Effect of Pattern Distribution on Perception of Relative Motion in Low Levels of Illumination

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ONE of the most frequent causes of accidents, as reported by the National Safety Council, is following too closely behind another vehicle. Many interpretations may be placed upon such a general classification but complaints indicate the incidence of one motor vehicle running into the rear of another at night, either moving or stationary, is much too frequent to be assigned to chance.

The exact reason for following too closely is usually not stated. Various reasons of general nature have been given. In some cases poor vision is blamed. Blinding lights, fog, rain or snow, carelessness, or similar conditions are also mentioned. Whatever may be the alleged reason given for front and rear-end contact of two vehicles headed in the same direction, it is axiomatic that a driver in any reasonable condition or state of mind would not deliberately drive into an object or vehicle plainly visible within stopping distance. It should be stated that the driver did not see the obstacle in time and was unable to adjust his stopping distance accordingly. It is also conceivable that the driver was too slow in making a proper judgment.

Hoppe and Lauer (2) found that increased tailgate perceptibility would decrease judgment time, and errors of discrimination of relative motion and change in distance. Likewise relative brightness was found to decrease the difficulty of making judgments according to verbal reports. Their study was made with several types of targets but with speed differentials not to exceed 10 mph.

THE PROBLEM

The present study was designed to test the primary hypothesis that driving speed is a factor in discrimination of relative motion in low illumination. A corollary hypothesis may be stated as follows: The distribution of pattern-detail, well above the threshold of resolution by the retina, has no affect on the perception of relative motion under mesopic vision and other conditions imposed. It was assumed that: (1) variations in the abilities of subjects used affected all experimental conditions in a similar fashion; (2) the absence of manipulation as experienced in driving would tend to place observations and results on the conservative side so far as the margin of safety in distance judgment is concerned; (3) the time required to make an incorrect judgment of direction of movement is the

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best available estimate of the true time required for a correct perception; (4) trials made when distance is decreasing are of more practical value than the reverse; (5) systematic errors are minimized by rotation of stimulus presentations; and (6) subjects were motivated to do a careful job of making judgments.

Due to limitations of time, the design of the experiment was restricted to the use of one control condition and two treatments of tailgate or targets. One color of reflectorized material, a red having a reflection characteristic of 35 as compared with a flat-white surface designated as unity, was used for the overlay pattern.

APPARATUS

The scotometer, as described by Stalder, Hoppe, and Lauer (3) was used to make the measurements. It was adapted to give various equivalent scale-speeds ranging from 10 to 50 mph. by increments of 10 mi., plus or minus 1 mi. per hr.

This apparatus used consists essentially of a dark tunnel approximately 43 ft. long having two moving belts painted neutral gray to resemble a concrete paved roadway. The shoulders and surroundings are painted flat black. The belts may be moved in either direction by a manual control at any desired speed through two Vickers hydraulic transmissions. By attaching miniature cars and panels to the belts the conditions of actual highway operation are simulated more or less realistically. That this is the case was shown empirically (2) by comparison of runs made on the road and in the laboratory with correspondingly scaled distances. The results showed similar parallel and comparable trends with full-sized and miniature apparatus.

By an optical system of periscopic mirrors, the observer viewed an area of the same angular proportions as he would through an average windshield when driving on the highway. Impinging and opposing lights were calibrated to give lighting conditions equivalent to those found from standard headlight illumination on the highway. Three 4- by 5-in. targets were used as shown in Figure 3. A, is a control target painted flat black, having a reflection characteristic of 0.04, and with one taillight as shown. The latter is 3/16 in. in diameter, having a scale value of $4\frac{1}{2}$ in. across the lens. Targets B and C each have 6.25 sq. in. of reflectorized pattern applied as shown. This would be the equivalent of about 25 sq. ft. of surface on a tailgate of actual size. It will be noted that the border was delineated somewhat more in Target B than in the checker-board treatment used for Target C. This target gave a more nearly even distribution of reflectorized pattern. The material used for reflectorization of both targets was 35 times flat-white as stated.

The designs were chosen purely as experimental expedients for comparing concentrated versus distributed areas of reflectorized material. They were not intended as suggestions for actual use on vehicles.

