced to give a brightness of 12 to 18 foot lamberts. This was the result of preliminary night 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 above demonstration indicated the need for a systematic study of highway sign illumination, however, in relation to a number of factors.

Calculation of sign area necessary per letter of sign text, required information with regard to 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.

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 (a) scrambled letters in a six-letter combination for determination of true legibility, (b) familiar California names "without knowledge" as to the names which would be used and (c) 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 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 (a), (b) and (c) 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 previously obtained by Forbes and Holmes and decreased in similar fashion at night for the capital letters. Somewhat different distance values reported in another previous study can be accounted for on the basis of certain uncontrolled variables in the method of recording which was used in the other study.
6. 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.

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	"	1.18
C	0.80	0.11	"	1.06
D	0.81	0.20	"	1.16
E	0.77	0.21	"	1.13
F	0.74	0.17	"	1.06
G	0.80	0.11	"	1.06
H	0.82	0.30	"	1.27
I	0.20	0.30	"	0.65
J	0.77	0.16	"	1.08
K	0.84	0.16	"	1.15
L	0.77	0.16	"	1.08
M	1.04	0.30	"	1.49
N	0.84	0.30	"	1.29
O	0.84	0.10	"	1.09
P	0.82	0.25	"	1.22
Q	0.84	0.10	"	1.09
R	0.82	0.20	"	1.17
S	0.82	0.80	"	1.05
T	0.75	0.04	"	1.94
U	0.83	0.30	"	1.28
V	0.92	0.08	"	1.15
W	1.08	0.08	"	1.31
X	1.01	0.08	"	1.24
Y	1.01	0.06	"	1.22
Z	0.82	0.26	"	1.23

Average Width Weighted for Occurrence in California Place Names

Neat Letters = 0.81

Letter plus spacing = 1.13

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	"	1.26
c	0.85	0.14	"	1.16
d	0.84	0.23	"	1.24
e	0.85	0.14	"	1.16
f	0.55	0.10	"	0.82
g	0.85	0.23	"	1.25
h	0.84	0.34	"	1.35
i	0.25	0.34	"	0.76
j	0.47	0.12	"	0.76
k	0.83	0.23	"	1.23
l	0.25	0.34	"	0.76
m	1.42	0.34	"	1.93
n	0.85	0.34	"	1.36
o	0.88	0.12	"	1.17
p	0.84	0.23	"	1.24
q	0.86	0.23	"	1.26
r	0.65	0.20	"	1.02
s	0.83	0.09	"	1.09
t	0.67	0.10	"	0.94
u	0.85	0.34	"	1.36
v	1.01	0.06	"	1.24
w	1.32	0.08	"	1.57
x	1.03	0.10	"	1.30
y	1.07	0.08	"	1.32
z	0.87	0.14	"	1.18

Average Width Weight for Occurrence in
California Place Names

Neat Letters = .77
Letter plus Spacing = 1.15

Table 3

Actual Medians and 85 Percentile Values
for "Scrambled" Letter Observations
Based on Total Distribution for Four Words of Each Size

Daylight Observations						N=109 to 112	
Capitals			.	Lower Case			
Letter Height (Inches)	Distances in Feet		"Loop" Height (Inches)	Distances in Feet			
	Median	85 Percentile		Median	85 Percentile		
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		

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					
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

Letter or "Loop" Height	Distance in Feet					
	Capitals			Lower Case		
	Median	85 Percentile		Median	85 Percentile	
	Scrambled					
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	



Figure 1

An Example of a California Freeway Sign
Using Lower Case Letters



Figure 2a

Observations in Progress
Showing how the observers spread out as each makes his own
judgments. The sign bridge is in the far distance.



Figure 2a

Observations in Progress
Showing how the observers spread out as each makes his own judgments. The sign bridge is in the far distance.



Figure 1

An Example of a California Freeway Sign
Using Lower Case Letters



Figure 1

An Example of a California Freeway Sign
Using Lower Case Letters



Figure 2b

Two Observers Recording an Observation
The 25 ft. interval markers can be seen on the right.



