

PERCEPTION AND VISIBILITY OF AUTOMOBILE LICENSE PLATES

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SYNOPSIS

Increasing motor vehicle speeds and interstate travel have emphasized the need for easy and accurate identification of vehicles under various traffic conditions, while growing registrations have tended to cause crowding of license plates and the use of legends difficult to perceive and retain. Tests have accordingly been devised to compare the merits of plain numeral and letter-numeral systems, various sizes and styles of legends, and various groupings, including the so-called "Devine" system. Based on observations by 50 persons of specially designed black and white cards, 2,500 carefully controlled readings were obtained. Among the conclusions drawn, it was found that all six-character combinations were superior to seven-digit numbers, that the use of letters increases the difficulty of perception, and that grouping of characters by twos or threes improves perception. A gain in visibility seemed to result with six and seven-character plates when the "Devine" system was used. No appreciable difference was noted between round and block numerals, but open-type numerals were superior to both. Numerals with a width one-half their height were more visible than those with a smaller ratio of width to height. The flat-top three was very frequently mistaken for 5, while 8 and 9 also caused considerable confusion.

During recent years, the improvement of both automobiles and roads has produced a concurrent rise in average traveling speeds. This in turn, causes a need for license plates of higher visibility, yet sufficiently restricted in size so that they will not be unduly expensive, nor improperly illuminated by the tail light at night. Regardless of its size, the plate should be as efficient as possible. The very large number of cars registered by some states has created legends apparently difficult to perceive and retain, and in many cases, has resulted in crowding of the plate. In some cases, various letter-figure combinations are being employed in an attempt to remedy this condition—with varying degrees of success.

REQUIREMENTS OF LICENSE PLATES

License plates should identify the vehicle in such a manner as to be easily and accurately read under various traffic conditions and should show that the proper plate is being carried. County name, symbols, advertising matter, and

other extraneous items tend to reduce legibility and to cause confusion.

The identity of the state is usually given by the color combination and the state name. Since cars now travel freely among the states, this identification has become of growing importance. Professor Wiley in his bulletin "License Plates for Illinois," suggests that the state name should be visible at least half as far as the license number, and in any case, it should be visible for at least 70 feet. At present, most plates are very deficient in this respect.

It is essential that enforcement officers be able to recognize the proper yearly plate. This information is ordinarily given by the color combination and the year in numerals. The year should be as visible as the state name, and the color combination should be changed from the previous year. Identification of type of vehicle is accomplished usually by key letters in the license number, or by the words "truck," "commercial," "dealer," etc., placed on the plate.

The intrinsic legibility of a license

plate will depend upon the combined effect of the following items:

- (a) Size and shape of plate.
- (b) Height and width of characters.
- (c) Style and width of stroke of characters.
- (d) Spacing and grouping of characters.
- (e) Color combination.
- (f) Amount of gloss on the figures and background.
- (g) Area ratio of legend to background.
- (h) Content and arrangement of the items on the plate.
- (i) Number of characters in the legend.
- (j) The letters selected for use in combinations.
- (k) The number of letters used in the legend.

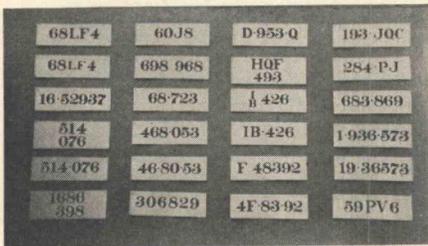


Figure 1

External conditions which will also affect the legibility are:

- (a) Distance of the observer from the plate.
- (b) Angle at which observer views plate.
- (c) Intensity and color of plate illumination.
- (d) Angle at which most of the light strikes the plate.
- (e) Conditions of vehicle movement (i.e., stationary, slow or high speed, receding or approaching, smooth or rough road, etc.)
- (f) Amount of dirt or moisture on the plate.
- (g) Atmospheric conditions.
- (h) Position of the plate on the vehicle.
- (i) Amount of dust which is thrown up by the car, or by passing traffic.

Many of these later items are beyond the control of the plate designer. It has been assumed that the plate which is most legible and most easily perceived when stationary and under varying conditions of daylight will be the most satisfactory under the many varied traffic conditions. This will probably be approximately so except for the matter of color combination. Dr. A. R. Lauer found that certain color combinations

which were satisfactory in daylight were indistinct under artificial illumination.¹

In this paper, investigations are reported with particular reference to:

1. A comparison of the perceptibility of the various systems of numbering used by states whose registrations exceed one million passenger cars.

2. The effect on perception of the different methods of grouping the characters, including the proposed "Devine" system.

3. The effect on perception and retention of introducing one or more letters in the legend.

4. A comparison of the visibility of different styles of numerals.

5. Limited studies of width of stroke, and its effect on the visibility.

PERCEPTION TESTS

Purpose: The object of these tests was to compare the merits of the plain numeral and the various letter-numeral systems grouped in different ways. The effect of using letters the same size, or either larger or smaller than the numerals in the group, was experimented with. So far as possible the many variables with which the experimenter finds himself confronted in this type of investigation were eliminated.

Apparatus: For significant comparisons, it was necessary that the variables of size, style and stroke of the characters, spacers, borders, symbols, and color combinations be eliminated in the tests. The use of actual plates, therefore, was not possible. Cards were made using black characters 2 in. high on a white background. A few of the cards used are illustrated in Figure 1.

The device used for displaying the cards to the observer for a carefully controlled interval of time is illustrated in

¹ Unpublished Bulletin, "A Psychological Analysis of the Legibility of Automobile License Plates."