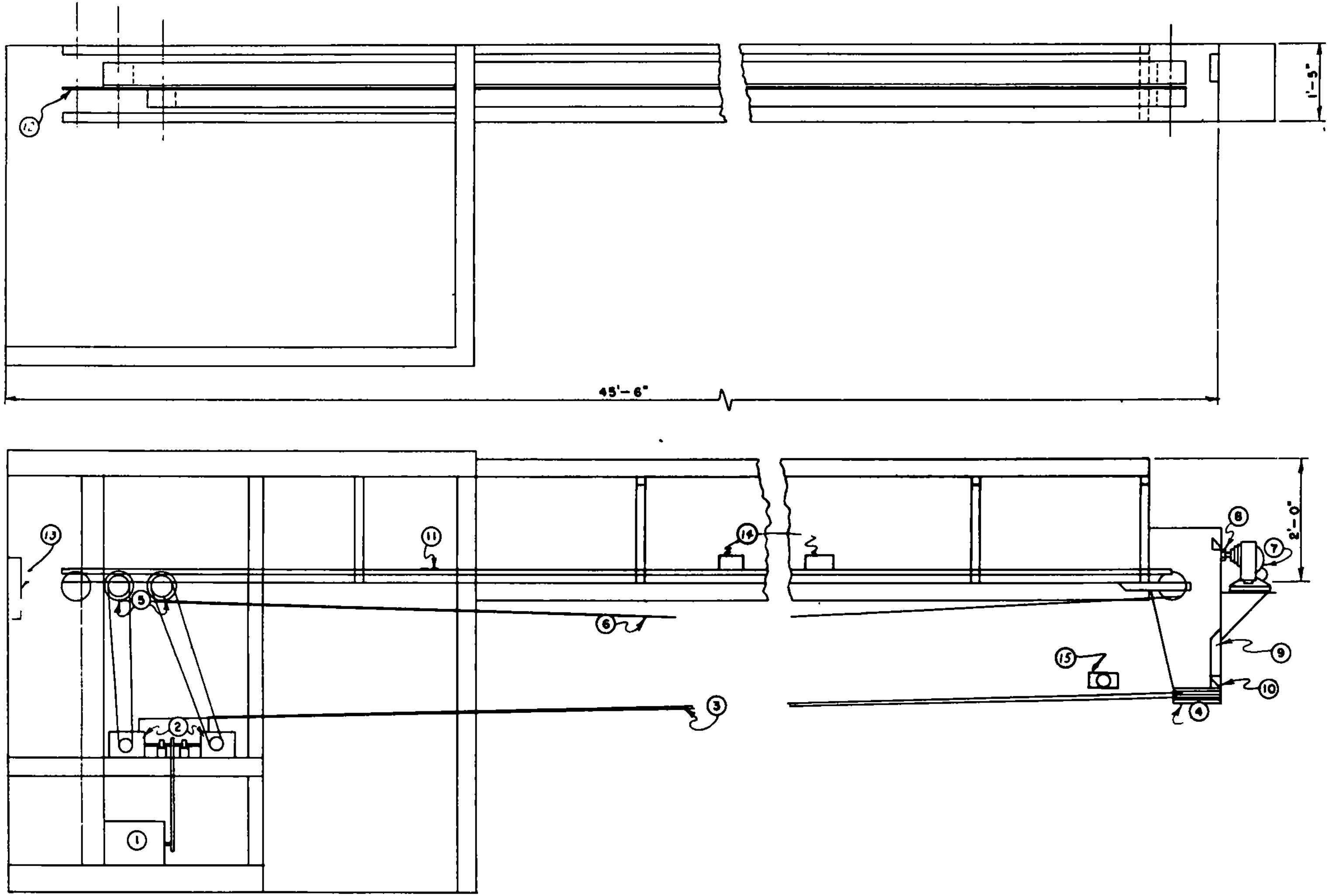

Figure 1. Schematic diagram of the scotometer, or dark tunnel.

