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NIGHTTIME LEGIBILITY OF LICENSE PLATES

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16. Abstract

This study evaluated the legibility of license plates under field viewing conditions. The independent variables were: plate background luminance, legend luminance, glare, and subject age. The plates were mounted on the front and rear of a vehicle and the subjects were driven slowly past, pressing buttons to indicate legibility distance.

The results indicate a general superiority for fully reflectorized plates, especially under conditions of glare. The older subjects, in particular, seemed to benefit from the highly reflective plates.

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EXECUTIVE SUMMARY

This was a field study intended to investigate several factors that were expected to influence the nighttime legibility of license plates.

Method

Background reflectivity. Four levels of background reflectivity were used: a non-retroreflective black, and three white retroreflective levels (0.51, 1.86, and 3.90 cd/lux/plate at 0.2° and -4°).

Legend contrast. Two levels of contrast were used. For the reflectorized background plates, the contrast ratios were about 5:1 and 16:1. For the non-retroreflective background plates the coefficient of luminous intensity was 0.7 and 2 cd/lux/plate at 0.2° and -4° for the low- and high-contrast conditions.

Approach direction. The test vehicle with the plates was viewed from the front (in which case it was to the left of the subject vehicle) or the rear (in which case it was directly in front of the subject vehicle).

Vehicle lights. The lights of the license plate vehicle could be on or off. This meant low-beam headlamps in the front, presence lamps and license plate lamp in the rear.

Subjects

Twelve subjects participated in the study. Half were under 30 years of age (mean of 26 years), half above 65 (mean of 68 years). They were selected to be as homogeneous as possible on low-luminance visual-acuity measures.

Procedure

Three subjects were tested at a time. They drove or rode in a car which moved at 16 km/h past the vehicle with the test license plate and indicated by pressing a button the point at which they could determine the order in which the six numbers on the license plate were arranged.

Results

In general, plates having high background luminance and contrast characteristics performed best. The difference between background luminance levels was particularly noticeable in the presence of headlamp glare.

Differences between older and younger subjects were large, the older subjects providing legibility distances 30-40% less than the younger subjects.

1.1 Method

1.1.1 Variables. The following variables were investigated:

1.1.1.1 Background Reflectivity. Four levels of retroreflective treatment were used. These were:

1. Painted - black
2. Retroreflective - white (coefficient of luminous intensity [CIL] about 0.51 cd/lux/plate [5.5 cd/ft-C/plate] at 0.2° and -4°)
3. Retroreflective - white (CIL about 1.86 cd/lux/plate [20 cd/ft-C/plate] at 0.2° and -4°)
4. Retroreflective - white (CIL about 3.90 cd/lux/plate [42 cd/ft-C/plate] at 0.2° and -4°)

In figures to be presented later in this report, these levels will be designated as B (black) and L, M, and H for the low, medium, and highly retroreflective plates, respectively.

1.1.1.2 Legend Reflectivity. Two levels of legend reflectivity were provided for each level of background reflectivity. The levels depended on the background.

1. For the black backgrounds, the legend CIL values were about .19 and .07 cd/lux/plate [2 and 0.7 cd/ft-C/plate] at 0.2° and -4°.
2. For the two mid-level retroreflective backgrounds, the legends were established to provide contrast ratios of 18:1 and 5:1.

3. For the highest-level retroreflective background, the legends were established to provide contrast ratios of 16:1 and 5:1.

(Note: Four plates of each type were used in the study. Table 1 lists photometric data for each. In figures to be presented later in this report, high-contrast will be designated as 1, low-contrast as 2.)

1.1.1.3 Approach Direction. Two levels.

1. Front. In this case the vehicle bearing the test license plates appeared to the left of the subject vehicle.
2. Rear. In this case the vehicle bearing the test license plates appeared directly ahead of the subject vehicle.

The main difference in the approach directions would be in the amount of illumination reaching the test plates from the low-beam headlamps of the subject vehicle.

1.1.1.4 Vehicle Lights. The lights of the vehicle bearing the license plates could be on or off. When approaching from the front, "lights on" meant the vehicle's low-beam headlamps were illuminated. When approaching from the rear, "lights on" meant the vehicle's license plate lamp and presence lamps were illuminated. The subject vehicle's low-beam lamps were always on.

1.1.1.5 Replications. Each condition was measured twice.

TABLE 1

Photometric Specifications (cd/lux/plate) of License Plates Used in Validation Study

	WHITE BACKGROUNDS			
	Observation Angle			
	0.2°		1.0°	
Contrast Ratios	16:1	5:1	16:1	5:1
	3.90	3.93	.83	.83
	4.00	4.13	.86	.88
	3.98	4.25	.86	.88
	4.05	4.07	.85	.86
Contrast Ratios	18:1	5:1	18:1	5:1
	1.72	1.92	.43	.47
	1.76	1.96	.44	.48
	1.75	1.94	.45	.47
	1.64	1.84	.43	.47
Contrast Ratios	18:1	5:1	18:1	5:1
	.49	.49	.11	.11
	.48	.53	.11	.16
	.46	.56	.10	.12
	.52	.50	.12	.11
	BLACK BACKGROUNDS			
	Observation Angle			
	0.2°		1.0°	
	.18	.06	.05	.03
	.19	.06	.05	.02
	.19	.07	.05	.03
	.18	.07	.05	.03

Note: All measurements were made at an entrance angle of -4°.

