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Variables Influencing the Attention-Getting Quality of Automobile Front-Turn Signals

by Rudolf G. Mortimer and Paul L. Olson

Abstract—*The time taken to detect and respond to front turn-signals by subjects who are simultaneously carrying out another signal monitoring task was used as the criterion in a study designed to evaluate the effect of the color and position of the signal on the front of the car, as well as the effect of viewing distance and the ambient (day, night) viewing condition.*

It was found that under most conditions a new type bulb (1157NA) with an amber tinted envelope was most rapidly detected; while, in general, the clear (1157) bulb was somewhat superior to the amber coated (1157A) bulb. Response times were shorter in the night condition when the signal was seen against headlamp glare than the bright day condition. Turn signals placed in the chrome surface of bumpers are detected less readily than if they are away from the bumper in daytime, and at night the signal placed nearest the headlamp required the greatest time to be detected. At 300 feet detection times were longer than at 100 feet.

Introduction

Front turn signals were changed from white to amber on all American cars in 1964. Most European cars now show amber, flashing, turn signals to the front and rear.

It was considered that the use of an amber, flashing, turn signal at the front would increase the detectability of the signal because of the increase in contrast between it and chrome parts reflecting sunlight in daytime; and at night it would provide increased contrast against the headlamp—as compared to a white turn signal.

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Some research carried out at the British Road Research Laboratory (Moore, 1956) found that certain types of amber, flashing, turn signals were detected more rapidly than white signals. However, it should be noted that these results are confounded by the beam distribution, area, shape and the location on the vehicle of the specific signals that were compared.

In order to obtain the amber light for the turn signal, three methods have been used: (1) the lens was tinted amber, (2) the bulb was coated with an amber film, (3) an amber filter was placed between the bulb and lens.

Each of these methods for obtaining an amber signal involves the use of the same basic bulb (type 1157) used to generate the white signal. It has been argued (Allen & Clark, 1964) that the loss in light output incurred in obtaining the amber signal would result in a reduction in detectability of that signal compared to the white turn signal.

However, the detectability of a turn signal is not solely a function of brightness. While the threshold of detection of a signal is dependent upon its brightness (when area and temporal factors are held constant), turn signals are generally operated at considerably above threshold conditions, and their detectability depends on their conspicuity in comparison to the other objects in the driver's field of view. Thus, a more relevant criterion for the evaluation of turn signals would be a measure of their "attention-getting" quality. This criterion is probably a function of both brightness and hue.

Thus employing a criterion of attention-getting quality, an experiment was designed to achieve the following:

1. To explore the utility of a method for systematic evaluation of turn signal lights.
2. To evaluate the detectability of flashing front turn sig-

FIGURE 1 The secondary task light jig showing the turn signals and headlamps.

nals using clear lenses and type 1157 (clear), 1157A (amber coated) and 1157NA (amber glass) bulbs.

3. To determine the effects on detectability of these turn signals of: viewing distance, proximity to chrome surfaces, proximity to headlamps and when being viewed in bright sunlight or at night against headlamp glare.

Method

Apparatus

1. *The Secondary Task Lights*

A wooden board, carrying nine 1965 Pontiac front turn signals arranged in a 3 x 3 matrix, was attached to the front of a car. Above each of the three columns of turn signals was placed a type 2, 5¾ inch headlamp. Figure 1 shows this lighting assembly. It will be noted that the bottom row of turn signals is sandwiched between two chrome plated tubes, 2 inches in diameter. The separation between the bottom turn signal and the one in the mid-position was 3.9 inches; and the latter was 1.75 inches from the top indicator. The top indicator was 1.75 inches from the headlamp above it. Lateral separation between columns of indicators was 3.0 inches.

A control panel was placed inside the car by means of which a turn signal could be selected and made to flash. The flash rate was 60 fpm, with a 75 per cent "on" time per flash. The reflecting surface of each turn signal housing had been sprayed with flat white paint for uniformity, and the bulb holders were rotated to ensure that all filaments were in the same plane. In this way beam distribution and intensity could only be a function of the type of bulb used in the housing. A clear lens was used in all turn signals.