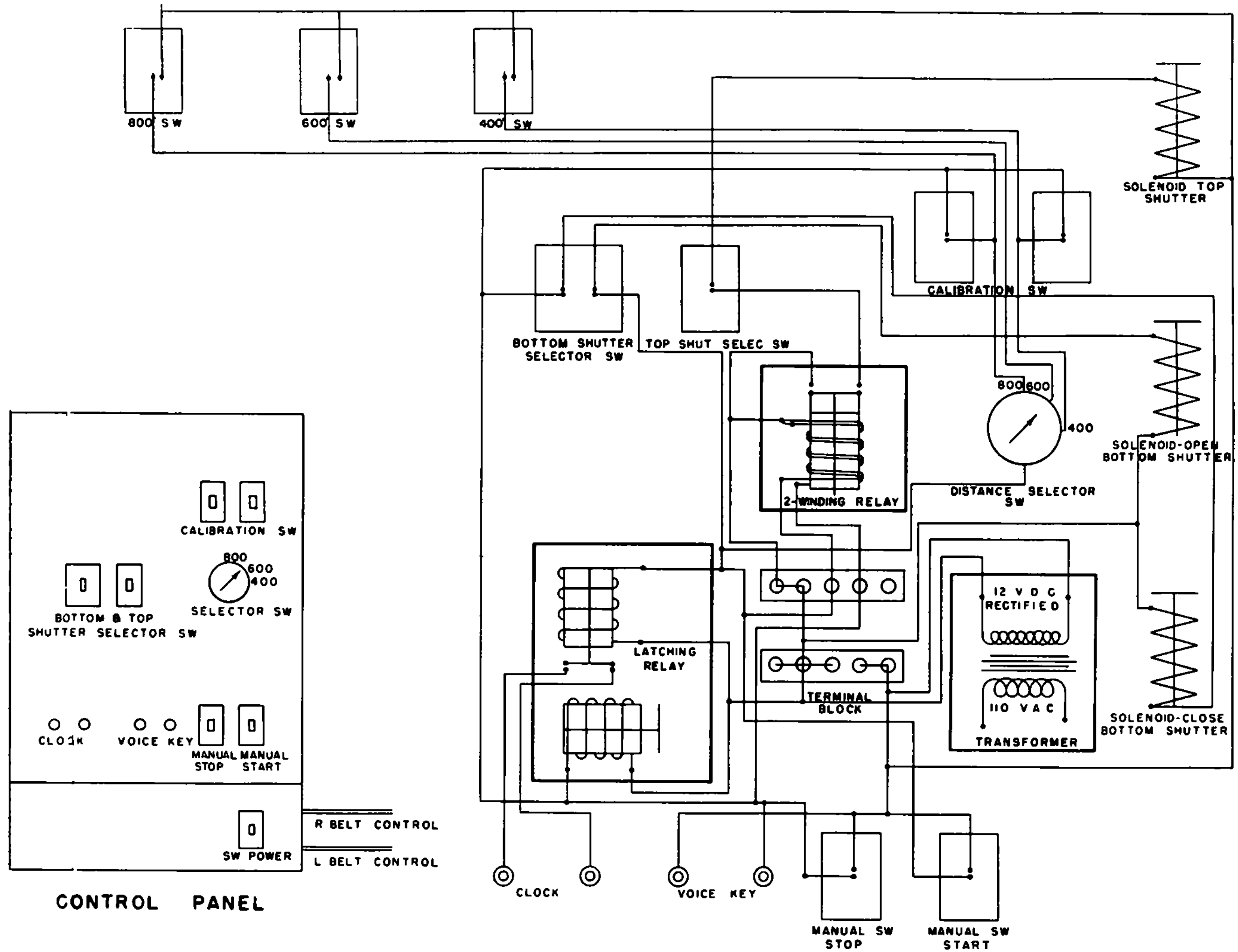

Figure 2. Schematic wiring diagram of control circuits for scotometer.