1.1.1.6 <u>Subject Characteristics</u>. Twelve subjects participated in the study. Six were young (i.e., 18-30 years of age), six were older (i.e., 65-75 years of age). The individuals who participated in this study were selected to be as homogeneous as possible on the low-luminance visual-acuity measures.

1.1.1.7 <u>Seat Position</u>. Subjects either drove or occupied the center or right passenger position in the front seat of the test vehicle. The study was structured so that a total of two younger and two older persons served in each position.

The study required 64 trials per subject (4 levels of background, times 2 levels of legend, times 2 levels of approach direction, times 2 levels of lights, times 2 replications, equals 64).

1.1.2 <u>Equipment</u>. Two vehicles were required for this study. One, used to mount the license plates, was a full-size 1977 Plymouth. Simple hook fixtures were provided on it, front and rear, so that the test plates could be easily mounted over the standard plates.

The second vehicle, in which the subjects rode, was a 1973 full-size Ford station wagon that had precision distance measuring equipment with a digital readout. For this study, subjects responded by pressing buttons, causing miniature lamps in the vehicle's rear compartment to light. Both the distance readout and lamp displays were videotaped for later analysis.

The license plates were custom fabricated for the study by 3M laboratories in St. Paul, Minnesota. They were standard size (i.e., 30.48 x 15.24 cm [12 x 6 inches]). The legends were 6.67 cm (2 5/8 inches) tall, and had a stroke width of 8 mm (5/16 inch). The letter height to stroke width ratio was about 0.12. A photograph of a set of plates used in the study is shown in Figure 1.

As will be noted by an inspection of Figure 1, the legend on each plate consisted of the numerals 2, 3, 4, 5, 6, and 7, in various arrangements. The plates lacked other information typically found (e.g., state, year, motto).

1.1.3 Procedure. Subjects were run in groups of three. All were positioned in the front seat of the test vehicle. One was selected to drive, the other two occupied the center and right passenger seats. The experimenter and necessary recording equipment occupied the second seat. Each subject was given a silent push-button switch and the experimenter read the instructions. Briefly, the subjects were told to respond by pressing a button when they could read the plate well enough to determine the order in which the numbers appeared.

A schematic of the test arrangement is provided in Figure 2. The test was run on a low-volume two-lane road. It is high quality asphalt, flat and straight in the section used.

The vehicle with the test license plates was parked at the edge of the road. The subject vehicle was driven back

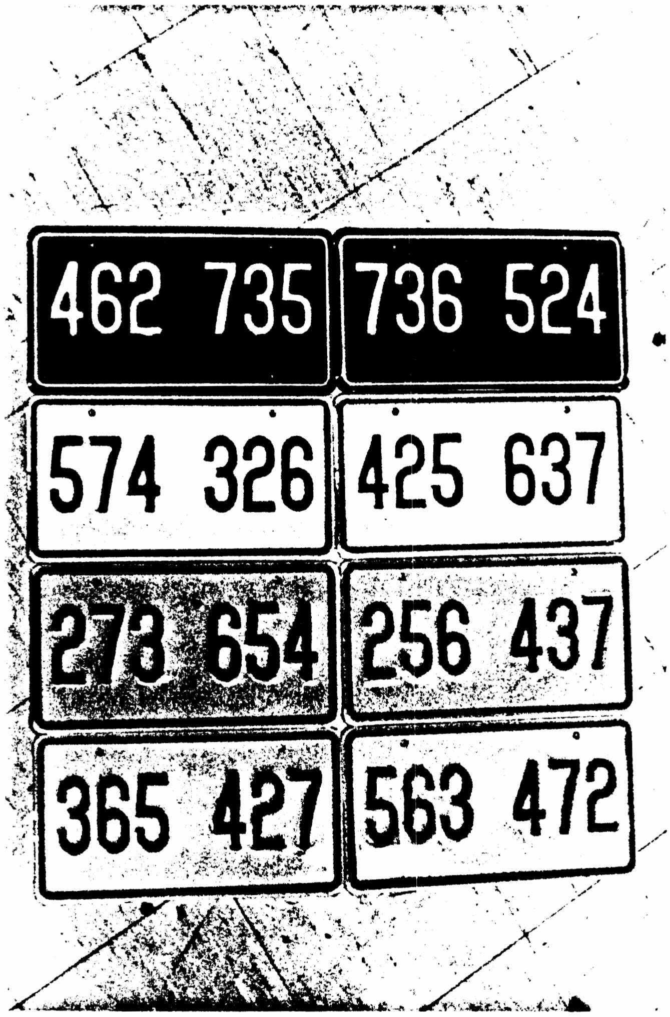

Figure 1. Set of license plates used in study.