Selection of Bulbs

A number of each of the three types (1157, 1157A, 1157NA) of bulbs to be used in the turn signals were obtained. Photometric measurements were taken on each bulb, and for each type the mean luminance was computed. Three bulbs were then selected, from each type, which produced close to the mean luminance. In this way a representative sample of bulbs was obtained for use in the experiment.

2. *The Primary Task Lights*

Another jig, for the primary task, carried two red lights with a white light set mid-way between them. A motor-driven programmer energized the red lights one at a time at various intervals.

3. *Recording Equipment*

Four standard timers, one for each subject, were used to record the elapsed time between the onset of the flashing of a turn signal and the response of a subject to it.

Subjects

A total of 48 subjects were used in this study, 24 in the day and 24 in the night. They were employes of the Research Laboratories or the Milford Proving Ground. Six were female. The subjects did not wear sunglasses.

Procedure

Four subjects were run in the experiment at a time. They were seated alongside each other. Fifty feet directly in front of them was placed the primary task light jig. The vehicle carrying the secondary task light jig was positioned, facing the subjects, either at 100 feet or 300 feet ahead of them and to their left, to simulate an approaching vehicle in an adjacent lane. The lateral separation was such that with the car in the 100 foot position the angle between the car center and the center of the row of subjects was 5.25°; and at the 300 foot position the angle was 1.75°. The experimental set-up is shown in Figure 2.

Each subject held a response box in which there were three push-button switches. Two switches were located in the lower right-hand corner of the box for convenient operation by the right thumb. The other switch was located in the lower left corner for operation by the left thumb.

The subjects were instructed to observe the primary task lights. As soon as they detected that a red light was on they were to depress the switch corresponding to the right or left light—whichever was lit—with the right thumb. When all the subjects had responded to a red light the light was immediately extinguished. In this way the subjects received feedback concerning the speed of their responses. In the event that one or more of the subjects failed to respond to a red light within six seconds from its onset it was automatically turned off. The responses of the subjects to the primary task were monitored by a panel of four lights in front of the experimenter (Figure 2).

FIGURE II The experimental set-up showing the experimenter's station, subject's station, primary and secondary task lights.

The primary task light program was so arranged as to provide for an average of six lights to be energized per minute, with variable intervals between their onset.

The subjects were further instructed that they were to depress the switch in the lower left corner of the response box as soon as they detected that a front turn signal on the vehicle ahead of them had begun to flash.

From the instant that a turn signal was energized a timer recorded the time that elapsed before a subject depressed the response switch. When all subjects had responded the signal was turned off. After a random interval, not exceeding one minute, another turn signal was presented.

In order to become familiar with the task each group of four subjects first received five practice trials in detecting the turn signals. At the same time they were responding to the primary task lights. The experiment was then continued until 90 reaction times to the turn signals had been obtained for each subject. At the end of 45 trials a 5 minute rest period was given.

Design of the Experiment

There were nine turn signals arranged in three rows and three columns. Each column contained a turn signal carrying the clear (1157), amber coated (1157A), and the amber glass (1157NA) bulb. Similarly, each row contained each of the bulbs. Thus, each bulb was housed once in each row and each column.

The order of presentation of turn signals was determined by randomly selecting a column and then randomnly selecting signals in that column until each had been presented five times. The next column was then selected, moving from right to left, and the procedure repeated. This was done until the signals in all three columns had been presented five times each. Forty-five trials were run with the car at 100 feet and another forty-five at 300 feet.

Half the subjects were run under conditions of bright daylight with the sun falling on the front of the car, and the other half of the subjects were run at night. In the night condition that headlamp above the column of signals being actuated was energized in the low beam position. The headlamps were aimed according to SAE specifications (SAE, 1963).