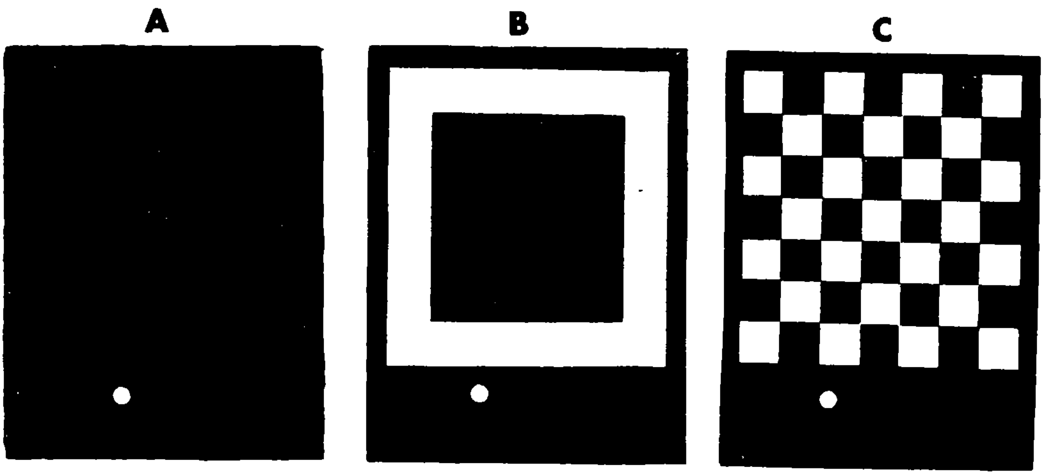

Figure 3. Targets used as stimuli.

METHOD AND PROCEDURE

The observer or subject was first measured for visual acuity since the selection of subjects with near normal vision would tend to reduce variance and thus effect greater economy in time needed for the observations. Next the observer was seated at the scotometer under a black hood with illumination approximately that of the average condition experienced in a car or other vehicle during night driving. The experimental conditions were presented in random and rotation order to reduce the possible effects of systematic error. Each of the three target treatments were presented at 10, 20, 30, 40, and 50 mph. in scale-speed, both with and without opposing lights. In order to keep the length of the experimental period short enough to avoid various fatigue effects and boredom, only two lighting conditions were used: (1) high-beam intensity of impinging lights without opposing light and (2) low-beam intensity of impinging lights with opposing light.

These are usual conditions expected on the roadway, assuming everyone drives with high beams but depresses his beam whenever meeting another vehicle.

The panel of the truck theoretically being overtaken is carried by the right-hand belt as seen from the eye of the observer. At a predetermined point the experimenter opens the shutter which starts a standard 1/100-sec. timer clock. The observer reports verbally the instant he detects whether the target is moving closer to him by saying "slower" and further from him by saying "faster." These responses correspond to the condition of a vehicle ahead moving slower or faster in relation to the driver as experienced in actual driving. An electronic voice-key closes the shutter the instant the sound is emitted, stopping the time clock and measuring the time for each judgment. There is a slight constant error due to lag in the relay. This is of the order of 70.4 milliseconds or about 2 percent of the mean judgment time for all targets.

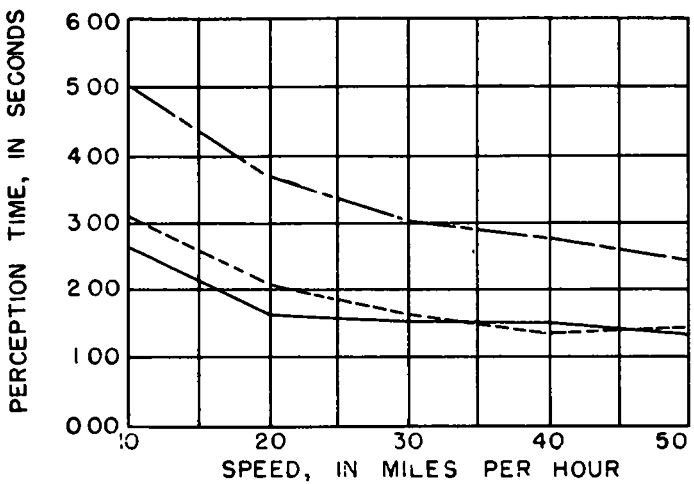

Figure 4. Mean perception time for decreasing distance, no opposing lights.

