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Perception-Response Time to Unexpected Roadway Hazards

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Perception-response (PR) time, the time from the first sighting of an obstacle until the driver applies the brakes, is an important component of stopping sight distance. The purpose of this study was to measure the PR time of unalerted subjects to an obstacle in their lane encountered while cresting a hill. Data were obtained from 64 subjects, of whom 49 were young and 15 older. Measures were made of the time from first sighting of the obstacle until the accelerator was released, as well as accelerator-to-brake time. The results indicate a 95th percentile PR time of about 1.6 s for both age groups.

INTRODUCTION

How much time should be allowed for a driver to respond to an unexpected obstacle in the roadway? The question has practical significance in highway engineering because of a concept known as sight distance. Sight distance is a criterion used in an effort to ensure that drivers will always have sufficient visibility to be able to deal adequately with a variety of potentially dangerous situations.

The concern of this investigation was with situations in which the driver's visibility distance is restricted by the configuration of the roadway itself (stopping sight distance). Examples are an obstacle hidden by a hill crest or a horizontal curve through a cut. The intent is to provide adequate forward visibility so that a driver could stop short of an unexpected obstacle. The determination of stopping sight distance includes consideration of what is generally referred to in highway engineering as driver perception-response (PR) time. PR time corresponds to reaction time in the psychological literature. It starts when the obstacle first becomes visible to the driver and ends when he or she applies the brakes. Thus, it allows for the driver to detect the obstacle, identify it, decide what action is appropriate, and put that decision into effect. For stopping sight distance, PR time is presently estimated as 2.5 s in U.S. practice.

Overestimating PR time unnecessarily increases roadway construction costs. Underestimating it increases the hazard level for motorists. Hence, there has long been an interest in arriving at an accurate estimate of PR time. Unfortunately, the problems in obtaining accurate data in a realistic situation from truly unalerted drivers are not trivial. As a result all studies in this area involve some compromises. However, many of the published studies have used alerted subjects or stimuli that raise questions concerning their applicability. For reviews of this work see Triggs and Harris (1982) and Olson,

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Cleveland, Fancher, Schneider, and Sivak (1982). In addition, the specific situation with which stopping sight distance is concerned has not been studied under any conditions.

METHOD

Independent Variable

Two age groups were used. There were 49 younger subjects, ranging in age from 18 to 40. Of these, 32 were male and 17 were female. There were 15 older subjects, ranging in age from 50 to 84. Of these, seven were male and eight were female.

Dependent Variable

Time was measured (1) from the first visibility of the obstacle until the subject released the accelerator, and (2) from accelerator release to brake contact. These two measures were then summed to obtain total PR time.

Equipment

The test vehicle was a full-size 1980 station wagon. It was equipped with a distance-measuring system (0.5-m accuracy), the output of which was displayed on digital counters. Digital timers (0.01-s accuracy) were used as well.

Test Site

In selecting a test site the first concern was safety. We sought an area with little vehicular and pedestrian traffic, no parking, and nothing solid to run into should the subject leave the road. In addition, the combination of speed and visibility distance had to be such as to challenge the subject. A site meeting these criteria was located on a crest vertical curve on a two-lane road in a rural area. The average visibility distance over the crest to the top of the obstacle was 46 m. Most of the subjects were traveling between 12 and 14 m/s when the object first became visible, meaning they had about 3 to 4 s to "collision."

Procedure

Each subject was seated in the driver's position of the test vehicle and was asked to adjust the seat and mirrors until they were comfortable. The experimenter rode in the rear seat on the right side.

Instructions were read to subjects before they started out. They were told that they were going to participate in a study of driving performance, but first they were to drive the test car a few miles to become accustomed to its characteristics.

When any questions had been answered, the drive started. The experimenter occasionally told the subject to turn, move into a particular lane, and drive at a certain speed. Another experimenter at the test site watched for approaching traffic and placed the obstacle (a piece of yellow foam rubber 15 cm high and 91 cm wide) on the left side of the subject's lane only when certain that the test vehicle was next.