The Independent Variables (Factors)

There are four factors of interest in this study:

A. Ambient illumination conditions under which the experiment was conducted.
   - A_1: Day, in bright sunlight
   - A_2: Night, against headlamp glare

B. Bulbs
   - B_1: Clear, 1157
   - B_2: Amber coated, 1157A
   - B_3: Amber glass, 1157NA

D. Distance of car indicating the turn
   - D_1: 100 feet
   - D_2: 300 feet

P. Position of the turn signal
   - P_1: Nearest to headlamp, 1.75 inches below headlamp
   - P_2: Mid position, 5.5 inches below headlamp, 1.75 inches above bumper
   - P_3: Between chrome strips of simulated bumper

Factorial Structure

The design can be seen to be a 2 (ambient) x 3 (bulb) x 2 (distance) x 3 (position) factorial. The subjects were nested in the ambient factor.

The Dependent Variable

The measure of performance was taken as the time, measured to 1/100 of seconds, to react to the onset of a turn signal. The lower the reaction time value the better is the performance.

Results

Each subject made 90 responses. There were 48 subjects so that a total of 4,320 reaction times were obtained. The data points were transformed to $\log_e$ values to obtain homogeneity of variance.

The normalized values were then treated by an analysis of variance (Table 1). It will be noted that all the main effects, A, B, D and P are significant. The two factor interactions A x D, A x P, B x D, B x P and D x P are significant, and the three factor interactions A x B x D and A x D x P are significant. Since three factor interactions

TABLE 1
Analysis of Variance of the Transformed Reaction Time Data

Source	df	MS	F
Ambient (A)	1	23.6516	19.35 XX
Subjects w.A	46	1.2225	
Bulbs (B)	2	3.3430	28.07 XX
A x B	2	0.0034	0.03
B x S w.A	92	0.1191	
Distance (D)	1	16.1259	32.98 XX
A x D	1	2.9534	6.04 X
D x S w.A	46	0.4889	
Position (P)	2	1.2271	10.05 XX
A x P	2	4.2899	35.13 XX
P x S w.A	92	0.1221	
B x D	2	1.1857	9.52 XX
A x B x D	2	0.5045	4.05 X
B x D x S w.A	92	0.1246	
B x P	4	0.8786	6.20 XX
A x B x P	4	0.1314	.93
B x P x S w.A	184	0.1417	
D x P	2	0.7577	7.22 XX
A x D x P	2	0.3853	3.67 X
D x P x S w.A	92	0.1049	
B x D x P	4	0.1621	1.25
A x B x D x P	4	0.1325	1.02
B x D x P x S w.A	184	0.1293	