Figures 2 to 4. A 4- by 6-ft. piece of $\frac{3}{4}$ -in. plywood is held in a vertical position by strap iron braces. The display window was cut out, and slotted guides were attached to the rear side of the board to permit the insertion of the cards. The arm "A" (Fig. 2) was cut

pivot "E." A bushing in the rocker arm permits the shaft "F" to revolve. This shaft passes through a short curved slot in the board (not visible in the pictures) thus allowing a small vertical movement of the rocker arm. A plywood cam "G" is rigidly attached to the shaft on the

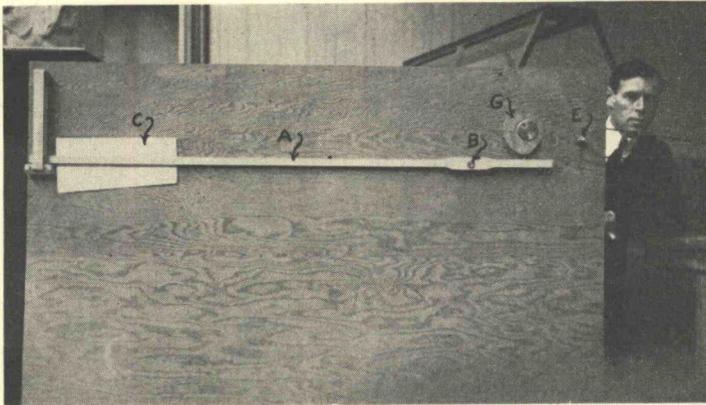


Figure 2

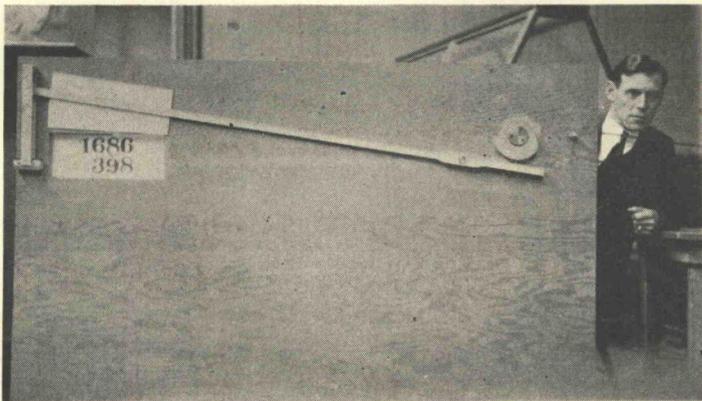


Figure 3

from hard wood, and mounted to the board by means of the pivot "B." The left end of the arm travels in a guide to prevent any tendency to horizontal movement. The screen "C" is attached to the arm, and by this means, the display cards are concealed and exposed as desired. The rocker arm "D" (Fig. 4) is attached to the board by means of the

front side of the board, and a 5-inch pulley is similarly attached on the rear side.

In Figure 4 can be seen the apparatus for operating the device. A $\frac{1}{8}$ H. P. 110-volt direct current motor was connected to the 16 to 1 speed reducer "J," by means of a flexible shaft. A 5-in. pulley was mounted on the vertical shaft

of the reducer, and belted to the 5-in. pulley "H" at the rocker arm. A rheostat in series with the armature of the motor permitted control of the motor speed from about 200 r. p. m. to 1200 r. p. m.

The spring "K" (Fig. 4) normally holds the rocker arm in its extreme high position. In this position, the cam completely clears the tracer on the right end of the shield arm so that the shaft may revolve continuously without exposing the card. An arrow inscribed on the back of the board together with the

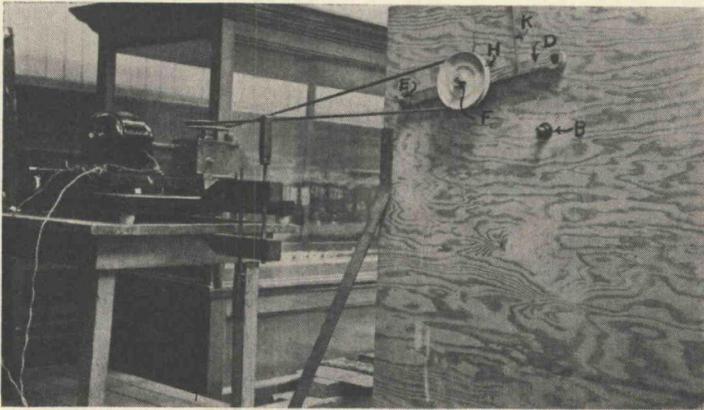


Figure 4

shaded portion of the pulley (Fig. 4) indicates to the operator when the small circumference of the cam is directly over the tracer on the shield arm. At this instant, the operator may press down the rocker arm to its low position. The arm is held down for one revolution of the cam, and then released. The card is thus exposed for a carefully controlled interval of time depending upon the speed of the motor.

Combinations Tested: Several states have registrations which total over a million passenger cars. Illinois employs the straight numerical system, thus having many plates with seven digits in the legend. New York, California, Michigan and Texas use one letter in a fixed posi-

tion, thus reducing the maximum number of characters to six. The total number of characters on Pennsylvania and Ohio plates is reduced to five by the use of two letters in combination with numerals.

In a system proposed by Mr. A. W. Devine, Assistant Registrar in Massachusetts, license numbers would be grouped in threes, and the second group placed *below* the first. Thus the number 123,456 would appear $\begin{matrix} 123 \\ 456 \end{matrix}$. Similarly, this could be applied to seven-digit

numbers, such a legend appearing as $\begin{matrix} 1234 \\ 567 \end{matrix}$. An application of the "Devine" system has been proposed in which two groups of three characters each would appear on *all* plates. The upper group would always consist of letters, and the lower group of numerals. In this way, certain letters could be used to give information as to the passenger car or truck classification. At least two samples of each of these types were tested.

Arrangement of characters was investigated. Six-digit numbers were grouped in twos, threes, and spaced equally. Seven digits arranged in the form 12-34567 were included. This occurs on Iowa plates since each of the 99 counties is

allotted a "county number," which is followed by the car number. Seven digits as arranged on Illinois plates were also included.

The effect of the relative positions of the letter- and number-groups was tested by placing the letter-group both first and last, and also by inserting the number group between the letters (as in Ohio and Pennsylvania). Some other combinations were included for comparison purposes.

