An Experimental Study of Four Methods of Reflectorizing Railway Boxcars

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● TWO years ago Stalder and Lauer (7) presented a study on the effective use of reflectorized materials on railway boxcars. This was the first time that a study of this nature, carried out with boxcars, had been reported. Hoppe (3) and later Hoppe and Lauer (4) showed that reflectorized materials on the back of trucks would greatly shorten the perceptual differential of distance between the driver and a vehicle ahead. Stalder and Lauer (5) had also shown that pattern distribution had a great deal to do with the effectiveness of illuminated surfaces of reflectorized material.

In the study of boxcars just discussed, two important conclusions were made: (a) the larger the patches of reflectorized material used, the lower the level of illumination needed, and (b) larger concentrations of a given amount of reflectorized materials are more effective than smaller ones.

In a bill introduced in Congress by H. R. Gross of Iowa, and from other recommendations made, it was stipulated that four-inch squares of reflectorized material be placed along the sill of the boxcar at distances of approximately four feet. In the absence of experimental data, this obviously was a best guess on the part of those who were advisers to the Congressman on this bill.

From the studies on boxcars already cited, it appeared that this kind of an arrangement would not be most effective. Consequently, for the purposes of the present investigation the following hypothesis was set up: For a given amount of reflectorized material an optimal utilization of this material must exist. It is axiomatic and well demonstrated that the use of reflectorized materials will help. The question to be answered is how can such reflectorized materials be used most efficiently.

PROBLEM AND APPARATUS

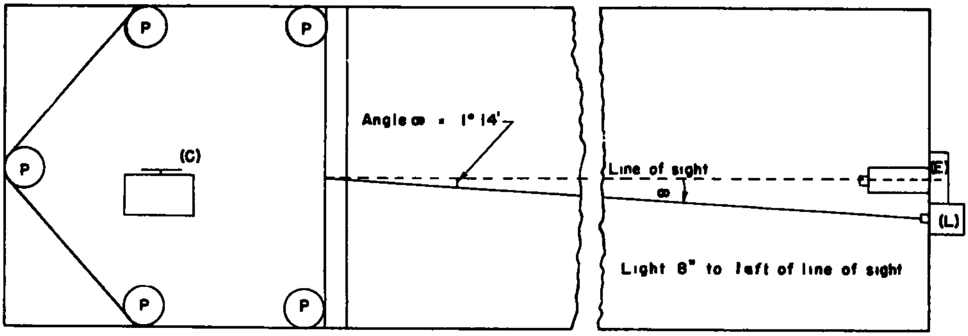
In the first study on boxcars already cited, three different groups of subjects were used for making the tests. Thirty, 30, and 25 subjects, respectively, were run. The subjects of each group were different and may conceivably have differed with respect to visual acuity, night vision, motivation, cultural background and other influences. It was thought desirable to set up the present study using a random-block design which would make possible the presentation of all conditions used to all subjects. By this design it was thought that 40 subjects would suffice to give adequate data for the purposes of evaluating the results found.

This first study has been described by Stalder and Lauer (7). Only a few statements will be made to orient those who are unfamiliar with the study.

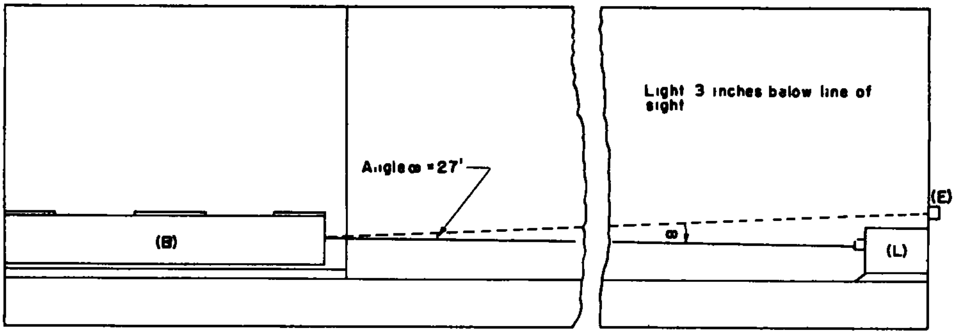
The Scotometer as designed by Stalder, Hoppe, and Lauer (6) was used with the Clason Acuity Meter as a source of illumination in the first series. For series two and three a Viewmaster Model S Projector was used as the luminant with a variac control.