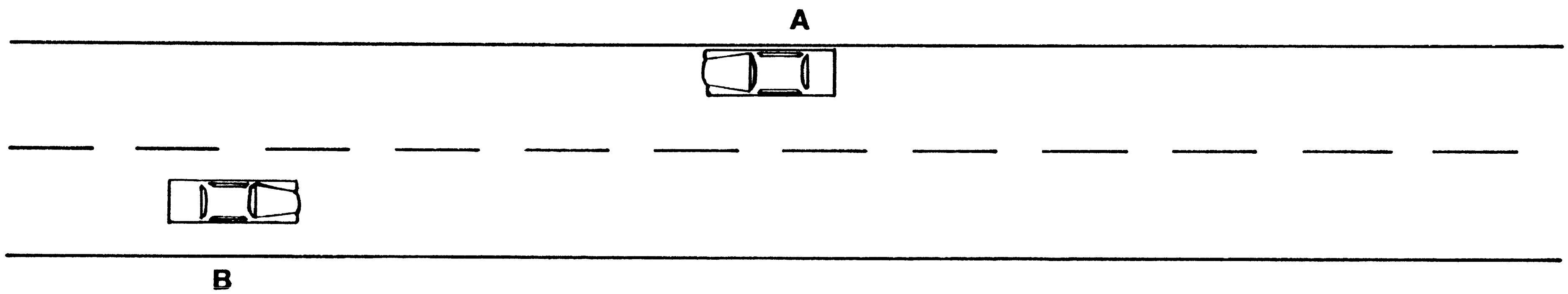

Figure 2. Diagram of test setup.
A = license plate vehicle
B = subject vehicle

and forth past the license plate vehicle at a speed of about 16 km/h (10 mph). The subject doing the driving was instructed to stay in the center of the appropriate lane. When approaching the license plate vehicle from the rear the driver was instructed to stay in the lane as long as possible, then move left to pass.

As noted earlier, the subjects responded by pressing buttons to indicate when they could read the license plate. These button presses caused lamps to light on the video display. The experimenter pressed a button also, when the subjects were abreast of the test plate, lighting a fourth lamp on the display. In reducing the data, the experimenter subtracted the distance at which each subject's lamp came on from the distance at which the experimenter's lamp came on. This yielded the legibility distance measure.

The treatments described earlier were presented in different randomized orders for each group of subjects.

The subjects were given four practice trials at the start of the test. A rest period of about five minute's duration was provided at about the half-way point in the test.

1.2 Results and Discussion

1.2.1 Main Effects. There were five main effects considered in the statistical analysis. These results will be described separately.

1.2.1.1 License Plates. Differences among the plates were highly significant ($p < .01$). Mean legibility distances (in meters) are as follows:[1]

	High Contrast	Low Contrast
Black background	22.3 m (116%)	20.7 m (107%)
Low reflective	19.5 m (101%)	19.3 m (100%)
Medium reflective	22.0 m (114%)	21.5 m (113%)
High reflective	22.8 m (118%)	22.1 m (115%)

The low reflectance plates were significantly ($p < .05$) poorer than all others, with the exception of the black background, low contrast plate. The differences between the six better plates were not statistically significant.

In addition, this factor was involved in several interactions of interest to be described later.

1.2.1.2 Subject Age. The mean legibility distances were: young, 25.3 m; old, 17.2 m. This difference is significant ($p < .01$). Age also enters into one significant interaction that will be described later.

Clearly, the older subjects in this study could not read the plates as well as the younger subjects. The legibility distance difference is substantial; the older subjects had to be about one-third closer than the younger subjects.

1.2.1.3 Seat Position. The mean legibility distance for each seat position was as follows:

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[1]The percentages in parentheses are the normalized values obtained by setting the smallest distance in the first table to 100%.

Driver	23.8 m (123%)
Mid passenger	21.2 m (110%)
Right passenger	18.7 m (97%)

These differences are not significant ($p > .05$). (This is a rather weak test statistically, since it is between subjects.) However, seat position is involved in two interactions.

1.2.1.4 <u>Plate Location</u>. The mean legibility distances associated with plate location were as follow:

Front	20.3 m (105%)
Back	22.3 m (116%)

This difference is significant ($p < .01$). The difference was expected, given that when approaching from the rear the test plates were much more favorably located relative to the beam from the subject car's headlamps.

Plate location was a variable in three interactions.

1.2.1.5 <u>Lights</u>. The mean legibility distances associated with the vehicle lights were as follows:

Lights on	21.3 m (110%)
Lights off	21.2 m (110%)

This difference is not significant. However, lights appears as a factor in one interaction.