Figure 3

Lower Case Alphabet Letter Designs

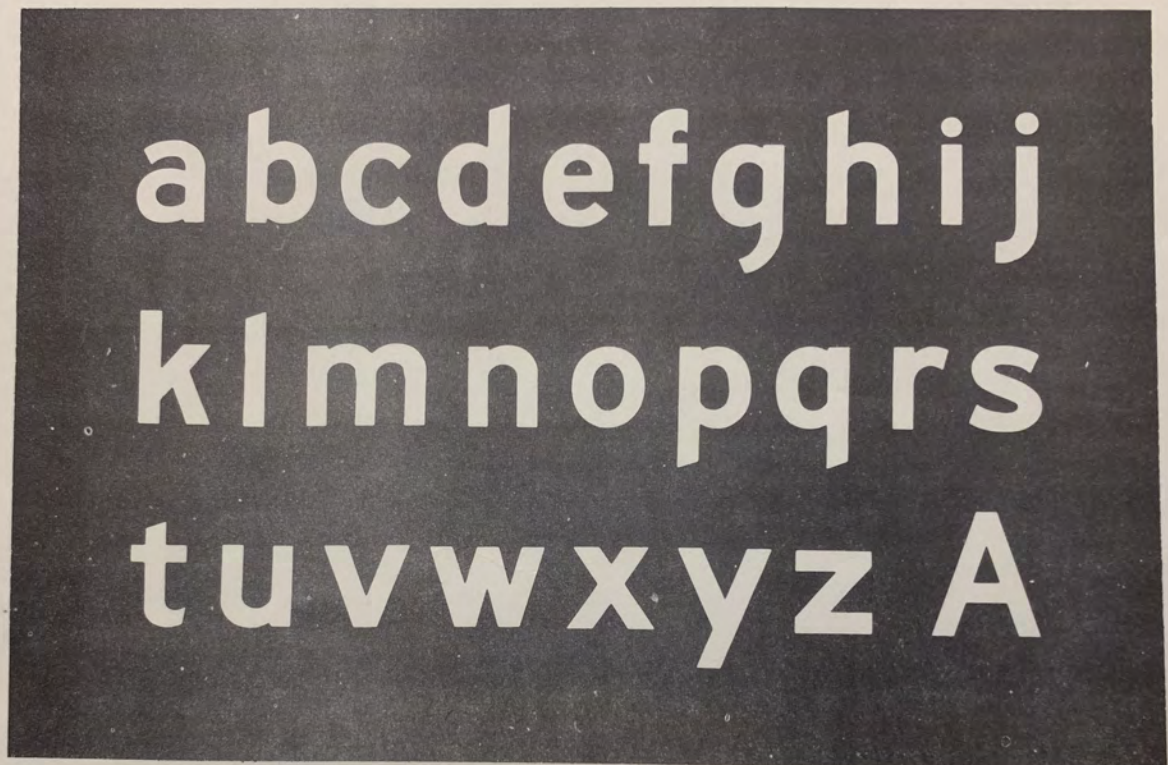


Figure 3

Lower Case Alphabet Letter Designs



Figure 2b

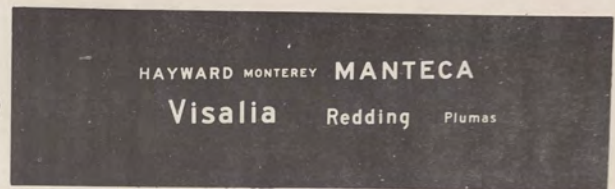
Two Observers Recording an Observation
The 25 ft. interval markers can be seen on the right.



Figure 4

The Sign Bridge in Operation
Test signs are being assembled on the table while
others are being hoisted into place.