After driving about 6 km the subject was on the approach to the test site. Shortly before the obstacle came into the subject's view, the experimenter pressed a button, starting a distance counter and timer. These were shut off by the subject's releasing the accelerator and were used to calculate speed. Releasing the accelerator started another counter and timer. The timer was shut off when the brake pedal was touched, giving accelerator-to-brake time. The experimenter shut off the counter as the front of the test car reached the obstacle.

After the subject had been briefed on the true purpose of the study, the next step was to measure the distance at which he or she could first detect the obstacle. To do this the subject maneuvered the car until the top of the obstacle was just visible over the hill crest, then drove slowly forward until the ob-

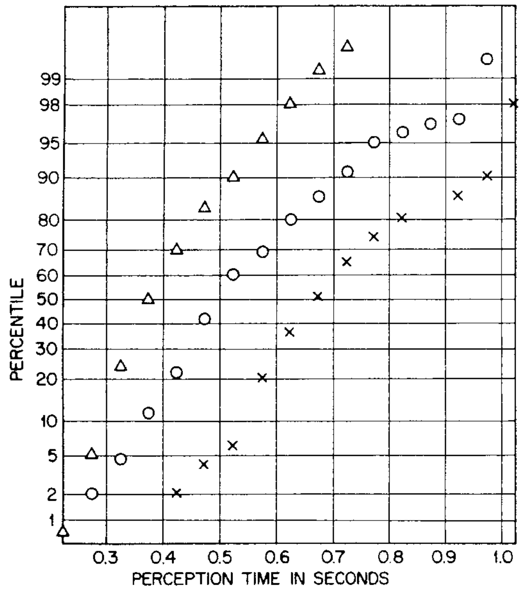

Figure 1. *Normal probability plot of perception times for young subjects (X = surprise, O = alerted, Δ = brake).*

stacle was reached. The experimenter measured this distance with the on-board equipment.

Next, five trials were run under "alerted" conditions. The subjects were asked to drive up the road at about the same speed as before, releasing the accelerator and tapping the brake pedal as quickly as possible after seeing the obstacle. The obstacle position was changed on each trial by moving it up or down the reverse slope of the hill.

At the completion of the alerted trials an auxiliary brake lamp, 10 cm in diameter, was attached to the front of the hood, directly in front of the subject. The subject was instructed to drive back along the route that had been used to arrive at the test site and when the light came on to release the accelerator and tap the brake as quickly as possible. After two practice trials, five additional trials were taken on this task. These will be referred to as *brake trials*.

Data Reduction

Perception time is defined as the interval between first possible sighting of the obstacle and accelerator release. This was obtained by subtracting the distance from the obstacle at which the accelerator was released from the maximum visibility distance to the obstacle and dividing the difference by speed.

Response time is defined as the interval between release of the accelerator and contact with the brake pedal. This was measured directly on each trial, as noted earlier.

Total time was obtained by summing the first two measures. This corresponds to PR time in stopping sight distance.

RESULTS

Younger Subjects

Figures 1, 2, and 3 are normal probability plots of the time data for the younger sub-

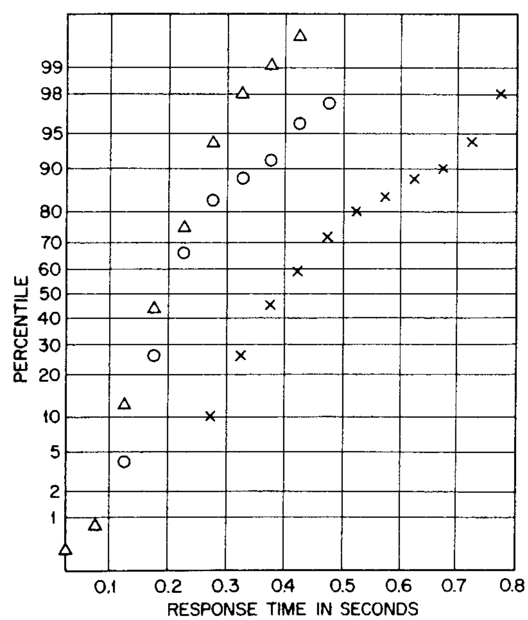

Figure 2. *Normal probability plot of response times for young subjects (X = surprise, O = alerted, Δ = brake).*