1.2.2 <u>Interactions</u>. Figure 3 shows the mean legibility distance associated with each seat position. It will be noted that there are substantial and consistent differences between seat positions, and that the differences

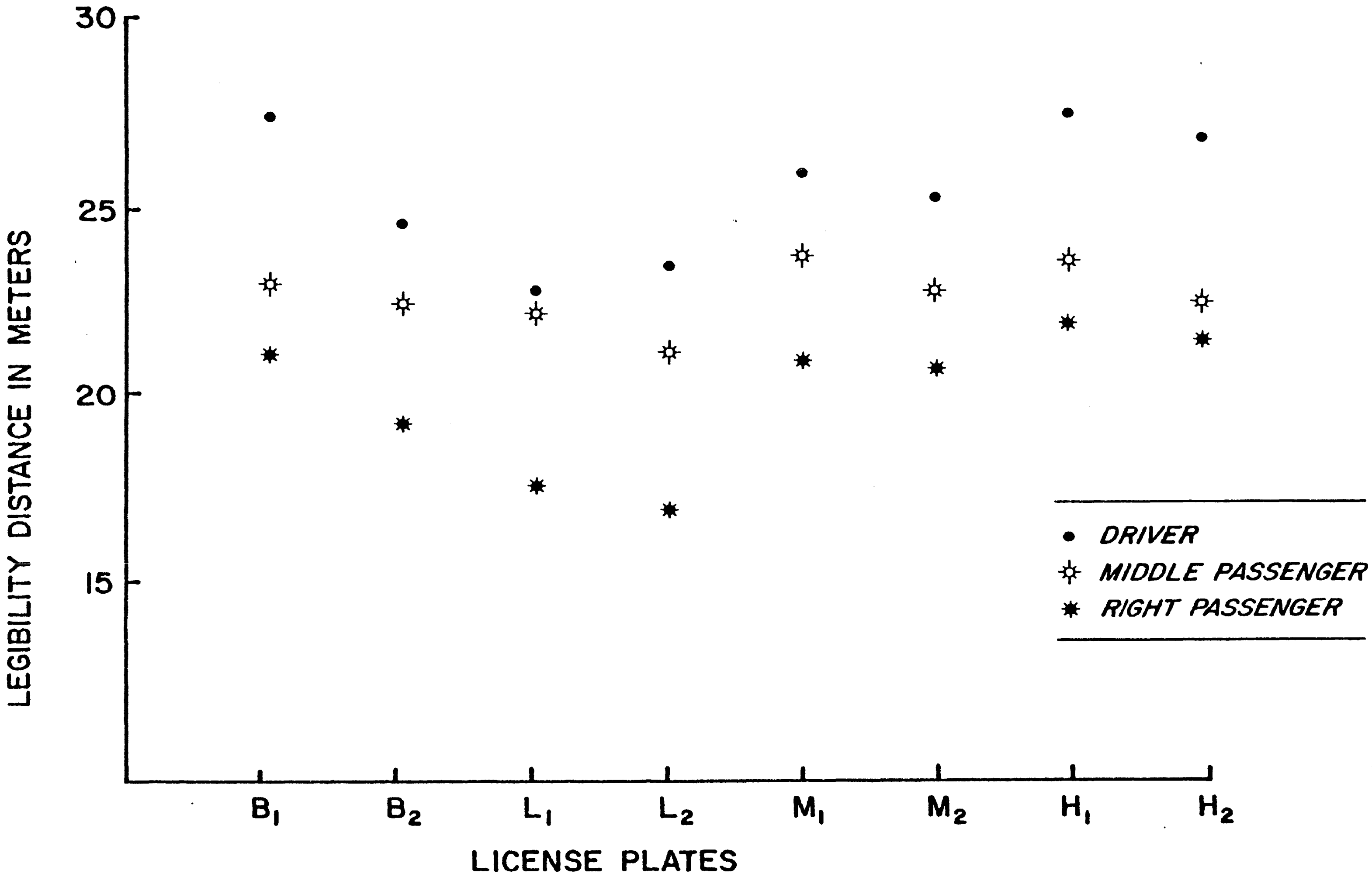

Figure 3. Mean visibility distance associated with each plate at each seat position.

from plate to plate are less for the mid-passenger than for the two outboard passengers.

Because subjects in this study were nested within seat position, it is not clear whether the differences in Figure 3 reflect subject effects, position effects, or some combination of the two. However, if the differences were largely position effects, it would be reasonable to expect larger differences between positions comparing front and rear presentations than are shown in Figure 4. This is because of the different viewing conditions and observations angles that occur in the front and rear presentations. Thus, the differences in Figure 3 probably largely reflect between-subject effects.

The position x license plate interaction is considered further in Figure 4, which separates the performance of each plate on the front and rear of the test car. The general pattern of Figure 3 is repeated here in terms of the differences between seat positions. However, of particular interest are the differences between the plates in the front and rear positions, and the way these differences disappear as the luminance of the plates increases. The latter phenomenon is shown more clearly in Figure 5, which sums across subjects.