(b)



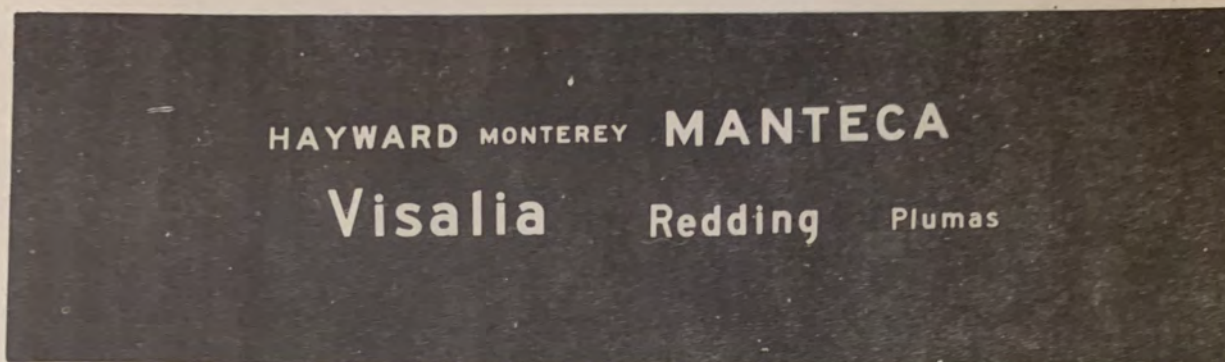
(a)



Figure 5

Six Word Combinations in Place
(a) Daylight (b) Night
From a distance, the background appeared to be an
even black rectangle against the sky

(b)



(a)



Figure 5

Six Word Combinations in Place

(a) Daylight (b) Night

From a distance, the background appeared to be an even black rectangle against the sky



(b)

(a)

Figure 4

The Sign Bridge in Operation
Test signs are being assembled on the table while
others are being hoisted into place.

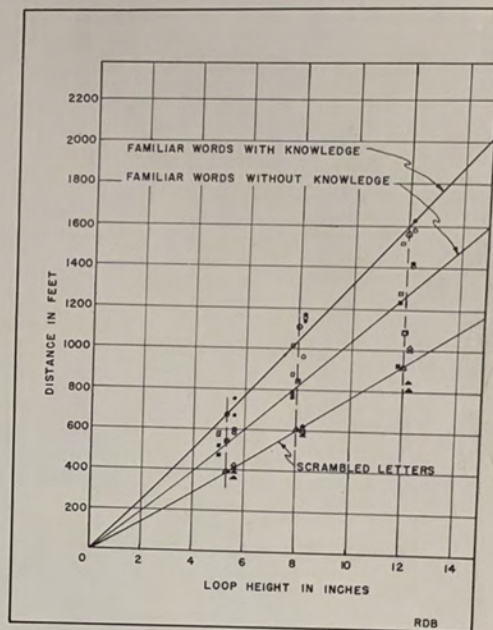
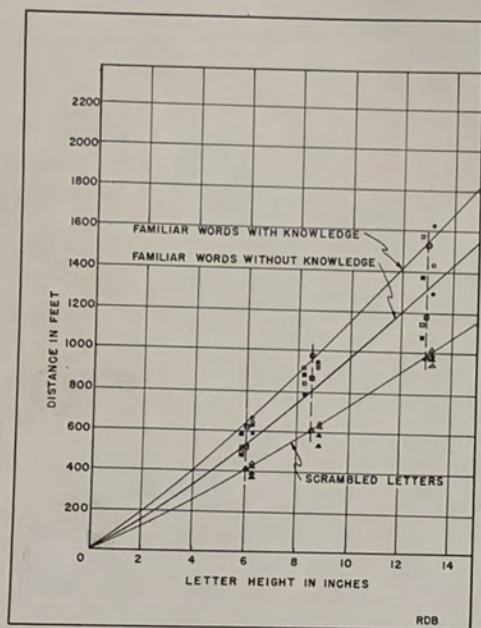


Figure 6

Effects of Familiarity - Daylight
 Capital letters, left; lower case, right
 Medians of total distribution of 4 words on vertical dashed
 line; individual word medians to right or left of line.
 Trend lines fitted by inspection.