Method of Testing. An attempt was made to preclude or at least reduce to a minimum all the possible variables that enter into a psychological investigation of this kind. It will be understood, for example, that one group of six digits might be much more difficult to perceive and retain correctly than another group of six, due to the particular digits used in the two groups. In testing the effect of systems of grouping, therefore, it would be erroneous to compare the number 698 968 grouped in threes with the number 11·22·33 grouped in twos, or with the number 654321 spaced equally. To eliminate this condition, the fifty cards were carefully arranged in two groups, designated "A" and "B." For testing the effect of grouping, one number would appear as 638 492 in the "A" group, and the same number would appear differently grouped in "B," viz, 63·84·92. The two groups were perceived by the same observers, with an interval of approximately a week between the two tests to obviate the possibility of memory affecting the results. Differences in perception could then be attributed mainly to the effect of the grouping.

As an observer proceeds through the test, he will gradually improve somewhat in his perception due to practice. It is hoped that this factor was minimized to a negligible amount by starting the series of cards at different points for various observers, so that what might

be the first card for one observer would come near the middle or end of the series for another. Also, about half of the observers were given the "A" group first, and then the "B" group the following week. The other half viewed the two series in the reverse order. To further eliminate this factor, and also furnish an additional check on the results, a counter number was used for each item tested. For example, if the number appeared in the form 382·465 in the "A" series, and the form $\begin{matrix} 382 \\ 465 \end{matrix}$ in the "B" series, then

a different number would appear as $\begin{matrix} 963 \\ 287 \end{matrix}$ in the "A," and as 963·287 in the "B." Similar procedure was employed for the various items that were to be investigated.

Preliminary tests were made with several different observers to determine a suitable speed at which to operate the mechanism. It was decided to operate the motor at 640 r p m, thereby producing a cam speed of one revolution in $1\frac{1}{2}$ min. The cam was designed to expose the card during 45 per cent of its revolution. The interval of card exposure is thus calculated to be 0.67 sec.

The observer was seated at such distance from the board that the cards would be easily visible. A test sheet numbered from 1 to 25 was provided. The following instructions were read:

"Various number and letter groupings as appear on existing license plates and some proposed groupings will be placed in the opening behind the shield. The shield will be opened for a short interval of time, and you are to observe and record the legend which appears."

"Regardless of the arrangement on the card, you are to record the legend in a straight line. For example (showing a sample of Connecticut plate $\begin{matrix} B \\ X \end{matrix} 288$) this should be recorded as BX288, and (showing a sample of the Devine system $\begin{matrix} 377 \\ 398 \end{matrix}$) this is to be recorded as 377398. Any dots or dashes which may appear are to be neglected."

TABLE 1
SUMMARY OF RESULTS OF PERCEPTION TESTS

"A" group					"B" group				
Number	C	N	%W	%C	Number	C	N	%W	%C
36 286	2	1	2	98	68LF4	9	5	10	90
F48392	42	20	40	60	60J8	0	0	0	100
593 652	25	15	30	70	468 053	15	7	14	86
DQ 953	32	16	32	68	193 JQC	16	11	22	78
1 652 937	98	35	70	30	1686 398	108	40	80	20
68LF4	5	5	10	90	D 953 Q	22	9	18	82
306 829	3	3	6	94	698 968	69	23	46	54
LZP 047	43	20	40	60	HQF 493	42	20	40	60
46 80 53	23	11	22	78	284 PJ	2	2	4	96
P 284 J	8	5	10	90	16 52937	72	31	62	38
T D385	5	3	6	94	329E	1	1	2	98
514 076	13	6	12	88	683 869	48	20	40	60
3E29	1	1	2	98	68 723	2	1	2	98
59PV6	10	4	8	92	I B426	9	5	10	90
1686 398	113	39	78	22	1936 573	98	35	70	30
9ZT63	18	10	20	80	9zt63	19	12	24	76
HQF 493	67	29	58	42	514 076	2	2	4	96
683 869	31	14	28	72	LZP 047	48	25	50	50
J608	2	1	2	98	59 36 52	34	16	32	68
1306 536	23	13	26	74	TD385	6	4	8	92
9E 27 04	11	7	14	86	1306 536	44	19	38	62
19 36573	107	34	68	32	4F 83 92	28	16	32	68
IB 426	2	1	2	98	306829	11	7	14	86
698968	81	32	64	36	59PV6	12	6	12	88
JQC 193	41	23	46	54	E92704	28	15	30	70

KEY

- C = Total number of individual characters wrong or omitted
 N = Total number of times the legend was perceived incorrectly
 %W = Per cent of the time the legend was perceived incorrectly
 %C = Per cent of the time the legend was perceived correctly

"I will call 'READY' as a warning each time before the shield is to be opened. You will observe the card, and then I will give you sufficient time to record the number. Try your best to get the correct legend."

The 25 cards were successively inserted in the opening and the recordings made. A week later, the same procedure was followed with the remaining series of cards. Fifty individuals were tested in this way, making a total of 2,500 readings. Most of the observers were students at the University of Vermont, but some older people from various walks of life were also included.

Table 1 gives a summary of the results obtained from the 100 test sheets.

Effect of the Number of Characters
As will be observed from these data, the particular combination of digits used in a group will greatly affect its correct perception and retention. Certain number groupings possess inherent characteristics which render them difficult to perceive correctly. Thus, the number "306,829" was correct 90 per cent of the time, while the similar group "698,968" fell as low as 55 per cent. The large number of errors in the latter were due mainly to the fact that the observer tended to record the same digits of the two groups in similar sequence, namely, "698,698". However, in comparing the relative perceptibility of 5-, 6-, and 7-digit groups, the use of several groups of each kind will tend to reduce this effect, and seem to justify the following discussion.

The percentage of correct readings of the all-numeral groups are given in Table 2.

Thus, for the short observational period of a fraction of a second, which would be the case when attempting to obtain the license number of a speeding car, it may be seen that the difficulty of perception increases greatly with the increase in the number of characters. The 5-digit groups were read

correctly practically all the time while those with 6 digits were perceived correctly only three-fourths of the time. When the digits were increased to seven, the correct readings fell off to considerably less than half the total. Other things being equal, 6-digit plates are decidedly superior to those with 7, and 5-digit plates in turn are much more easily perceived than those with 6.

Assuming an observational period of 0.67 second, little benefit apparently would be gained by an attempt to reduce five-digit plates to four.

Effect of Use of Letters Many states have introduced letters into license numbers, either for classification purposes, or to reduce the number of characters.