The data indicate that the altered performance of the front mounting relative to the rear is due to an interaction with the headlamps-on condition. This is shown in Figure 6. When the plates were mounted on the rear of the test car,

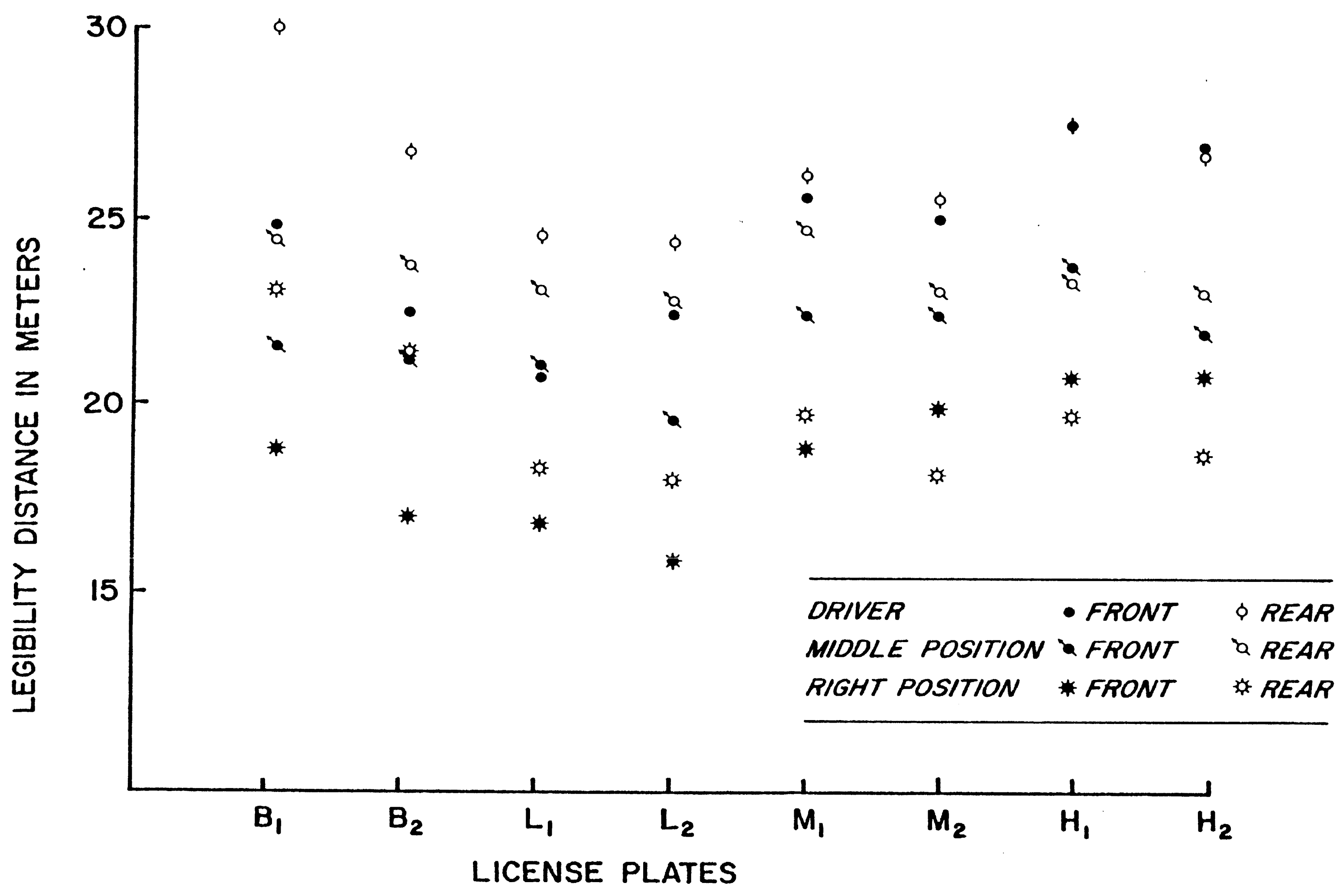

Figure 4. Mean visibility distances associated with each plate, seat position and approach direction.