In the first study (7) the distance from the eye of the observer to the stimulus belts was only 29 ft. It was impossible to get the projector located in such a fashion as to reduce the angle of viewing below 27 min. In the present study the distance from the subject to the stimulus object was lengthened to about 43 ft, 6 in. The same carrier for the belts in the first study was adapted for use at the end of the Scotometer tunnel to secure additional distance. Instead of a reversing motor which gave some difference in sound when the direction of rotation was changed, a ½ hp shifting-brush motor was employed and set so that the effective speeds could be established at any desired point.

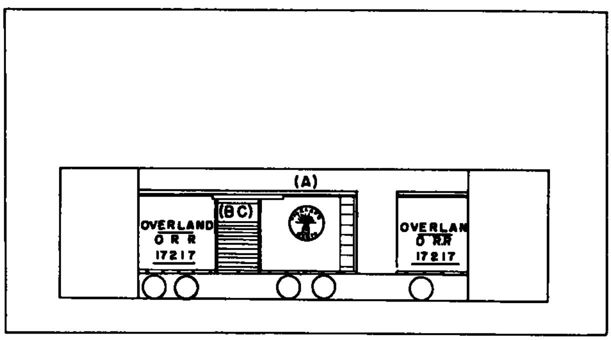
For the first study the belt was calibrated to run around 50-mph scale speed. In the present study the scale speed was set at 40 mph, as that speed was considered more typical of realistic situations than the 50-mph simulated speed. The results in observation apparently made very little difference at various speeds used in a pilot run.



A TOP VIEW SHOWING ANGLE BETWEEN LIGHT AND LINE OF VISION IN SERIES TWO



B SIDE VIEW SHOWING ANGLE BETWEEN LIGHT AND ANGLE OF VISION IN SERIES THREE



C CLOSE-UP OF APERTURE OPENING SHOWING SECTIONS OF TRAIN EXPOSED MOVEMENT WAS REVERSED IN RANDOM ORDER

Figure 1. The subject sits at the right with his eye at the scope (E). The two top sketches A and B show the experimental conditions used in Series 2 and Series 3 respectively. The lower sketch C shows the aperture and reproduction of lettering used on the boxcars. It will be noted that the Overland Route mark is several times larger than the small sill markers. The cross-bars below (BC) on the door were quite subdued and were not noticeable as in the drawing.

Also the signal system between the experimenter and subject was changed somewhat and a double lighting system was placed on the Scotometer panel with thumb switches at each side of the observer. Instead of asking only for a response of "right" or "left" in the present study, the subject was instructed to not only respond but to press the key to the side in which direction the train was moving. Thus if the train were first observed to be moving to the right, he pressed the right-hand key and at the same time called out "right." If the train were observed as moving to the left, he pressed the left-hand key

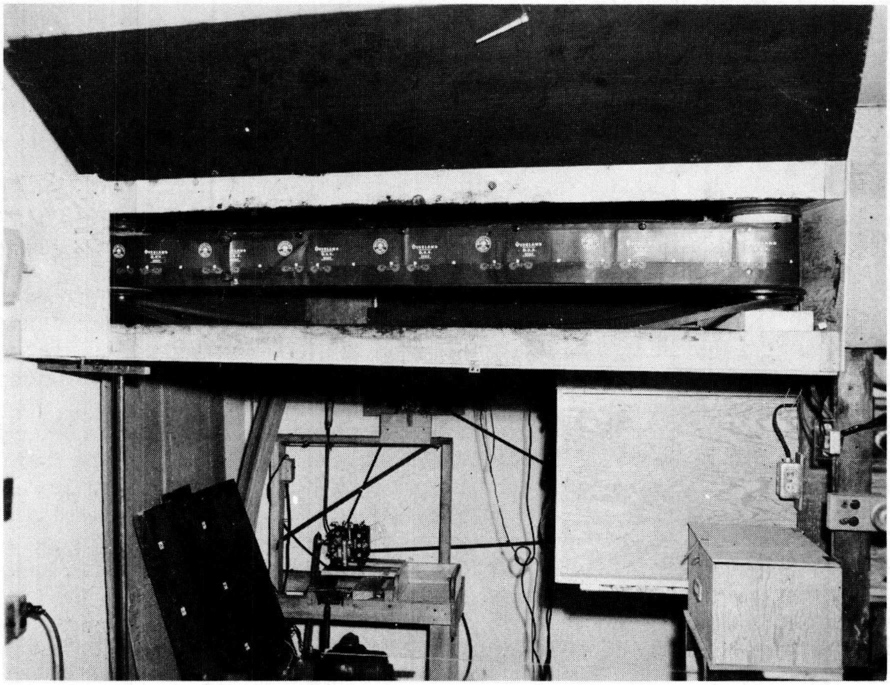


Figure 2.

and at the same time responded by saying "left."