TABLE 2

	Number of groups tested	Per cent read correctly
5-digit	2	98
6-digit	12	74
7-digit	8	39

Some disadvantages may result from this practice. Supposing, for example, that one character has been missed in an attempt to catch the number of a speeding car. If the plate contains numerals only, the car must be one of ten. If 24 letters are also used, the vehicle may be one of 34, thus greatly increasing the difficulty in tracing the car. The similarity of some letters to certain other letters and numerals introduces more elements of possible confusion. Obviously, certain letters are inherently poor for this reason, and should not be used.

License numbers are frequently reported by telephone or radio. Hence, the question of audible confusion between letters of similar sound should be considered. The selection of proper letters for use will be discussed later.

It is claimed that letters on license plates increase the perception time. This

was tested by comparing groups containing one, two, or three letters with all-numeral groups. Again, the variable due to the different characters used can be minimized only by employing several groups of each type for comparison.

The average percentages correct for all the groups of each type were computed, and found to be as in Table 3.

It appears reasonable to conclude that the introduction of letters increases errors in perception, and that the errors increase in proportion to the number of letters used.

To study further the combined effects of the number of characters in the legend,

of grouping will to some extent affect the perception of any one type. However, since approximately the same methods of grouping were employed for the numbers in either the 5-, 6-, or 7-character class, the above comparative results seem justified.

From these data, it may be noted that any 6-character group is superior to all 7-character groups. Six-character plates containing one letter (used by California, Michigan, and New York) should be perceived correctly 32 per cent more of the time than the 7-digit plates (used by Illinois, and to some extent by Iowa). Five character plates with two

TABLE 3

Characters used in the group	Number of groups tested	Read correctly	Error increase due to letters
6 numerals—0 letters	12	% 76	%
5 numerals—1 letter	4	71	5
3 numerals—3 letters	6	57	19
5 numerals—0 letters	2	98	
3 numerals—2 letters	14	87	11
3 numerals—1 letter	4	98	

and the use of one or more letters, Figure 5 was constructed. From Table 2, the percentages correct for the all-numeral groups were plotted and connected with a full black line. From Table 3, it was found that the inclusion of one letter in a 6-character group increased the perception error 5 per cent. It was assumed that the introduction of one letter in a 5- or 7-character group would have a similar effect. This may not be strictly true, but probably is nearly so. Groups including one letter are plotted with a dotted black line. Similar procedure was followed with groups containing two and three letters, and plotted with the dash line and the dot-dash line respectively.

It should be remembered that these are average values for several numbers grouped in different ways. The method

of grouping will to some extent affect the perception of any one type. However, since approximately the same methods of grouping were employed for the numbers in either the 5-, 6-, or 7-character class, the above comparative results seem justified. From these data, it may be noted that any 6-character group is superior to all 7-character groups. Six-character plates containing one letter (used by California, Michigan, and New York) should be perceived correctly 32 per cent more of the time than the 7-digit plates (used by Illinois, and to some extent by Iowa). Five character plates with two letters (Ohio and Penn.) show 16 per cent improvement over the 6-character style just mentioned, and are 48 per cent better than the 7-digit groups. No advantage in perception would be gained by the introduction of a letter to reduce 5-digit plates to four characters. Both types were read correctly 98 per cent of the time. The disadvantages involved with the use of a letter seem to outweigh any advantage of possible plate size reduction.

Effect of Method of Grouping With the use of the straight numerical system, the normal method of grouping has been by threes. Thus, the 7-digit Illinois plate appears as "1·234·567". The system of employing distinguishing county numbers followed by the vehicle number has brought about a

different grouping in some states The same number would appear on Iowa plates as 12 34567 The introduction

TABLE 4

Group	Number of times read incorrectly	Per cent read correctly
698 968	23	54
698968	32	36
306 829	3	94
306829	7	86
593 652	15	70
59 36 52	16	68
468 053	7	86
46 80 53	11	78
Average for the legends spaced equally		61%
Average for the same legends grouped in threes		74%
Average for the legends grouped in twos		73%
Average for the same legends grouped in threes		78%

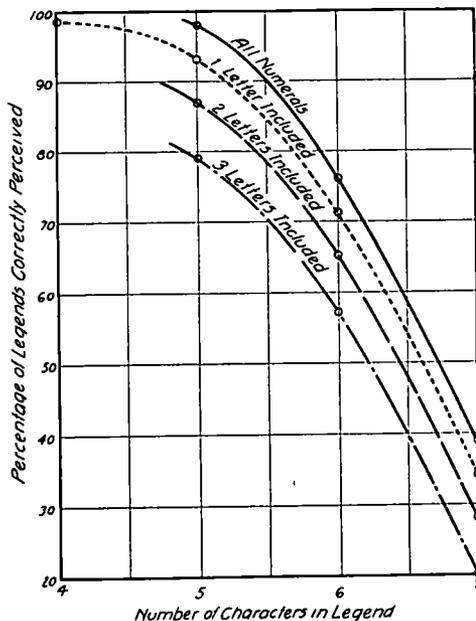


Figure 5 Curves Showing Effect on Correct Perception of Number of Characters in Legend and Number of Letters Included in the Legend

TABLE 5

State	Group	Number of times read incorrectly	Per cent read correctly
Michigan	F 48392	20	60
N Y and California	4F 83 92	16	68
Michigan	E 92704	15	70
N Y and California	9E 27 04	7	86
Average for Michigan type			65%
Average for N Y and California type			77%

of letters has led to other variations California and New York use three groups of twos, thus "5E 46 · 82," while Michigan separates the letter from the numerals, thus "F 17785" (not consistently, as there is no separation on many Michigan plates) On the 2 letter-3 numeral Ohio plates, one will note the following arrangements AB · 345, 345 · AB, A · 345 · B, 3 · AB · 45, and 34 · AB · 5 Pennsylvania and New Jersey do not separate the characters into groups

A comparison was made of the perception due to different ways of grouping In order to eliminate the variable due to the particular characters appearing in the group, one arrangement of certain characters was used in series "A," and a different grouping of the same characters was placed in series "B" The results of 6-digit numbers grouped in twos, threes, and equally spaced are in Table 4

The best grouping for 6-digit num-

bers appears to be by threes. This result would be expected, as this is the normal method of grouping derived from our decimal system. However, the difference between grouping by threes and by twos may not be enough to be significant. Preference between these two ways probably varies with the individual, some remembering easier by twos, and others by threes. Six digits grouped

Table 6 shows a comparison of the 7-digit groupings used on Illinois and Iowa plates.