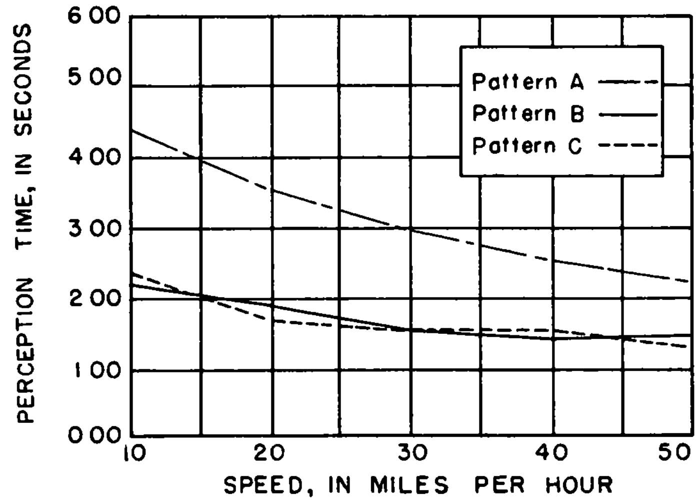

Figure 5. Mean perception time for decreasing distance, low-beam, low opposing lights.

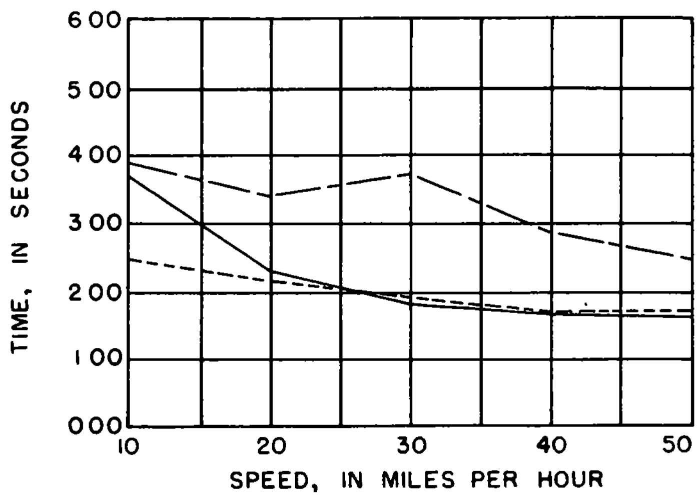

Figure 6. Mean perception time for increasing distance, high-beam, no opposing lights.

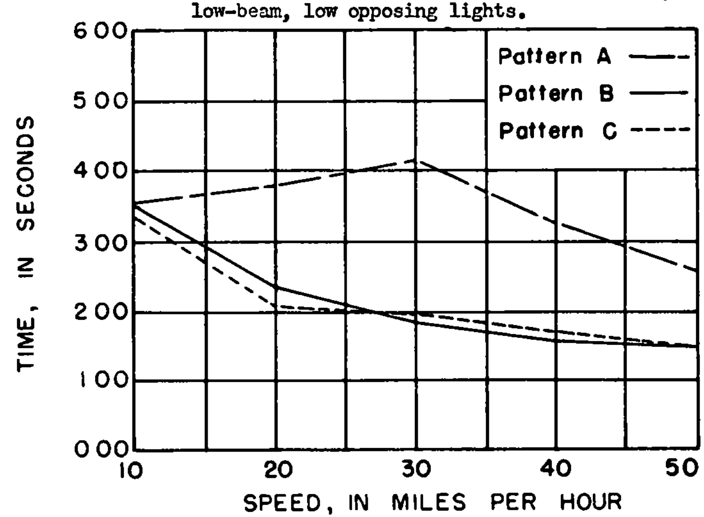

Figure 7. Mean perception time for increasing distance, low-beam, low opposing lights.

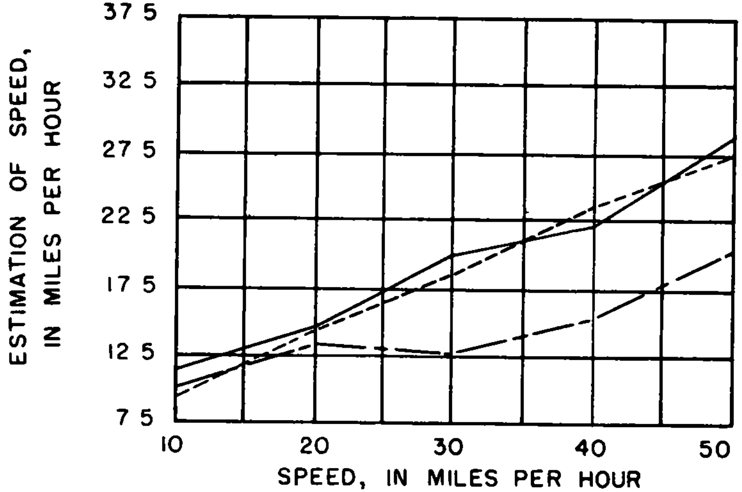

Figure 8. Mean speed differential estimations for high-beam, no opposing lights.