The guide lights were in such a position that the experimenter, who was adjusting the shutter at a gradual rate of change, was able to catch the response both auditorily and visually and thus avoid any reasonable chance of error. A test of the reliability of dial readings from the shutter showed these to be of the order of .96 and above. This was in agreement with the earlier study in which the reliability of observations was found to run about .97. To get this reliability, 10 readings on each belt were made and the first 5 correlated with the second 5. Very slight practice effect was noted.

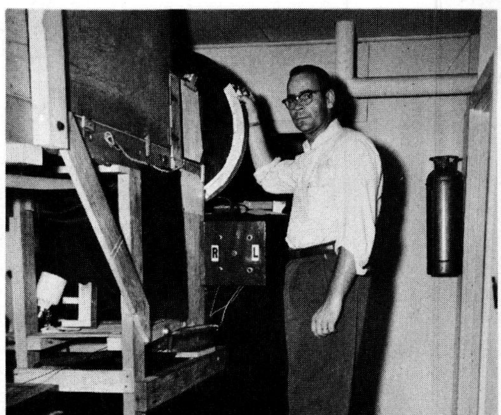


Figure 3.

PROCEDURE AND DESIGN OF THE STUDY

The procedure consisted of giving each subject 10 trials on each of 4 belts, all having the same amount of reflectorized material on the side of the cars. Belt #1 had one large square of reflectorized material placed in the middle of the car. Belt # 2 had 2 square pieces of reflectorized material, each ½ the area of 1, located towards each end of the car. Belt #3 had 3 square pieces, each ⅓ the area of 1, placed along the side of the car—one in the middle and one towards each end. Belt #11 had 11 small markers, each 1/11 of the area of #1, placed along the sill of the car. (See Figure 1)

No other reflectorized materials were used on the side of the car for this set of experiments. Thus the 4 belts were given to each subject in randomized order and so set up that each would have approximately the same number of 1st, 2nd, 3rd and 4th positions in the set of trials. In this way any systematic error such as practice effect which might appear could be minimized.

One other additional feature was added in the present experiment. It is a well known fact to psychologists that the autokinetic illusionary movement might well enter into any such experiment, at least theoretically. In order to minimize this possibility, or at least to keep the apparent fixation point constant, a very small dim red light was placed just below the reflectorized portions of the passing belt. The belt was carried by three pulleys and passed across the aperture directly at right angles with the line of vision of the subject. Having this small, dull red light just below the point of observation and instructing the subject that he was to fixate this light at all times, the possibilities of any autokinetic effect were at least minimized with respect to the reflectorized patches on the box cars.

The general design of the study has been described for the most part as being that of a random block and the procedure being that of having each subject view the four belts successively. Ten readings were made on each belt and the mean of these 10 readings used as a score for each belt.

Each subject was also given a night vision test. All subjects had fairly good acuity and none was below average. This and other factors, of course, were experimentally controlled by the design of the experiment.

In a repetition of such a study it would probably be advisable to measure also the daytime acuity by precise methods. While it would not affect this experiment, the data would be of interest.

Each subject thus made at least 40 observations which were recorded. Two or 3 preliminary trials are given to familiarize each subject with the experiment. After being placed in the apparatus, and being allowed to dark-adapt for 4 or 5 minutes, the directions were read to the subject and he was given the preliminary trials.

In all, there were 1600 observations made which served as a basis of the statistical analysis of this study. Reliabilities for the readings on each belt were computed and are shown in Table 1.

TABLE 1

RELIABILITY OF READINGS FOR EACH BELT

Belt #11 (11 small markings on sill)	.88
Belt #3 (3 markings, one at center and one each end)	.96
Belt #2 (2 markings, one at each end)	.97
Belt #1 (1 marking in center)	.94

The first 5 trials were correlated with the second 5 trials and corrected by the Spearman-Brown formula. Belt #11 was least reliable, probably due to the difficulty inherent in the marking as found from this experiment.