The small difference between the two seems to warrant no definite conclusions. Suffice it to state that 7-digit numbers grouped in any way are not readily perceived.

Connecticut plates are unique for two reasons. First, they are "permanent,"

TABLE 6

State	Group	Number of times read incorrectly	Per cent read correctly
Illinois	1 652 937	35	30
Iowa	16 52937	31	38
Illinois	1 936 573	35	30
Iowa	19 36573	34	32
Average for Illinois type			30%
Average for Iowa type			35%

TABLE 7

Group	Number of times read incorrectly	Per cent read correctly
IB 426	1	98
I B 426	5	90
TD385	4	92
T D 385	3	94
Average for conventional form		95%
Average for Connecticut form		92%

TABLE 8

Group	Number of times read incorrectly	Per cent read correctly
(Penna) 68LF4	5	90
68LF4	5	90
(Penna) 9ZT63	12	76
9ZT63	10	80
59PV6	4	92
59PV6	6	88

either by twos or threes are quite superior to the same equally spaced.

A comparison of the groupings employed by California, New York, and Michigan is shown in Table 5.

Some advantage is to be gained by grouping in twos rather than merely separating the letter from the numerals. This seems in accord with the previous findings, as the Michigan type is in effect a 5-digit number spaced equally, with an additional character to observe

and are not renewed annually. Secondly, the system of numbering is different from that of any other state, the legend consists of two letters, one placed over the other, followed by three numerals. A serious objection to this arrangement is that the letters are made much smaller than the numerals, thus materially reducing visibility.

Comparisons were made with groups arranged in this manner, and the same groups arranged in the conventional

form The numbers used were as given in Table 7

The results are insignificant as far as perception is concerned

Pennsylvania uses combinations of letters and numerals A maximum of two letters appear on the plate These are always placed together, but may appear in any position in the legend The letters

No appreciable difference was noted in the perception of the legend due to the relative size of the letters From the standpoint of legibility, they should be made at least as large as the numerals

Devine System of Grouping In 1936, Mr A W Devine, Assistant Motor Vehicle Registrar in Massachusetts, suggested a form of grouping which departs

TABLE 9

Group	Number of times read incorrectly	Percent read correctly
514 076	6	88
514	2	96
076		
683 869	20	60
683	14	72
869		
1686 398	39	22
1686	40	20
398		
1306 536	19	62
1306	13	74
536		
LZP 047	25	50
LZP	20	60
047		
HQF 493	29	42
HQF	20	60
493		

6 characters—all numerals	conventional	74
6 characters—all numerals	Devine	84
7 characters—all numerals	conventional	42
7 characters—all numerals	Devine	47
6 characters—including 3 letters—conventional		46
6 characters—including 3 letters—Devine		60
All groups with conventional arrangement		54
All groups with Devine arrangement		64

Average % read correctly

are made smaller than the numerals Such practice is diametrically opposed to the recommendations of Professor Wiley It is claimed that letters are inherently less legible than numerals, and therefore should be made larger Comparisons of the perception of such groups were made, employing letters larger than, smaller than, and the same size as the numerals These are tabulated in Table 8

considerably from conventional methods now used Essentially, the license number is arranged in *two* lines of three characters each The year and state name are placed vertically at the ends of the plate It is suggested that letters only be used in the top row, and numerals in the bottom, but there seems to be no reason why the arrangement could not be applied to all numeral legends The fol-

lowing advantages are claimed for this system

1 The plates would be considerably shorter, but somewhat wider than most of the present ones. This should provide for more satisfactory illumination from the tail light.

2 All plates would be the same size—an advantage in manufacture, mailing, and mounting on the car.

3 This license number is arranged on a "spot" form instead of an extended line. It should be more easily taken in by the eye.

4 The group of letters is distinctly separated from the group of numerals. People would soon learn that letters only appear in the upper row, hence transposition of letters with figures would be reduced.

Comparisons between the "Devine" and the conventional grouping were made to determine whether accuracy of perception would be increased by this proposed form. The numbers tested, and the results are given in Table 9.

There are indications that some advantage in ease of perception is to be gained by the use of the suggested Devine system. The difference is not overwhelming, averaging 10 per cent for all the groups. It should be noted, however, that this radical departure from the conventional method of displaying numbers might show a decided increase in ease of perception when people became more accustomed to seeing this method of grouping. With the other advantages of plate size previously mentioned, the system may have considerable merit, and deserves serious consideration. The chief objection to the 3 letter-3 numeral form is its low perception value. In this respect, it would be far inferior to any existing plates, save the 7-digit numbers of Illinois and Iowa. Furthermore, many three-letter combinations would arise which would form ludicrous or undesirable words, and should be omitted.

SUMMARY OF TEST DATA

1 All combinations of 6 characters were superior to 7-digit numbers. Five-character legends, in turn, were better than those with 6. There is a greater average difference between 6-character and 7-character groups (34%) than between those with 5 and with 6 (22%).

2 The presence of letters in the group increases the difficulty of perception, this difference increasing with the number of letters appearing.

3 There is not much difference between 6-digit plates grouped by threes or by twos, but either is superior to those with the digits spaced equally.

4 Six-character plates containing one letter are better when grouped by twos than when the letter only is separated from the rest of the number.

5 On 5-character plates containing 2 letters and 3 numerals, it may be slightly preferable to place the letters and numerals in separate groups, although no marked difference was observed.

6 An attempt to contrast the letters with the numerals by the use of small letters (Penna. and Conn.) does not aid in the perception of the number. From the standpoint of legibility, the letters should be made at least as large as the numerals.

7 Some advantage in perception seems to be gained with 6- and 7-character plates if the "Devine" system of grouping is employed. The greatest difference occurs when letters are used in the top row, and numerals in the bottom. It is doubtful if any benefits would accrue if used for plates with less than six characters.