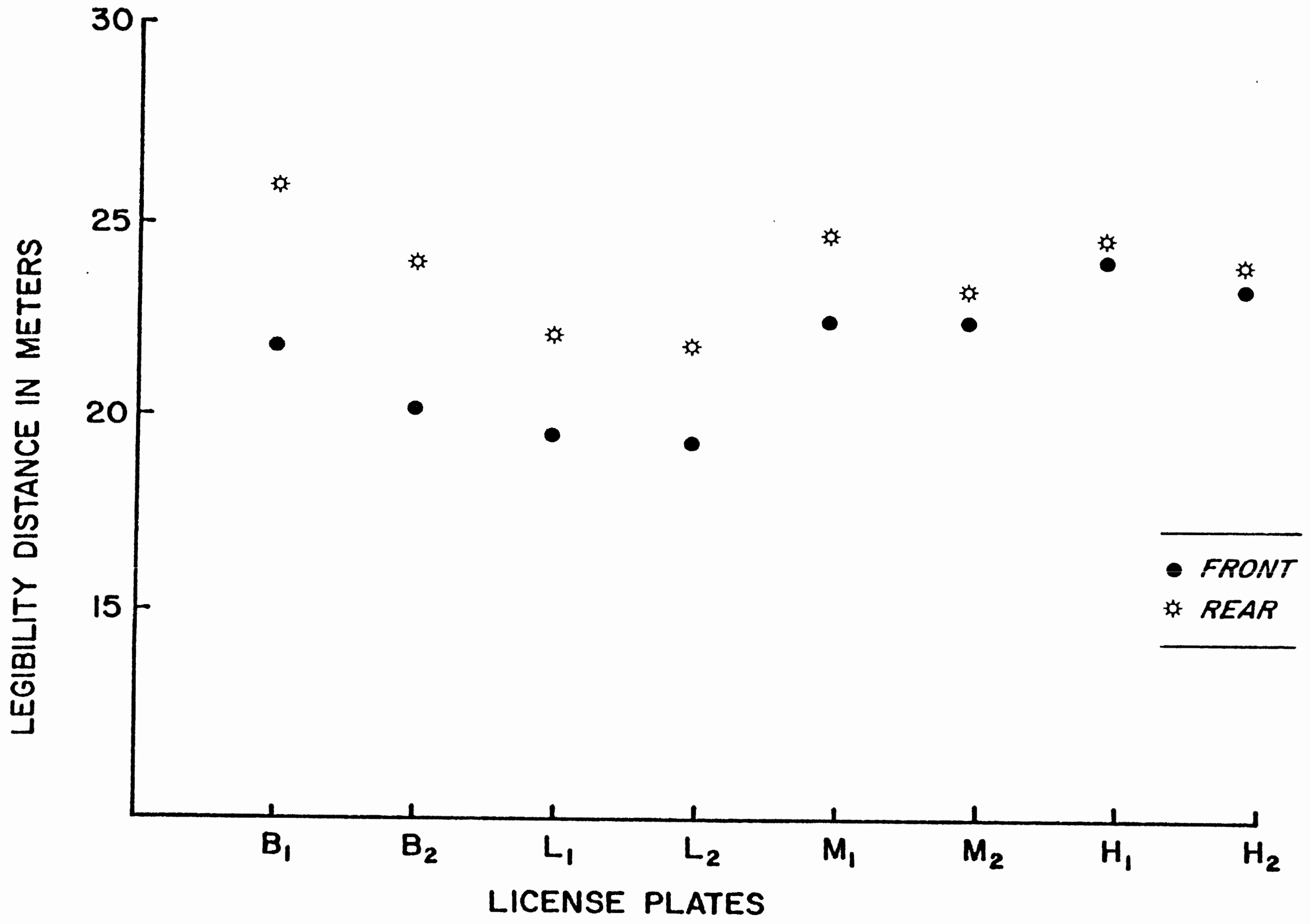

Figure 5. Mean legibility distances for each plate and approach direction.