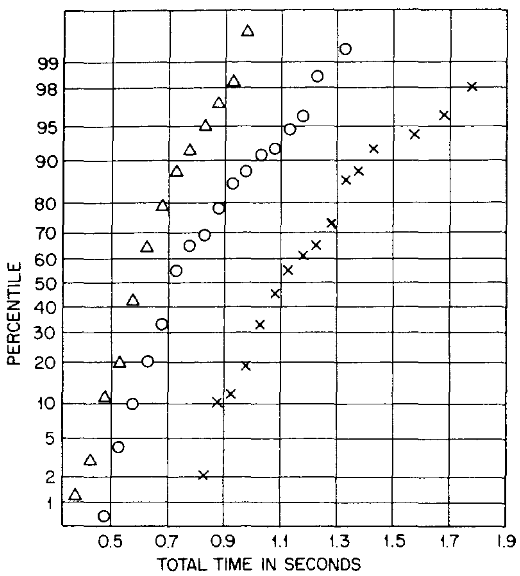

Figure 3. *Normal probability plot of total perception-response times for young subjects (X = surprise, O = alerted, Δ = brake).*

jects. Figure 1 is perception time, Figure 2 is response time, and Figure 3 is total PR time. Each figure shows the data from all three conditions, labeled *surprise, alerted,* and *brake.*

The distribution of perception times for the surprise and alerted conditions (Figure 1) are very similar, differing at each percentile by about 0.2 s. However, the distribution for the brake condition is much shorter. The 5th- to 95th-percentile range for the surprise and alerted conditions are about 0.5 s, whereas that for the brake condition is about 0.3 s.

Although the distributions for perception time in the surprise and alerted conditions are of almost identical width, this is not true of response time (Figure 2). In this case, the 5th- to 95th-percentile range for the surprise condition is again about 0.5 s. However, the range for the alerted condition is about 0.3 s, and that for the brake condition is about 0.18 s.

The total PR times are shown in Figure 3. The young to middle-aged drivers in this test produced a 95th percentile PR time of about 1.6 s.

Older Subjects

Figures 4, 5, and 6 summarize the time data for the older subjects. They should be compared with Figures 1, 2, and 3.

Figure 4 shows the distribution of perception times for the surprise, alerted, and brake conditions. The older subjects' perception times in the surprise and brake conditions were slightly longer on average than were those of the younger subjects, whereas their perception times in the alerted condition were about the same.

The response times for the older subjects are shown in Figure 5. These data should be compared with Figure 2. In the surprise condition, the response times for the older subjects averaged less than those of the younger subjects. However, the response times of the

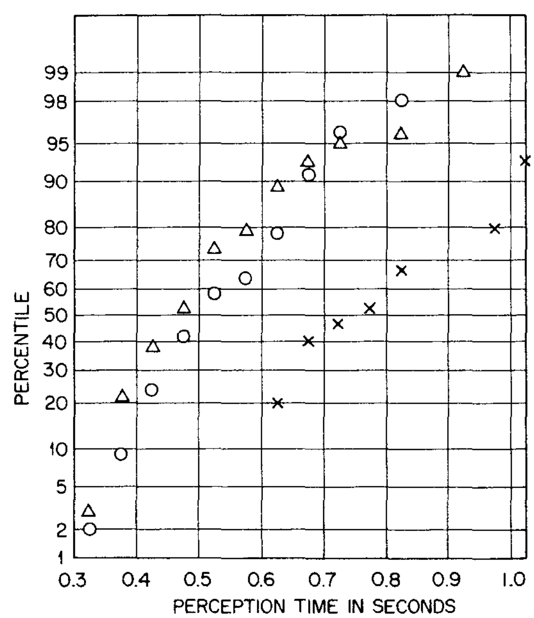

Figure 4. *Normal probability plot of perception times for older subjects (X = surprise, O = alerted, Δ = brake).*