SELECTION OF LETTERS FOR USE ON LICENSE PLATES

In many states, the use of letters on license plates is a necessary expedient if the legends are to be restricted to a reasonable length. The use of key letters

also aids materially in the identification of certain classes of vehicles. Their use seems to offer no serious objections, provided the letters to be so employed are selected with care. Confusion arises between letters more frequently than between numerals because there are many more of them and because many bear a resemblance to other letters, or to certain numerals. No extensive investigation on letter confusion seems to have been made, but Dr. Lauer says the letters A, F, H, K, M, R, S, U, W, X, Y, and Z appear to be best.

VISIBILITY TESTS

In connection with a study of Vermont license plates made for the Motor Vehicle Commissioner of that State, limited tests were made of the visibility of several styles of numerals. This was done essentially for the purpose of comparing the numerals used on the present Vermont plates with others of the same height designed for greater legibility, but the results seem to be of sufficient general interest to be included in this paper.

Types of Numerals Compared: Four styles of numerals were tested for visibility: round, block, open, and round as used on the Vermont 1937 plates. To eliminate variables of color, size, spacing, etc., cards were used having black figures on a white background. Figure 6 illustrates some of the combinations used in the test. All numerals were made 3 in. high, the present height of figures on Vermont plates. Numerals are 1½ in. wide, with the exception of the Vermont style which are 1¼ in. Two widths of stroke ¾ in. and ¼ in. were employed. The round and block numerals represent the styles in most common use at the present time. The open style is an attempt to design a style which will emphasize the distinctive features of each numeral with the hope of reducing possible confusion of various digits to a minimum. Styles

somewhat resembling this open type have already been used by several states, notably New York, Pennsylvania, and the District of Columbia, but in most cases, the figures would seem to be too narrow for their relative height.

Method of Testing: The figures were arranged in groups of five or six to simulate the arrangement on the majority of license plates, and placed on a back-

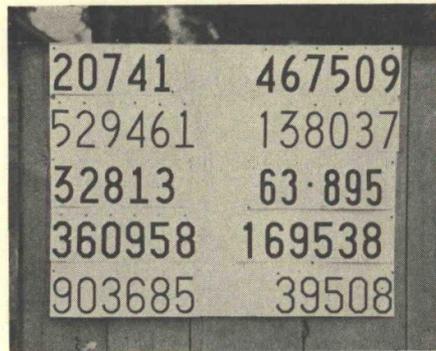


Figure 6. Showing Styles of Numerals Tested

In the order illustrated, they are as follows:

1. Round style, ¾-in. stroke
2. Open style, ¼-in. stroke
3. Open style, ¾-in. stroke
4. Block style, ¾-in. stroke
5. Round style, ¼-in. stroke
6. Open style, ¾-in. stroke
7. Open style, ¼-in. stroke
8. Vermont 1937, ¾-in. stroke
9. Round style, ¾-in. stroke
10. Block style, ¼-in. stroke

ground as shown in Figure 6. Stakes were placed at 10-ft. intervals from the display of figures up to a maximum distance of 200 ft., and marked with the proper distance. The observer was first placed at the 200-ft. point, and asked to read the groups of digits as they appeared to him at that distance. Those that were very indistinct were omitted. His readings were recorded. He then moved up to the 190-ft. point and repeated the process. At each point, however, the readings were made in a different order

to eliminate as far as possible variations due to the effect of memory or eye-fatigue. This process was continued until any one group was read correctly at two consecutive stations. Said group was then considered to be visible to the observer at the more distant of the two points, and was not considered further. The observer thus moved forward in 10-ft increments until all groups had been read correctly.

in place of the correct digit which appears at the head of the column. In the open type groups, both a flat top three and the rounded three were included. In one of the open type and one of the round type groups, the digit "1" both with and without a base was included. Block and Vermont type numerals not listed in this table were not included in the test.

Style of Numerals In order to determine the effect of the style of numerals

TABLE 10
SHOWING THE MAXIMUM DISTANCES AT WHICH THE VARIOUS NUMERAL GROUPS WERE
READ BY EACH OBSERVER

Observer number	Open style $\frac{3}{8}$ -in stroke	Open style $\frac{1}{2}$ -in stroke	Round style $\frac{3}{8}$ -in stroke	Block style $\frac{3}{8}$ -in stroke	Block style $\frac{1}{2}$ -in stroke	Round style $\frac{1}{4}$ -in stroke	Vermont style $\frac{3}{8}$ -in stroke
1	150	150	130	120	130	120	120
2	190	190	160	170	160	140	160
3	100	100	100	80	90	90	80
4	160	140	150	130	130	130	110
5	160	150	120	130	130	120	120
6	180	170	160	160	150	160	160
7	160	150	150	150	160	140	150
8	130	130	130	120	120	110	120
9	160	150	160	150	150	150	140
10	160	150	150	150	140	150	130
11	160	160	140	140	150	140	140
12	130	140	120	120	120	110	120
13	150	150	150	150	140	140	130
14	170	160	160	160	150	150	130
Average	154	150	141	138	137	132	129

These tests were made outdoors under varying conditions of weather, to correspond somewhat with actual traffic conditions in daylight. No tests were made with artificial illumination. Fourteen observers were tested in this way.

Tabulation of Results Table 10 was compiled from the test sheets. It shows the maximum distance at which a group of each style and width of stroke was visible to each observer. From these readings, the average visibility distance for each type of numeral was calculated.

The confusion of digits is shown in Table 11. The numbers appearing in the columns are those given by the observers

on visibility, variations of height, width, and stroke must be eliminated. These factors were the same for the open, round, and block types with $\frac{3}{8}$ -in stroke, and also for the same three styles with $\frac{1}{2}$ -in stroke. From Table 10, the average visibility distance of these groups is as given in Table 12.

No appreciable difference in visibility is found between the round and block styles. This result might be expected, as the angular corners of the block figures become rounded to the eye when viewed at a distance, and the numerals then closely resemble the round type in appearance.