XX Significant at .01 level
X Significant at .05 level

FIGURE III

MEAN REACTION TIME AS A FUNCTION OF BULB, VIEWING DISTANCE AND AMBIENT ILLUMINATION

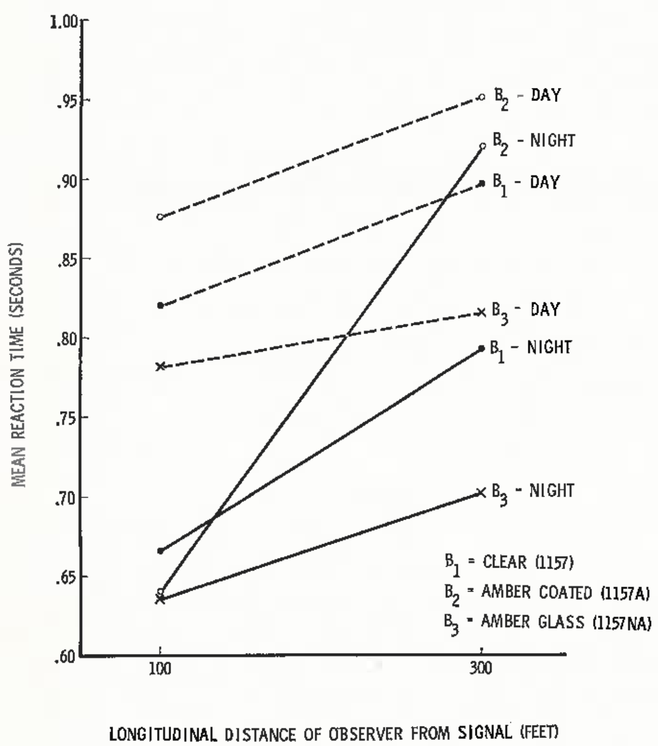
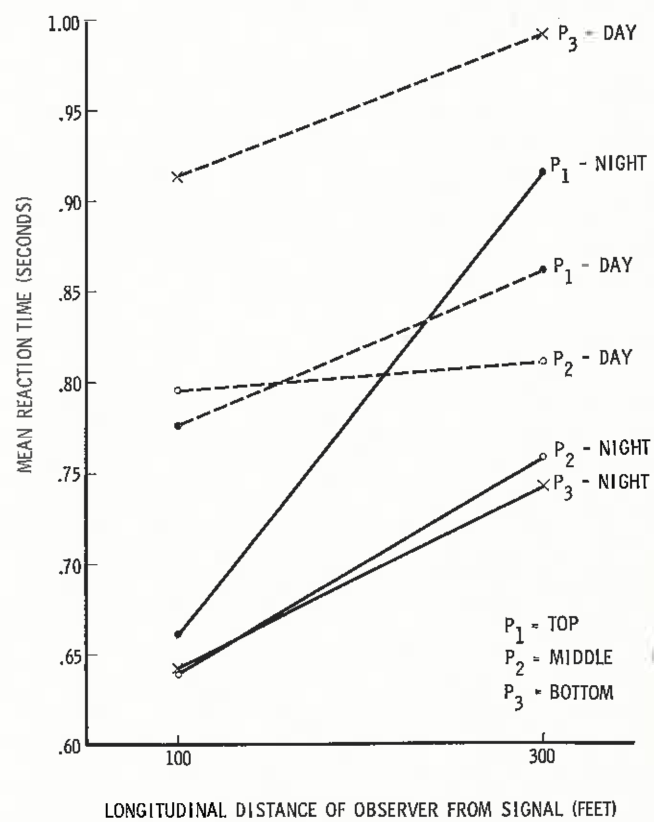


FIGURE IV

MEAN REACTION TIME AS A FUNCTION OF POSITION, VIEWING DISTANCE AND AMBIENT ILLUMINATION



involving all the four factors in the experiment are significant an analysis to determine differences between three-factor treatment means will reveal the major findings in the experiment.

Figure 3 shows the plot of the A x B x D (ambient x bulb x distance) interaction. This shows the mean reaction time for all subjects as a function of the type of bulb, the viewing distance and the ambient illumination. A Duncan range test was performed on these data, in normalized form. For the Duncan tests differences were taken as significant if they met or exceeded the .01 level of confidence.

It was found that at the 100 foot distance in the day condition, the amber glass bulb elicited significantly shorter reaction time than the amber-coated bulb. Performance with the clear bulb was not significantly different from either the amber glass or amber-coated bulb.

At 300 feet in the day condition the amber glass bulb was superior to the other two, which did not differ significantly.

At 100 feet in the night condition there were no significant differences in the reaction times to the three bulbs.

At 300 feet in the night condition the amber glass bulb was significantly superior to the other two, and the clear bulb was also significantly superior to the amber-coated bulb.

Figure 4 shows the ambient x position x distance interaction.

From the Duncan analysis it was found that when viewing distance was 100 feet or 300 feet in the day condition, locating a turn signal in the bumper led to significantly longer reaction times than when the signal was in the mid position or below the headlamp. Location of the signal in either the mid or top position made no difference in performance.

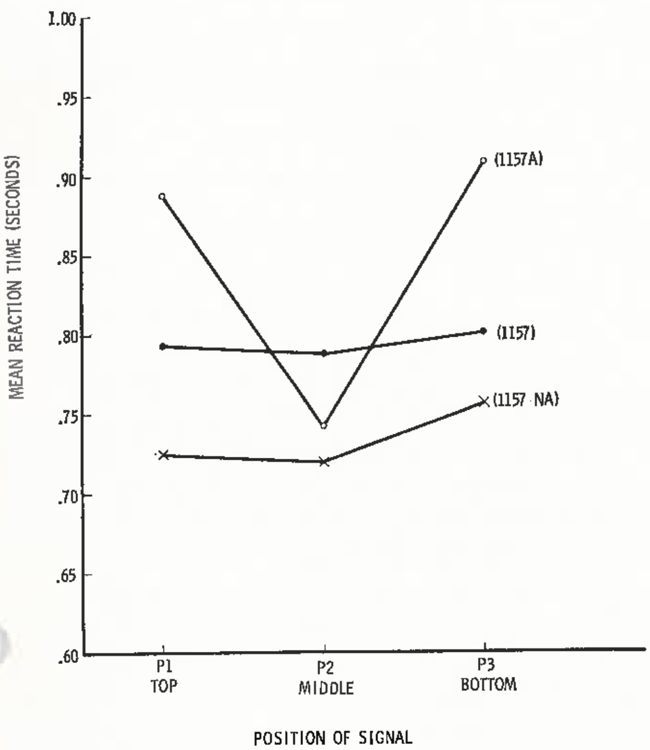
At 100 feet in the night condition there were no significant differences in reaction time attributable to the location of the signals.