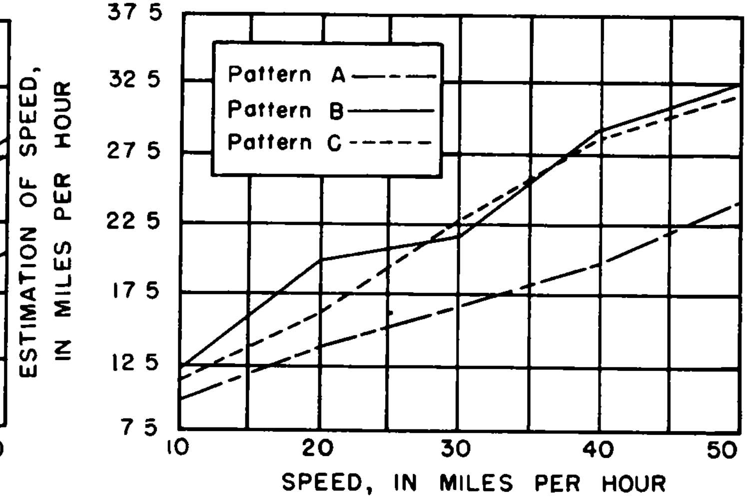

Figure 9. Mean speed differential estimations for low-beam, low opposing lights.

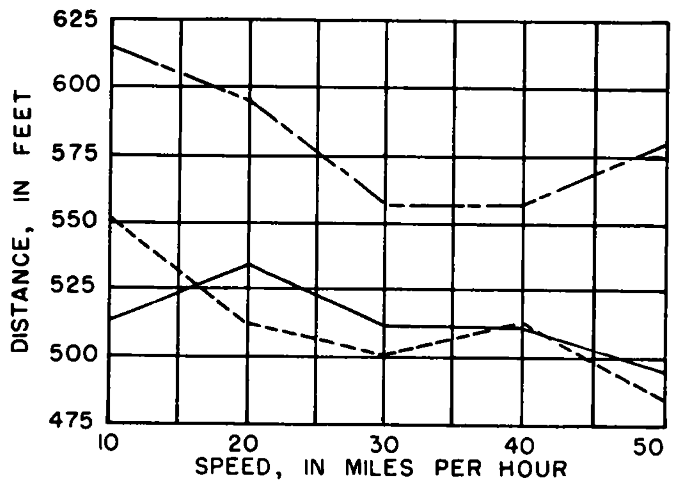

Figure 10. Mean distance judgment estimation for high-beam, no opposing lights.

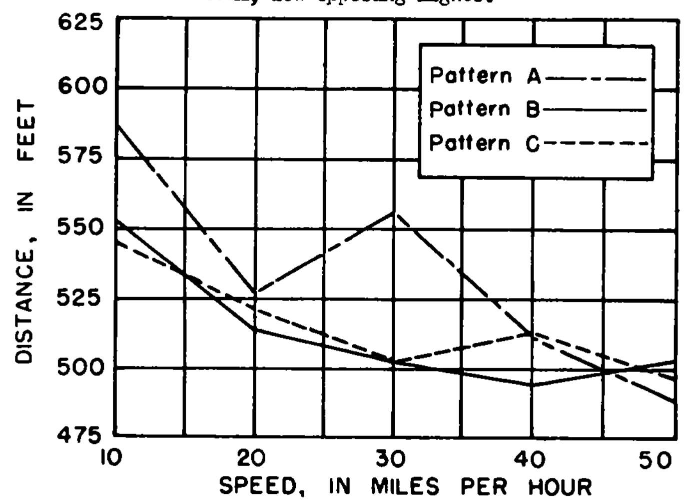

Figure 11. Mean distance judgement estimations for low-beam, low opposing lights.