The open style seems to show a decided advantage in visibility for the numerals with both the $\frac{3}{8}$ - and $\frac{1}{4}$ -in stroke. Other factors being the same, the open type of numeral is more visible than either of the much-used round or block types.

The digit one with a base was found to be visible at an average distance of 194 ft as compared with 174 ft for the one without a base. The former should be used. The rounded three was visible at a greater distance than the flat top.

TABLE 11

COMPARISON OF CONFUSION BETWEEN THE DIGITS OF THE VARIOUS STYLES OF NUMERALS

Numerals heading the columns are the ones that should have been given. Below each of these are listed the digits that were actually given by the observers.

Open type $\frac{3}{8}$ -in stroke											Open type $\frac{1}{4}$ -in stroke											
1	2	3	3	4	5	6	7	8	9	0	1	1	2	3 ^a	3 ^b	4	5	6	7	8	9	0
		1	1	5	5	6	1	3	7	6				4	1	6		4		0	6	
		1	5		6	1	7	8						5	0			4			6	
		1	5		8	1	7	8						5				4			6	
		3	5		0	0	9	8						5				8			6	
		3	5				9	0						5							8	
		3	5											5								
		7	5											5								
		7	5											5								
		8	5											5								
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		5																				
		6																				
Round type $\frac{3}{8}$ -in stroke											Round type $\frac{1}{4}$ -in stroke											
1	1	2	3	4	5	6	7	8	9	0	3	5	6	8	9	0						
		3	1	0	3		6	3	2	3			6	8	4	1						
		5	1	0			6	9	3	7			8	8	5	2						
		8	1					9	3	7					5	3						
		8	1					9	8	7					5	3						
		8	2					9	8	8					6							
			5					9		8					6							
			7					9		9					6							
			7					9		9					6							
			7					9							9							
			7																			
			7																			
			7																			
			7																			

^a Flat top
^b Round

widths of numerals were employed. The round style with $\frac{3}{8}$ -in stroke are $1\frac{1}{2}$ -in wide, and the Vermont type are similar in all respects except their width, which is $1\frac{1}{4}$ in. The round style were visible at an average distance of 141 ft while the Vermont numerals dropped to 129 ft. Therefore, 3 by $1\frac{1}{2}$ -in numerals are quite superior to 3 by $1\frac{1}{4}$ -in numerals.

From a practical standpoint, the optimum ratio of width to height for license plate numbers involves other items such as the available plate size, and the spacing and grouping of the numerals. Quite extensive tests would be required to investigate this matter. For the space available on the Vermont plate, whose size is prescribed by law, it was found that numerals $1\frac{1}{2}$ -in wide were definitely superior to the $1\frac{1}{4}$ -in ones used at present.

Confusion of Digits In all the groups tested, little confusion was found to result with the digits 2, 4, 5, 6, 7, and 0. The digit "2" was confused to some extent, being given several times as 1, 3, 5, 7, and 8. The block "2" was not confused at all. There seems to be no explanation why this should be more distinct than either the open or the round "2."

The flat top three is very bad. It appeared only twice in the display of figures, and yet it was given as "5" a total of 28 times. It is certain that this type of three should never be used. The more rounded three was infrequently confused except in the case of the somewhat narrow Vermont numerals. In this case, it was given frequently as "1" or "7," probably due to the compressed nature of these figures. These same digits were given to some extent for the round style three with $\frac{3}{8}$ -in stroke, a fact which is not easily explained.

The digit "8" was confused considerably, being given most often as "9." This was particularly true for the block and round types where the "9" is differentiated from the "8" only by the small opening near the bottom of the "9." The

open style "9" should tend to reduce this confusion.

The digit "9" was confused more often than any other. It was given most frequently as "5" or as "8." For the narrow Vermont numerals, it was also given frequently as 1, 7, and 0. It is a very curious fact that "9" is the digit most frequently confused, while "6" is one of those least confused. Dr. Lauer obtained the same results in his tachistoscopic studies with numerals, and explains this apparent paradox in this way: "It may seem strange that nine is the most confused and six, which is an inverted nine, the least confused. This very interesting result may be explained by the fact that most cues in reading are secured from the upper half of the letters or characters. One can observe this for himself by placing a paper over the upper half of the letters and attempting to read. By reversing it so the lower half is covered, no disturbance is noted. Modification of the upper portions of the confused digits may make them more legible."

Since all numerals were spaced one half inch apart, no comparisons of legibility due to spacing can be made. In this regard, Dr. Lauer says, "The correlation with legibility was + 2186. This would be interpreted to mean that greater spacing between the numbers would greatly increase their legibility. Based upon measurements of sizes of plates now being used, these letters should not center closer than 2 in. It would be better to increase this distance if possible."

It was observed that digits in the end positions of the groups were more legible than when placed elsewhere. This fact tends to confirm the argument that wide spacing promotes greater visibility. Undoubtedly, the widest spacing of numerals consistent with a reasonable size of plate will be the best.

Summary The open type numerals are more visible than either the round

or block types. There is no appreciable difference in visibility between the latter two styles.

For numerals 3 in. high and $1\frac{1}{2}$ in. wide, a $\frac{3}{8}$ -in. stroke is preferable to a $\frac{1}{4}$ -in. stroke, although the difference is not momentous. Further study should be made on the question of best width of stroke.

Numerals whose width is half their height are more visible than those with a



Figure 7



Figure 8

smaller ratio of width to height. For good visibility, license plate numerals should be made wider in respect to height than is generally the practise at present.

The digits 1, 4, 5, 6, 7, and 0 are not seriously confused. The flat top three is very frequently confused with "5" and should never be used. The digit "8" is often confused, especially with "9." Nine is the digit most frequently confused, and is often given as "5" or "8." Since it is hardly feasible to omit any digit even though it may be confused frequently, numerals should be designed to emphasize their distinguishing characteristics. The open type 5, 6, and 9 should be of some aid in this direction. The digit "1"

should have a base, but the top should be small lest this digit be confused with "7."