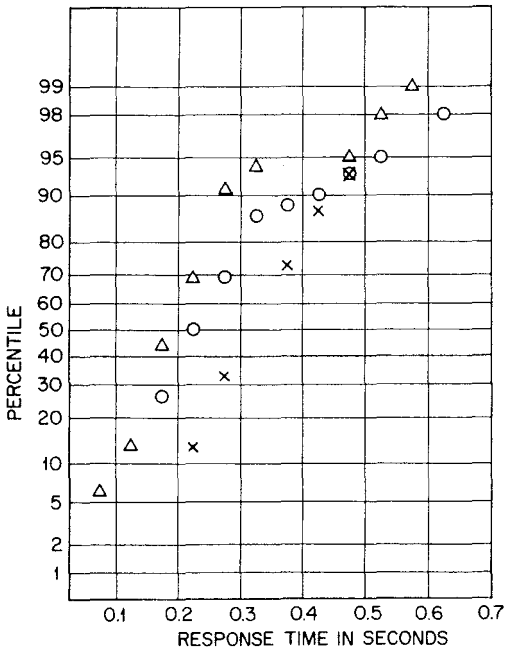

Figure 5. *Normal probability plot of response times for older subjects (X = surprise, O = alerted, Δ = brake).*

two groups were very similar in the alerted and brake conditions.

Figure 6 shows the total perception-response time distributions for the older subjects. This should be compared with Figure 3. The surprise and alerted distributions for these two groups of subjects are very close. Only the times for the brake condition tend to be longer for the older subjects.

CONCLUSIONS

The results of this study suggest that a 95th-percentile PR interval for a population of ordinary drivers confronted with an unexpected roadway obstacle is about 1.6 s. This applies to the specific situation investigated. For example, a more intimidating obstacle, or one for which the only possible response is braking, may have produced different (most likely shorter) PR times.

The subjects in this study were possibly abnormally alert relative to the general population of drivers. They had been driving for only about 10 to 15 minutes at the time of the surprise event, and the presence of the experimenter in the back seat may have made them more cautious and attentive than usual. As far as is known, none of them were under the influence of alcohol or any other drug. Given these circumstances, the distributions shown in Figures 3 and 6 are probably conservative relative to what would be found in the "real world." However, there is no way to accurately estimate the correction required. Available response time data for the possible variables (e.g., various drugs, fatigue) are generally not adequate, and their incidence in the driving population is not known.

At the least, it appears that the 2.5-s PR

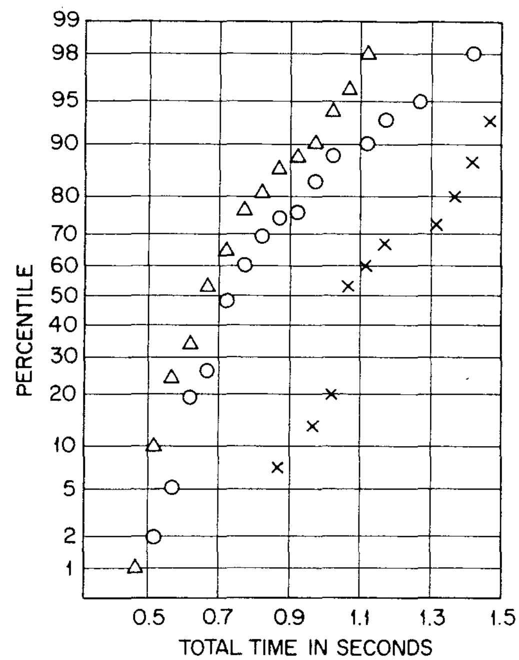

Figure 6. *Normal probability plot of total perception-response times for older subjects (X = surprise, O = alerted, Δ = brake).*

time estimate currently used in determining stopping sight distance is not too short, as some individuals have suggested (e.g., McGee, Hooper, Hughes, and Benson, 1983). If consideration is given to factors such as fatigue and alcohol, the results of this investigation suggest that 2.5 s may be a reasonable estimate of a higher-percentile perception-response time applicable to the stopping sight distance situation.

Past research has consistently shown that reaction time increases with age (Welford, 1977). Indeed, based on the brake condition of this test, which most nearly approximates classical reaction-time studies, one would conclude that older persons require more time to respond. However, in both the surprise and alerted conditions of this test the distributions of total PR times for the two age groups were basically the same. Admittedly, the number of older subjects in the sample is relatively small, but there is no evidence that older drivers require substantially greater sight distances in order to be able to respond safely to unexpected roadway hazards.

ACKNOWLEDGMENT

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