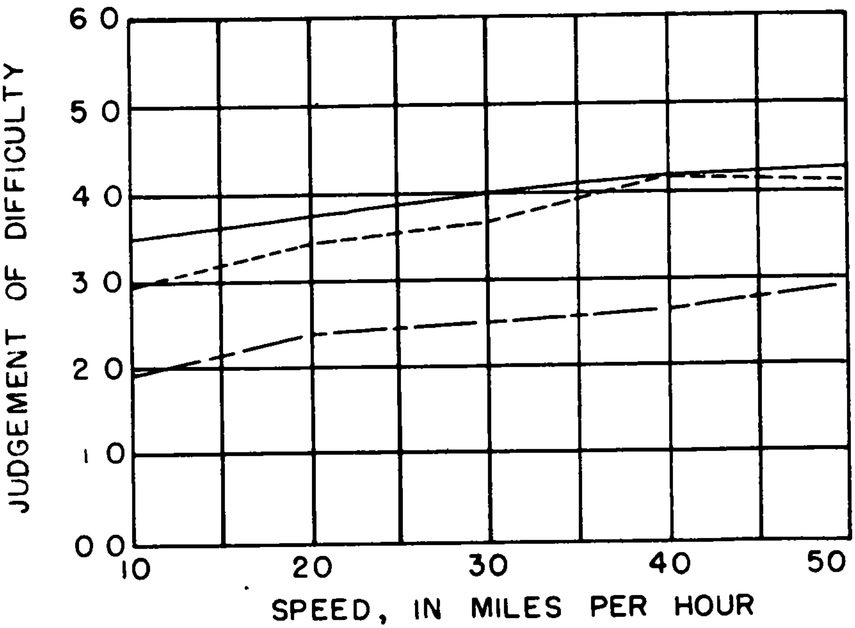

Figure 12. Mean judgements for level of difficulty, for high-beam, no opposing lights.

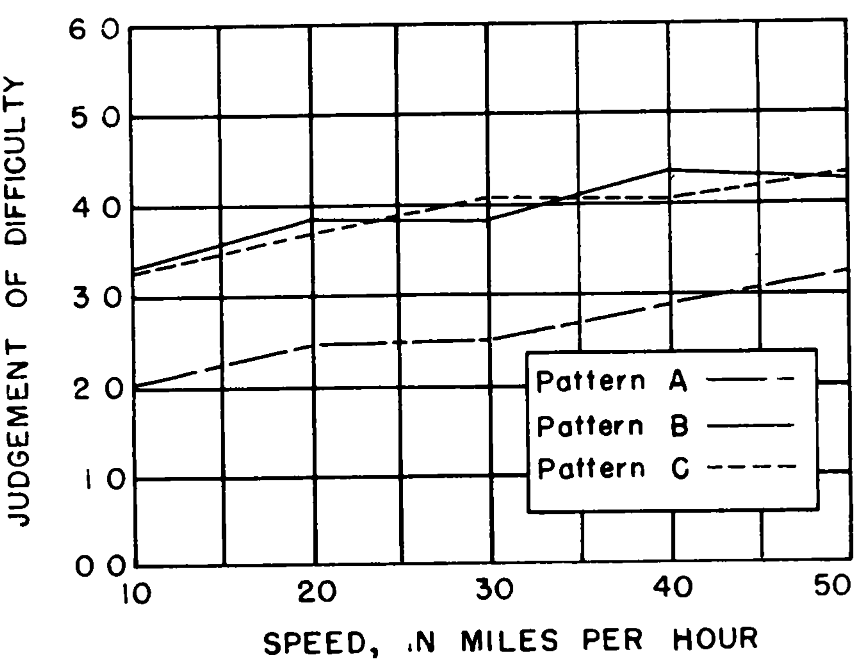

Figure 13. Mean judgements for level of difficulty, for low-beam, low opposing lights.

The subject is then asked to estimate: (1) the difference in speed of the moving vehicle ahead and his own imagined speed, (2) the difficulty of making a judgment, and (3) distance of the vehicle ahead. The request is structured to the extent that he is asked to consider the distances as being between 400 and 800 ft. and to make estimates by increments of 25 ft. Thus the vehicle ahead would be judged as being 400, 425, 450, and so on up to 800 ft. ahead.