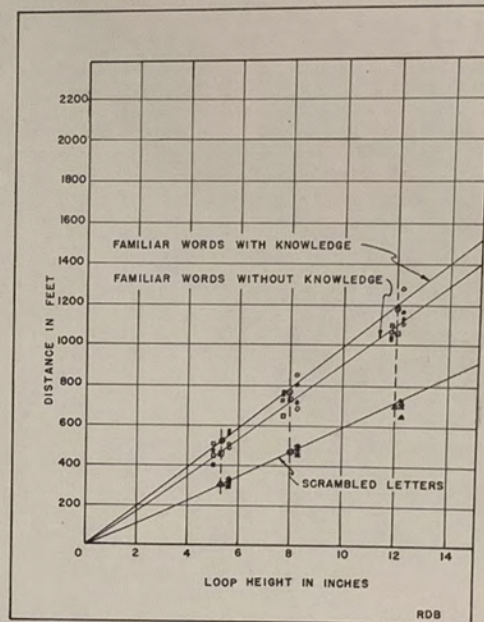
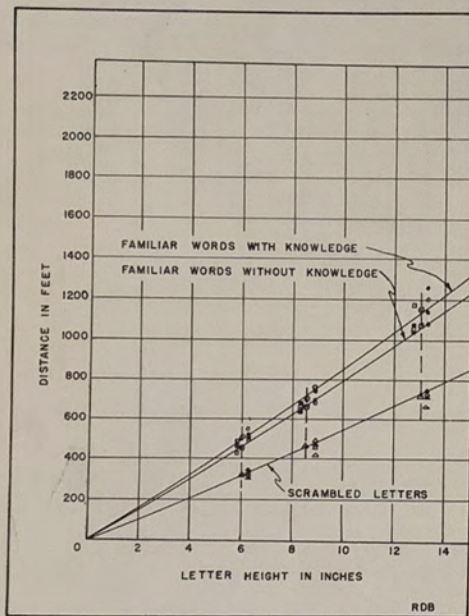


Figure 7

Effects of Familiarity - Night
 Capital letters, left; lower case, right.
 Medians of total distribution of 4 words
 on vertical dashed line; individual word
 medians to right or left of line.
 Trend lines fitted by inspection.
 Illumination by fluorescent tubular lights;
 brightness 12-18 foot lamberts

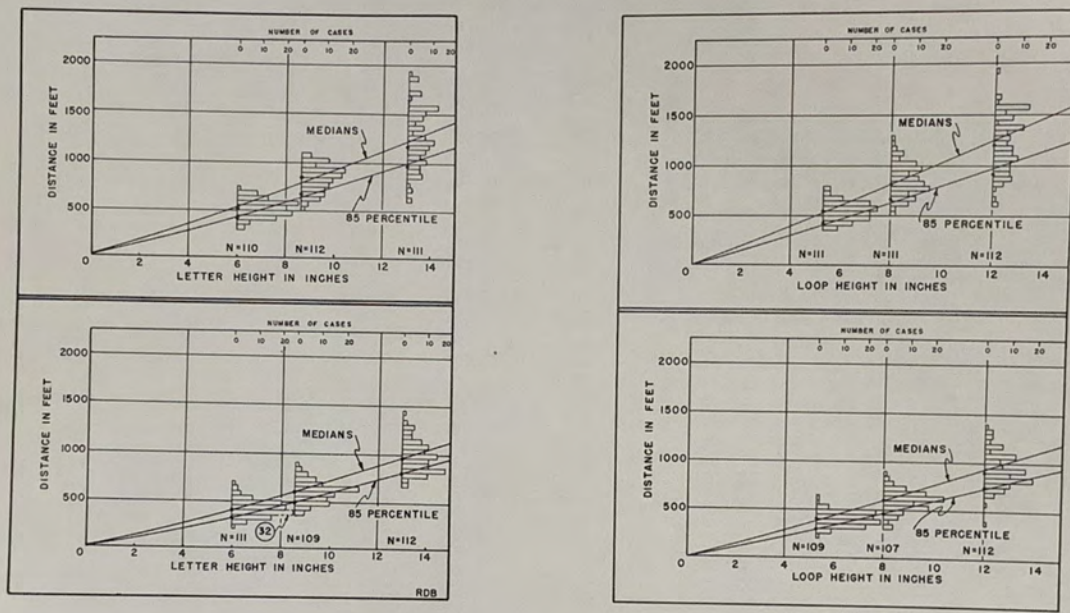


Figure 8

Variability of Observations of "Scrambled" Letters and Place Names "Without Knowledge", as shown by total frequency distributions of four test words for each size, form of letter and type of observation.