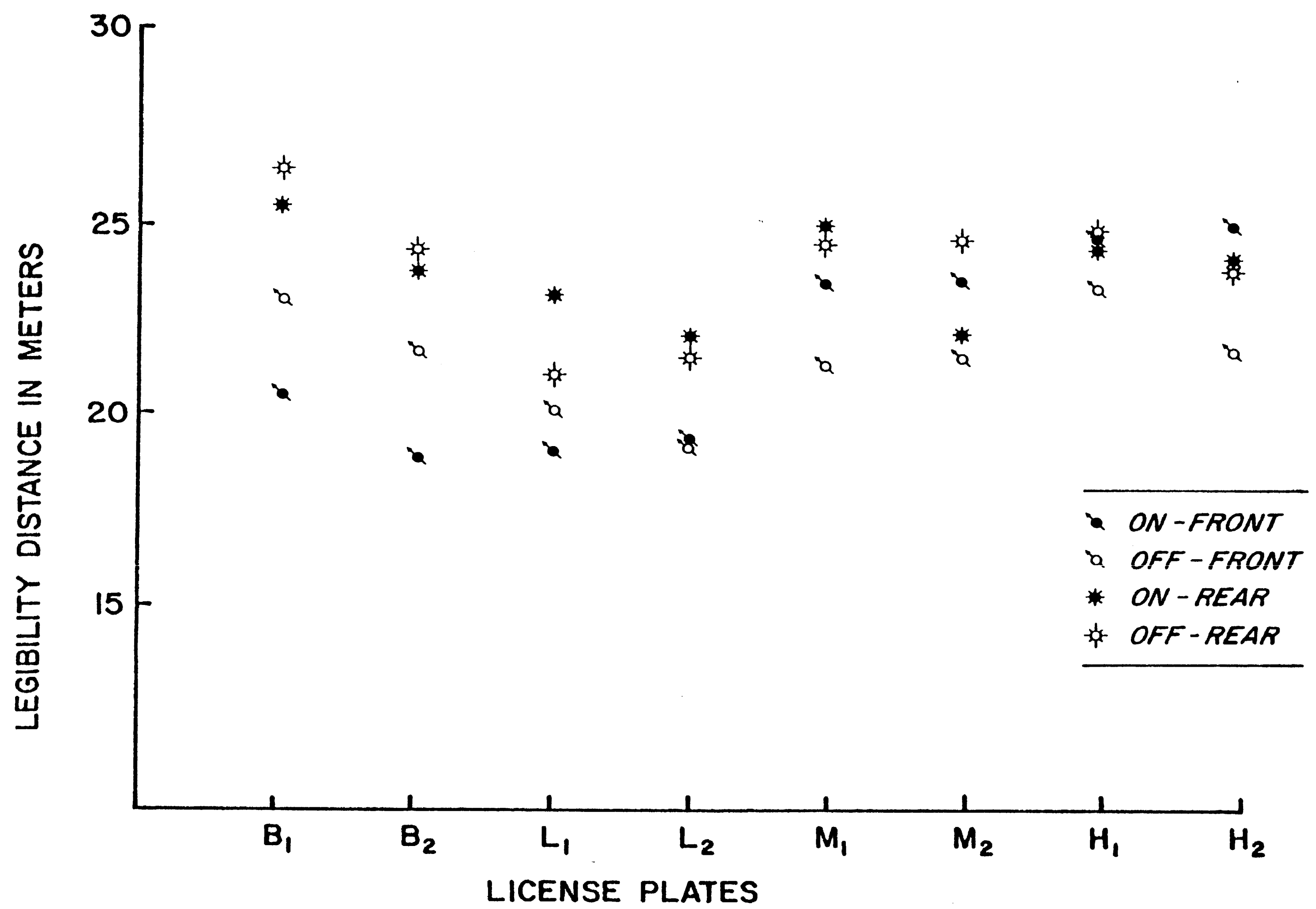

Figure 6. Mean legibility distances for each plate as a function of the lights and approach direction factors.

the legibility distances for the various plates were little affected by the lights condition. When the plates were mounted on the front of the test vehicle, there was a greater (and statistically significant [$p < .05$]) difference in legibility distance associated with the lights condition. More important, the direction of the difference reverses. Headlights-on reduced legibility distance for the black background plates, had no (statistically significant) effect on the low-retroreflective plates, and increased legibility distance for the medium- and highly retroreflective plates.

A possible explanation for the reversal noted in Figure 6 is as follows: A comparison of the first and second levels of each plate suggests that the black background plates are more affected by changes in contrast than the fully retroreflective plates. The introduction of glare has an effect equivalent to adding a constant luminance to both the legend and the background, and thereby reducing contrast. Thus, the degraded performance of the black background plates under conditions of glare is not surprising. However, the same logic suggests that the fully retroreflective plates should be less affected by the glare condition used, not that legibility would be enhanced.

Further inspection of Figure 6 suggests that the medium- and highly reflective plates were in the optimum range, both in terms of luminance and contrast, while the low-reflective plate was below optimum. Under some conditions, glare can enhance visual performance because it causes the pupil to constrict. It may well be that the gain in legibility due to reduced pupil size was just enough to offset the loss of contrast for the sub-optimum L plates, but led to improved legibility on the M and H plates, where loss of contrast seems to be of little or no consequence.

Clearly, the foregoing is speculation, and further work is required. However, it seems obvious that fully reflectorized plates possess distinct advantages over legend-reflectorized plates under a variety of operating conditions.

Figure 7 compares the performance of subjects in the two age groups across the plates for front and rear presentations. The older subjects did much worse than the younger subjects. The relative performance across the various conditions is quite similar, however, with the exception of the L plates, where older subjects did relatively worse. This is a further argument in favor of using more efficient retroreflective materials on license plates, since it seems to help older drivers.