Thirty subjects were used ranging in age from 19 to 54 years. Each made 84 separate observations for a total of 2,520 judgments for all subjects. Reliability of observations ranged from 0.67 to 0.94. These are estimates made from the correlation of the sum of two trials using conventional formulas used for this purpose.

RESULTS

The data were analyzed on the basis of the following variables as aspects of the measurements made: (1) perception time, (2) estimation of speed differential, (3) estimation of distance, (4) judgment of difficulty, and (5) errors made in direction of movement.

In order to summarize briefly without going to the trouble of discussing each difference separately, it suffices to say that the mean differences obtained were subjected to the "t" test for significance. Approximately four out of five of the points on the graphs are significant between comparison of Conditions A and B and Conditions A and C. This is roughly equal to about one-line marking distance on the graph for the 1 percent level of confidence and a half line for 5 percent level of confidence as a rule-of-thumb comparison to be applied in studying the graphs.

Although close to the border of significance at times the experimental Condition B was slightly superior to C in the overall comparison.

It is also noteworthy that the errors in direction of movement were much more frequent at scale speeds of 20 mph. and below. Few errors were made at scale speeds above 20 mph. More errors were made when distances were increasing rather than decreasing, for Pattern A as compared with those for Patterns B and C. Differences compared for the latter types of errors were significant at the 1 percent level of confidence. However, it is assumed that decreasing distance is more important than increasing distance so far as discrimination is concerned when driving on the highway. It is more important for a driver to be able to detect the rate at which he is overtaking another vehicle than it is to determine how fast the other vehicle is moving away from him.

A correlation of 0.45 was obtained between visual acuity and perception time, although no one had less than about 67 percent vision. Clason Acuity.1/ This would indicate a marked disadvantage in perceiving relative motion by persons with poor vision. Standards for licensing as low as 27 percent Clason, or about 20/70, have been reported for some states. Vision of 50 percent Clason, or 20/40, is the average lower limit throughout most of the states.

1/ - Measurement units used by Bausch and Lomb in calibrating the Clason Acuity Meter.

Pattern B required significantly less time for perception of direction of movement at scale-speeds above 20 mph. than Pattern C, indicating an advantage of sharper target border delineation when possible to obtain it. It is hoped that Patterns B and C may be combined in a future study to evaluate additive effects.

Above 30 mph., scale-speed, the advantage of Patterns B and C were significantly superior to Pattern A by the criteria of evaluation used. Targets B and C were significantly judged to be closer than A for all but two conditions of lighting and speed and these two were borderline. Significantly used here in the sense of being at least at the 5 percent level of confidence.

The difficulty of perception and judgment was greatest for all lower speeds. Target A showed much higher average ratings for difficulty of estimation. The results confirmed the general findings of Hoppe and Lauer.

CONCLUSIONS

Considering the conditions of the experiment, the targets used, number of subjects making the observations and other limitations, the following conclusions may be made with a substantial degree of confidence:

1. Increasing visibility of a moving target or vehicle at mesoptic levels of vision will significantly decrease the time for accurate determination of direction and rate of movement, increase the accuracy of estimating or judging actual difference in speeds, increase the safety factor for stopping distance by reducing the apparent distance of the brighter targets, and decrease the errors in judgment of direction of movement.

2. Higher visibility is particularly effective at high differential speeds when the hazards of collision are greatest.

3. Equal areas of reflectorization are slightly more effective, with respect to the conditions used in this experiment, when the target is sharply delineated.

4. Perception time converted to distance travelled before reaching a judgment shows an advantage of 30 ft. or more at lower speeds to 75 ft. at higher speeds for the brighter targets. This conclusion involves the assumption that scale distances correlate highly with actual distance. This was shown to hold for certain targets by actual road tests in earlier experiments.

5. The primary hypothesis set up for investigation, that differential speed is a factor in judgment of relative distance, is confirmed.

6. The corollary hypothesis, that distribution of pattern detail has no effect on perception of movement, is only mildly rejected; further experimentation needs be made with different patterns, colors, and combinations of patterns with delineating borders for definite conclusions on this point.

7. Reflectorization of tailgates greatly increases perceptibility of relative motion over conventional nonreflectorized treatment of tailgates. This is particularly important when vehicles are travelling at higher rates of speed.

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