Left, capitals; right, lower case
 "Scrambled", below; "without knowledge", above
 Medians and 85 percentile points shown;
 trend lines by inspection

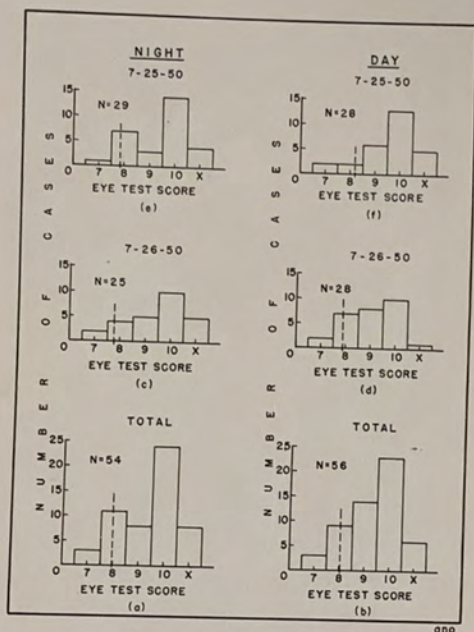


Figure 9

Frequency Distribution of Eye Test Scores
A score of 8 represents "normal" or 20/20 vision.

X = no test given.

Note that the two day groups and the two night groups show similar distributions, both having better than normal vision. Vertical dashed lines represent 85 percentiles. These are very close to a "normal" score.

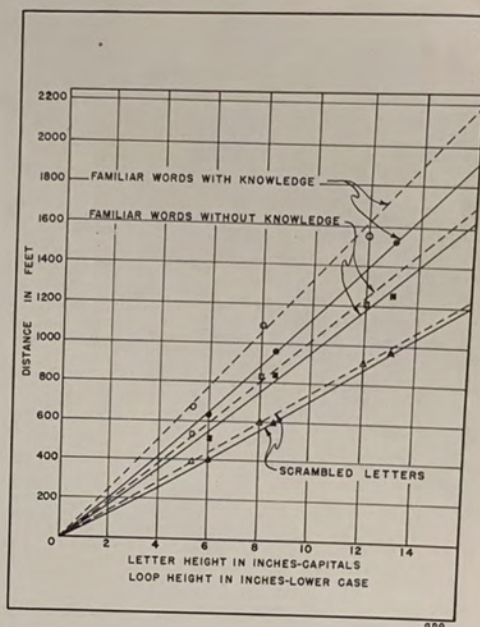


Figure 10

Comparison Based on Letter Height and "Loop" Height - Daylight

Capital letters = solid lines and symbols.
Lower Case = dashed lines, open symbols.