At 300 feet at night, however, placement of the turn signal in the top position, nearest the headlamp, led to significantly poorer performance than when it was located in the mid or lowest position. Locating the signal in the mid or lowest position made no difference in performance.

The two-factor interaction, B x P, is the only other interaction which provides information beyond the significant

FIGURE V

MEAN REACTION TIME AS A FUNCTION OF POSITION AND TYPE OF BULB



three factor interactions. It is shown in Figure 5. A Duncan test on these transformed data revealed that when a turn signal was located in the position nearest the headlamp, the amber glass bulb was significantly superior to the clear and amber-coated bulb, and the clear was significantly superior to the amber-coated bulb.

For the middle position the amber glass bulb was significantly superior to the clear bulb, but not significantly different from the amber-coated bulb. The amber-coated bulb was not significantly superior to the clear bulb.

When the signal was located in the bumper both the amber glass and clear bulb were significantly superior to the amber coated, but they did not differ significantly from each other.

The detailed results have been given by examination of the interaction effects as above. However, overall results are given by the main effects. These showed that reaction times were longer (1) in the day condition than in the night condition; (2) when the signal was positioned in the bumper and next to the headlamp than in the middle position; and, (3) at a viewing distance of 300 feet than 100 feet. When the signal contained the amber-coated bulb, reaction times were longer than for the clear bulb which in turn was poorer than the amber glass bulb.

Discussion

The results have shown that the use of reaction time data in this time-shared task can provide a useful index for the evaluation of turn signal devices.

An important finding was that the experimental bulb, with an amber glass envelope, was most readily detectable compared to the presently used amber-coated bulb and the clear bulb.

This finding is particularly important because the superiority of the amber glass bulb is relatively greatest in just those conditions which most reduce the detectability of the amber-coated bulb. While the average reduction in detection time for the amber glass compared to the amber-coated bulb is 13 per cent, the improvement reaches 20 per cent under some conditions as evaluated in this study.

Front turn signals are often located in the bumper moulding or adjacent to the headlamp. This study has shown that for day or night conditions, respectively, these locations are the ones that cause significant increases in detection times.

However, if the choice of locating a turn signal devolves into the selection of one of these positions then the data suggests that best overall performance will be preserved if the signal is placed close to the headlamp rather than in the chromed bumper. This location would also have the advantage of raising the height of the signal so that it lies closer to the line of sight of the driver; and since a greater proportion of driving is done during the day than night the detrimental effect of the glare from the headlamp would be encountered less frequently than the reduced contrast effect produced in the day when turn signals are within the bumpers.

The luminance of the amber glass bulb is approximately 75 per cent of that of the clear bulb. But, the present results have shown that in spite of the light losses caused by the amber envelope this bulb was detected more rapidly than the clear bulb. This indicates that the color of the signal is an important determiner of its detectability.

Conclusions

The amber glass bulb (1175NA) was superior in most conditions, and inferior in none, compared to the clear (1157) and amber-coated (1157A) bulbs.

The amber-coated bulb was not significantly superior to the clear bulb in any condition. The clear bulb was significantly superior to the amber-coated bulb when it was positioned near chrome surfaces or the headlamps.

Positioning a turn signal in the chromed bumper leads to poor detectability in bright, day conditions. At night, turn signals are more difficult to detect if they are located close to the headlamps.

Acknowledgment

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