TABLE 2

REFLECTORIZATION OF BOXCARS INTERCORRELATIONS BETWEEN SCORES MADE ON BELTS

N = 40

Belt	11	3	2	1
1	.5823	.7997	.8110	.94
2	.6965	.8701	.97	---
3	.6727	.96	----	
11	.88	----		

TABLE 3

DIFFERENCE IN MEANS IN UNITS OF CALIBRATED LIGHT

	11	3	2	1
Mean light units	21.24	7.38	7.44	5.95
1	15.29[a]	1.43	1.49	----
2	13.80[a]	0.06	----	
3	13.91[a]	----		
11	----			

[a] Significant at the 1 percent level of confidence. Others are not significant above the 15 percent level of confidence.

Two methods of analysis were applied and the results from both were considered. Since the subjects were common there was a correlation between the observations between scores made in the belts. These had to be partialled out, and after using a method proposed by Duncan (1) for analysis of variance, the older formula conventionally used for determining the significance of differences

$$S.D.\ diff = \sqrt{S.D.\ m1^2 + S.D.\ m2^2 - 2 r_{12} \times S.D.\ m1 \times S.D.\ m2}$$

was finally adopted as the check on the first method used. It is somewhat more precise. See Garrett (2).

RESULTS OBTAINED

From the first analysis, using the multiple range and multiple F test, it was found that only certain belts showed a significant difference. All three belts, #1, #2, and #3, yielded a highly significant difference when compared with belt #11.

However, in this analysis it was felt that with the use of more precise methods perhaps differences might be found between belts #1 and #2, and between belts #1 and #3. The computations were made and the results are given in Table 2. The difference between pairs of belts are given in Table 3.

APPLICATIONS

The difference noted for the best application, belt #1 which required 5.95 units of light as compared with the poorest application, belt #11 which required 21.24 units, gives a ratio of 3.57. Converted into distance at 1000 ft for a standard high-beam headlight of 75,000 bcp, this would be equivalent to a distance of 889 ft. If considered at a relative distance of 500 ft, the disadvantage would amount to 444 ft.

Even at 100 ft, which is a very short distance and far below the stopping distance at ordinary road speeds, the added increment needed for equivalent perception time would be almost 89 ft—about 1 second in terms of time at 60 mph. Hence, the advantage of single large reflectorized area becomes obvious. These calculations are based upon the assumption that the differentials in lighting have relative effectiveness at different levels of illumination.

SUMMARY AND CONCLUSIONS

1. Forty subjects were used in an experiment to determine the differences between 4 different types of belts reflectorized in different ways to represent miniature scale-size trains. The results generally confirm the hypothesis set up that a mass application of reflectorized material is superior to a distribution of the same material.

2. Belt #11 seemed to be inferior, partly because the retinal image lag tends to produce the effect of a line which could not be distinguished as moving across a space within the critical angle of incident light falling on the side of a train.

3. By the most precise statistical methods available, and with the number of cases involved, the differences between belts #2 and #3 were not significant. The differences between belts #1 and #3, and #1 and #2 were not substantial. This narrows down the problem to the two or three possibilities—one, two or three patches of reflectorization on the side of each car.

Further studies are being made of the relative effect of vertical strips and square patches of equal dimensions.

ACKNOWLEDGMENT

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REFERENCES

1. Duncan, David B., "Multiple range and multiple F tests." Biometrics, Vol. 21, #1, pp. 1-42 , 1955.

2. Garrett, H. E., Statistics in Psychology and Education. Longmans, Green and Co., New York, p. 207.

3. Hoppe, Donald A., "Perception of longitudinal speed differentials between automotive vehicles on the highway at night." Unpublished masters thesis, 1950, Iowa State College Library, Ames, Iowa.

4. Hoppe, Donald A. and Lauer, A. R., "Factors affecting the perception of relative motion in distance between vehicles at night." Highway Research Board Bulletin 43, pp. 1-16, 1951.

5. Stalder, Harold I. and Lauer, A. R., "The effect of pattern distribution on perception of relative motion in low levels of illumination." Highway Research Board Bulletin 56, pp. 25-35, 1952.

6. Stalder, Harold I., Hoppe, Donald A. and Lauer, A. R., "The Scotometer— a dark-tunnel apparatus for studying night vision of drivers." Proceedings, Iowa Academy of Science, Vol. 52, pp. 397-400, 1953.

7. Stalder, Harold I. and Lauer, A. R., "Effective use of reflectorized materials on railroad boxcars." Highway Research Board Bulletin 89, pp. 70-75, 1953.