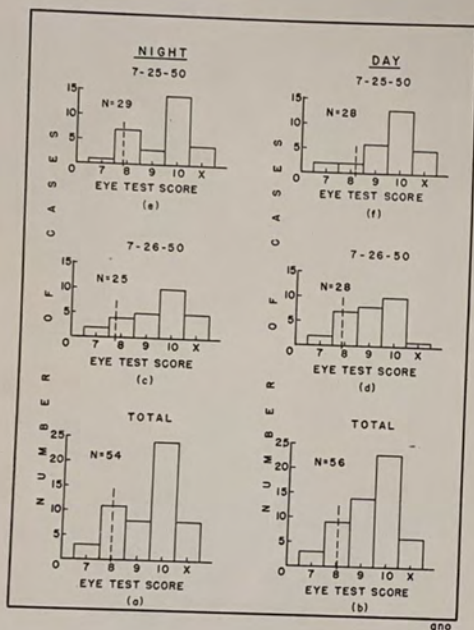


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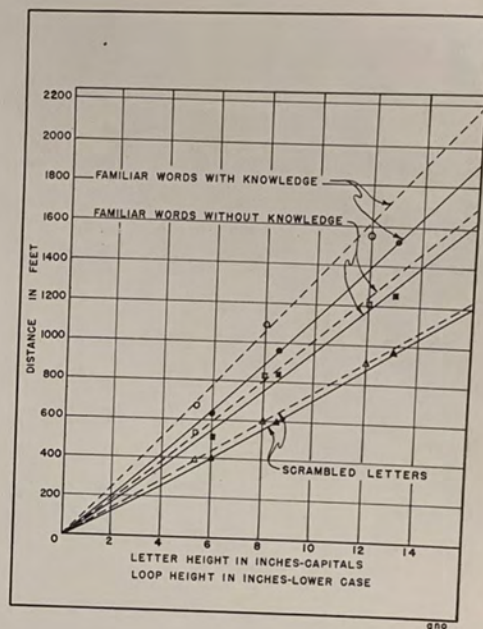


Figure 10

Comparison Based on Letter Height and "Loop" Height - Daylight

Capital letters = solid lines and symbols.
Lower Case = dashed lines, open symbols.

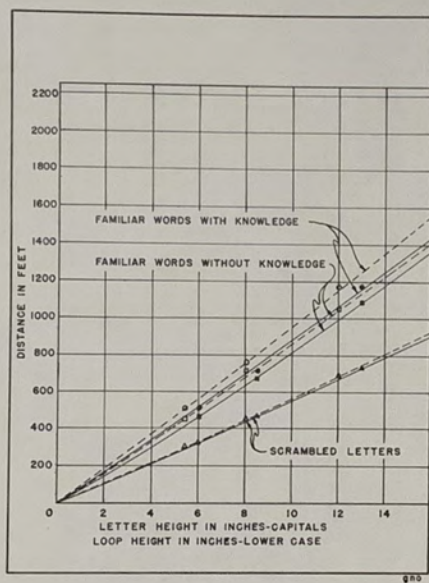


Figure 11

Comparison Based on Letter Height and "Loop" Height -
Night
Capital letters = solid lines and symbols.
Lower Case = dashed lines, open symbols.

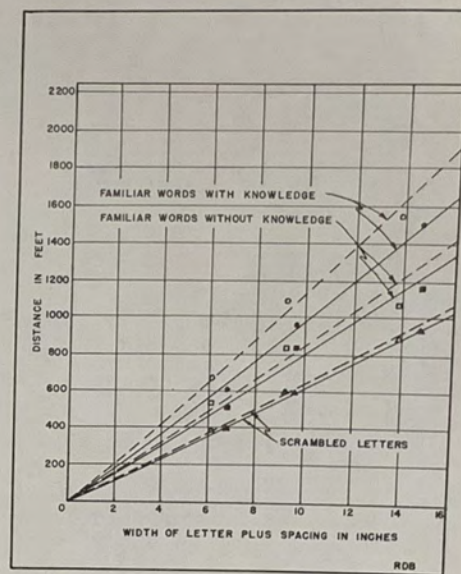


Figure 12

Comparison Based on Letter Width Plus Spacing -
Daylight
Capital letters = solid lines and symbols.
Lower Case = dashed lines, open symbols.

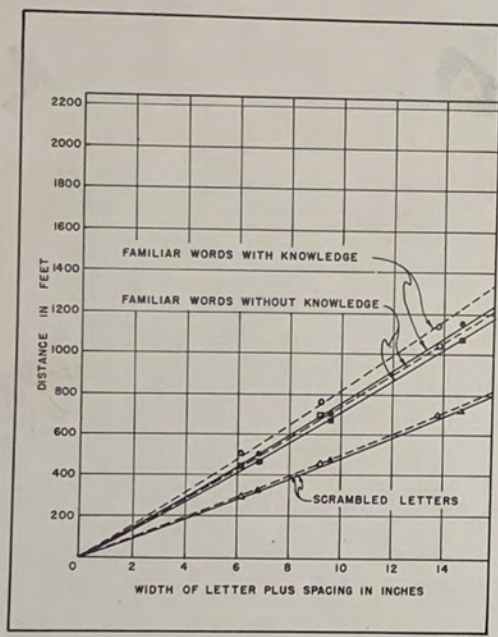


Figure 13

Comparison Based on Letter Width Plus Spacing - Night

Capital letters = solid lines and symbols.