1.3 Conclusions

The results of this study suggest that, given consideration to all viewing conditions, fully reflectorized license plates provide superior legibility compared with only legend-reflectorized plates. (This is an agreement with the findings of Israelsen and Canfield [1980].) Furthermore, within the range of materials studied, the

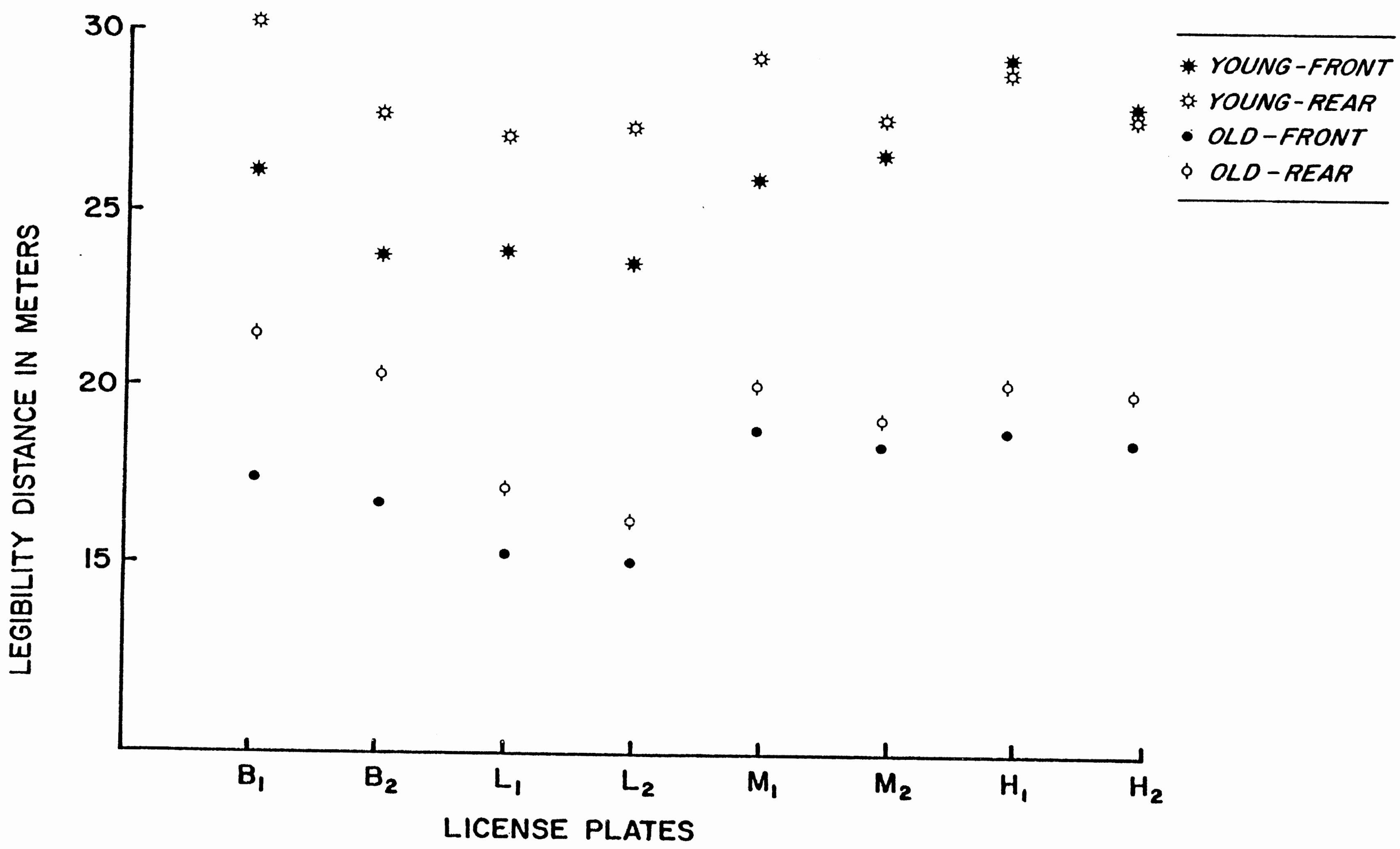

Figure 7. Mean legibility distances for each plate as a function of approach direction and observer age.

higher the luminance of the plate, the better the legibility provided.

The legibility of fully reflectorized plates is less affected by headlamp glare, a significant consideration. There is also evidence that fully reflectorized plates would suffer less in terms of legibility as they become dirty or degrade due to wear. This is suggested by a comparison between the two black-background plates. Level 2 represents a luminance loss which would be expected due to exposure to normal road conditions. Clearly, there is a significant change in legibility as legend luminance drops. On the other hand, a comparison of high and medium-retroreflective plates, also simulating normal wear or dirt accumulation, suggests that for these plates some loss of luminance has little effect on legibility.

The subject's task in the present study was to determine the order of six numbers. This is a difficult task. Additionally, half of the subjects were over 65 years of age. Consequently, it is not surprising that the obtained legibility distances were shorter than those obtained in studies utilizing a less demanding performance criterion and no elderly observers (e.g., Israelsen and Canfield, 1980).

In sum, the present data suggest that fully reflectorized plates provide improved legibility under both new and worn conditions.

1.4 Reference

Israelsen, C.E. and Canfield, R.V. Evaluation of legibility of reflectorized license plates. Logan, Utah: Utah State University, Utah Water Research Laboratory, June 1980.