License Plate Design: Illustrations of a few sample license plates submitted to the Motor Vehicle Commissioner of Vermont are here included to show what may be done in the way of plate design to increase visibility. Figure 7 is a replica of the plate used in Vermont for 1937. Its chief objections are: numerals too narrow in proportion to their height, year and state name too crowded and compressed, border unnecessary and cuts down the effective size of the plate, characters along the bottom of the plate partially obscured by the fastenings. The numerals were visible at an average distance of only 129 ft.

The numerals used on the plate shown in Figure 8 are of the open type, the most legible of the four styles tested. Numerals are spaced $\frac{1}{2}$ in. apart, with a $1\frac{3}{4}$ in. space between the groups. The border has been omitted, which increases the effective size of the plate. The letters used for the state name and year are much superior to those shown in Figure 7, but they are still somewhat obscured by the fastenings. The numerals are very well shaped and spaced for high visibility. This type of figures was visible at an average distance of 154 ft.

Figure 9 illustrates the arrangement of the plate which has been adopted in Vermont for 1938. The border has been omitted, however, in order to increase the effective size of the plate. The visibility of the state name and year is thus appreciably increased. This arrangement of these items also possesses the desirable feature that no part of either is partially obscured by the plate fastenings. From all appearances, these plates are far superior to those used last year.

The remaining five digits of the open style are shown on the plate in Figure 10. These may also be used for the round type with the exception of "0" which should be designed with semicircular top

and bottom and straight sides. A base has been retained on the "1" as this was found to be more visible than the digit "1" with base omitted. By omitting the border and abbreviating the state name and year, it was possible to increase the

size of the characters used for the name and year. Their legibility is considerably increased in this way.

All plates are 6 by 12½ in., the size prescribed for Vermont. All numerals are 3 in. high.



Figure 9



Figure 10

DISCUSSION ON AUTOMOBILE LICENSE PLATES

MR. JOS. BARNETT, *U. S. Bureau of Public Roads*: The visibility of license plates is associated with tail lights and their location. The present location of tail lights is about two feet above the ground, which appears to be very undesirable. Why it was put there possibly is a throwback to the lantern hung from the buckboard when horse-drawn vehicles predominated, but more likely is a throwback to the era of open body types when the top of a vehicle put back against the rear made it necessary to place tail light and license plate low enough to be visible.

At the present time only about one-third of one per cent of vehicles are constructed with open bodies so that the open body type as a factor may be disregarded. Tail lights and license plates on closed body types ought to be placed near the top of the vehicle. In their present location they are in the way of the fenders which appear to require replacing or repairing with increasing frequency; they are in the way of the gas tank; they are in the way of the trunk rack; they are in the way of the spare tire when at the rear; and they frequently are spattered with mud, re-

ducing the efficiency of the tail light and visibility of the license plate.

There also is the important matter of safety. Many night accidents are recorded in which the driver or a passenger obscured the tail light by standing at the rear of the vehicle either to change a tire or to get at the trunk rack, at which time they were ploughed into by following vehicles. Accidents of this character generally result in serious injury or fatality. One of the danger spots on a highway is the crest of a hill over which the sight distance generally is limited. A tail light at the top of a vehicle first is seen at a considerably greater distance than one near the pavement. This safety feature is recognized for trucks and busses on which some kind of light nearly always is located at or near the top. There is just as much justification for this practice for passenger vehicles.

Of course these observations do not detract from the value of Professor Aldrich's excellent work because, regardless of where it is put, the desirability of a license plate which is highly visible cannot be questioned. It does appear, however, that the automobile in-

dustry ought to take cognizance of the fact that license plates and tail lights are much more visible at the tops of vehicles than where they now are located

MR C M JOHNSTON, *U S Bureau of Public Roads*: I should like to make one observation on Mr Barnett's remarks and that is, sometimes the tail light goes out. Hence, if you put a tag at the top of the car, the driver of a vehicle approaching from behind might not see the license plate if he wanted to. If you have the plate a little lower, say chest height, then the lights of the approaching vehicle should at least shine on it and thus illuminate it for identification purposes. In other words, it is my opinion, that the maximum height of the license plate above the ground should be governed by the maximum elevation of the headlight beam permitted by law and the legible distance of the tag.

It might also be observed that an extinguished tail light makes a very good danger signal when reflecting rays of an oncoming headlight. This is another reason for not elevating the tail light too high.

DR A R LAUER, *Iowa State College*: Professor Aldrich and I corresponded on this point before. Two years ago we succeeded in measuring the reflection factor of different colors on the standard license plates used about 1929-30. A number of factors were studied relating to legibility. Professor Aldrich has taken up certain of these more in detail. One or two observations may be made relating to his paper. While the $\frac{3}{8}$ -in may be better than the $\frac{1}{2}$ -in stroke we found that if the stroke gets much larger than $\frac{3}{8}$ -in, there is a tendency for the number or letter to blur. This lowered the efficiency a great deal.

Another observation is that his model plates showed the state identifications at the bottom. We found this a decided advantage over vertical state identifications. In such cases the small letters

tended to run together and resemble a letter I or number 1. This point is related to another regarding technique. In the tachistoscope shown the shutter moves from the bottom of the number to the top then drops. This gives a longer exposure time for the lower part of the number. As a matter of fact the upper part of the letter or numeral is used most in visual perception of printed characters. Try laying a white card along the bottom line of letters. You will note that it does not affect your ease of reading the line. Now try covering the upper part of the line and notice how much it interferes with reading. Thus, the method of exposure might affect the results considerably, altho this may not be a factor in the present study.

It suffices to say that anything at the top of the license plate is likely to reduce the efficiency in visual perception of the number on the plate. Smaller identifications should be reduced to a minimum but if put on at all should be at the bottom.

Regarding the matter of tail lights placed over the numbers, we found in our studies that the amount of impinging light did not make a great deal of difference, within reasonable limits, when number plates of sufficient contrast between numbers and background were used. However, when black numbers were used on a dark green background the illumination had to be quite high for reasonable efficiency of the plates. In the latter plate the reflection factor of the numbers was about 4 per cent and that of the background only about 20 per cent. The difference was around 15 per cent. The best plates for low illumination were those with wide differences between background and number. It seems to me that the color combinations of the plates are of even more importance than the shape of letters or numbers, and slight differences in illumination which it is possible to throw upon them.