Lower Case = dashed lines, open symbols.

(c) Berkeley →
Telegraph Ave.

(b) BERKELEY →
TELEGRAPH AVE.

(a) Berkeley →
Telegraph Ave.

Figure 14

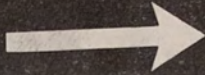
Illustration showing
Alternate Assumptions as to Vertical Spacing

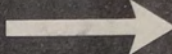
(a) 2.25 x "stem" height

(b) 2.5 x letter height

(c) 2.5 x "loop" height

out 2-2-11

(c) **Berkeley** 
Telegraph Ave.

(b) **BERKELEY** 
TELEGRAPH AVE.

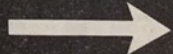
(a) **Berkeley** 
Telegraph Ave.

Figure 14

Illustration showing
Alternate Assumptions as to Vertical Spacing

- (a) 2.25 x "stem" height
- (b) 2.5 x letter height
- (c) 2.5 x "loop" height

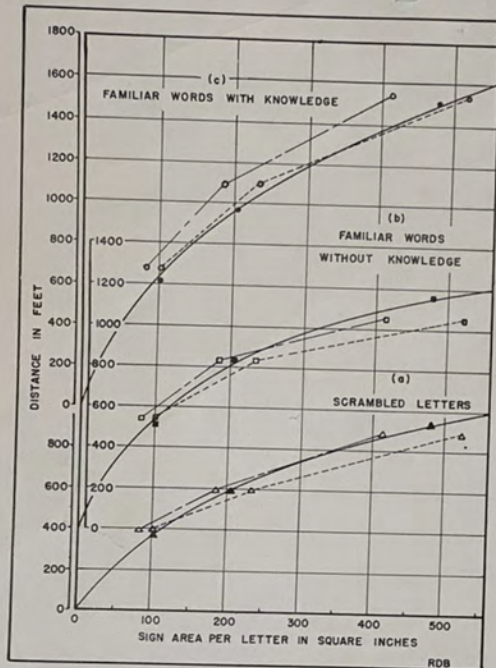


Figure 15

Comparison of Sign Area Required per letter -
for Daylight Observations

- = Capital letters, assuming 2.5 x letter height
- - - = Lower Case, assuming 2.5 x "loop" height.
- ... = Lower Case, assuming 2.25 x "stem" height

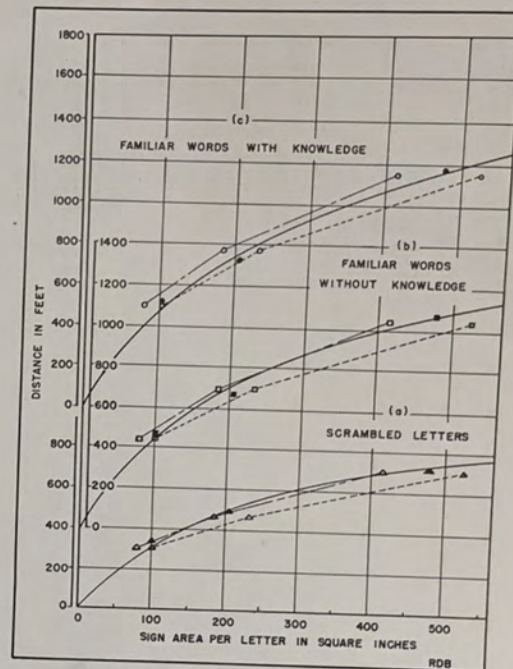


Figure 16

Comparison of Sign Area Required per letter -
for Night Observations