

Drivers' Brake Reaction Times

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The object of this investigation was to determine the distribution of brake reaction times which can be expected from drivers who have to brake suddenly and completely unexpectedly in traffic situations. The experiments were carried out as follows:

1. Brake reaction time was measured on a large group of drivers (321) in an anticipated situation on the road (Brake reaction time 1).
2. A small group of drivers (5) was repeatedly tested in the same way (Brake reaction time 2).
3. The same small group was repeatedly tested in a surprise situation (Brake reaction time 3).
4. The ratio of brake reaction time 3 to brake reaction time 2 was used as a correction factor and applied to brake reaction time 1.

The corrected median of the resulting distribution was 0.9 sec.; 25% of the group was estimated to have a brake reaction time longer than 1.2 sec.

INTRODUCTION

The usual driver reaction to a potential accident situation is sudden braking. As a consequence, one of the main factors determining whether or not the accident will be avoided is the driver's reaction time.

This report describes a methodological investigation of brake reaction time. An important methodological problem in studying brake reaction time has been the difficulty of getting measurements which would be applicable to ordinary traffic situations. Furthermore, from the point of view of traffic safety it is desirable to know the distribution of brake reaction time over the population of drivers. The specific objectives of the study were as follows:

1. To obtain a correction factor for estimating brake reaction time when braking is unexpected from brake reaction time measures obtained when braking is expected.
2. To determine the brake reaction time distribution in a representative sample of drivers when braking is unexpected.

Reaction time has long been the object of study in the fields of physiology and psychology. Two excellent surveys of reaction time investigations relevant to driving situations are those by Teichner (1954) and Forbes and Katz (1957).

The picture that has emerged from the

studies reviewed is that reaction time varies with the type of task involved, with level of attention over different sensory areas, and from individual to individual. Thus, for an accurate assessment of braking reaction time, the measurements must be made under conditions which are comparable to those in which the results are to be applied. Brake reaction time measures obtained in the laboratory and applied directly to actual traffic situations are likely to result in incorrect conclusions.

Lister (1950) summarized investigations which were directly concerned with brake reaction time. In the majority of these, however, the measurements have been made in "stationary" situations, usually under laboratory conditions, and always with the subject having a fairly high degree of expectancy. The procedure typically called for the subject to press a pedal as soon as a lamp was lit. The mean brake reaction time obtained under these conditions was found to vary between .45 and .60 sec.

Lister, in his investigations, split the total brake reaction time into perception time (time from the presentation of the stimulus until the foot starts to move) and movement time (time from the start of the movement until the foot reaches the brake pedal). He also compared brake reaction time measured in a stationary vehicle with that measured in a vehicle moving

DRIVING RT
REFS

at different speeds. When the expectancy of the drivers was relatively high, the perception time proved to be about .25 sec. (with very little variation) and the movement time about .15 sec. He ascribed increased brake reaction time variation in condition of lower expectancy to increased variation in perception time.

MEASUREMENT METHODS

Two methods of measurement were employed in this study. The brake reaction time on each of a large group of drivers was measured once under normal highway driving conditions, but with some degree of braking expectation. The second method involved repeated measurement of a small group of drivers, including measures obtained under no-expectancy conditions.

Method I: Single Measures of a Large Sample

Every southbound car along a road was stopped by the police and the driver was asked if he was willing to take part in the experiment (in fact, every driver participated). After he had received his braking instructions, he was allowed to proceed with his journey. Sometime during the next 10 km., the driver would hear a loud klaxon horn sound at the side of his car. This was the signal for immediate braking. The car was not to be brought to a standstill, however; the driver was to release the brake pedal and continue his journey as soon as the klaxon was silent.

About 5 km. from the police trap was a concealed measuring station. When a car passed a photocell this triggered a klaxon hidden in a letterbox at the side of the road. Simultaneously an electronic timer (accurate to .001 sec.) was started. A specially trained assistant, also well hidden but with a good view of the road, was on the alert to press a contact key as soon as he saw the car's braking lights glow. This contact also functioned as a circuit breaker so that the klaxon became silent and the time between its onset and the breaking of the circuit was recorded on the timer.

The accuracy of the measurements were obviously dependent on the reliability of the assistant's reaction time. Thus the standard error of his reaction time should be negligible compared to that of the brake reaction time. (The criterion used was that the spread of the assistant's reaction time should be less than 20% of the brake reaction time spread. Thus, with $\sigma^2_{tot.} = \sigma^2_{BRT} + \sigma^2_{RT}$, reaction time contributes only 4% of the total variance when the ratio $\sigma_{RT}/\sigma_{BRT} = 1:5$).

The accuracy of the assistant as a measuring instrument was controlled as follows:

1. The assistant was chosen on the grounds of his having a relatively constant simple reaction time, as measured in pretrials. He was then trained so that he would respond with as constant (not as short) a reaction time as possible.

2. During the actual measuring of the drivers' brake reaction time, the assistant was regularly "calibrated" with respect to his reaction time. During the course of the investigation proper, 322 such calibration measurements were made and were found to have a near-normal distribution with $M = .244$ sec. and $\sigma = .016$ and a range of .20-.29 sec. This means that the spread of the assistant's reaction time about the mean .24 sec. can be estimated as not shifting any single brake reaction time value more than .05 sec. in either direction.

Method II: Repeated Measures of a Small Sample

The apparatus used for repeated measures was connected to both the ignition and braking systems of the car, and functioned as follows: When the car's ignition system was switched on, an electric clockwork system started, which closed the circuit to the buzzer and the electric timer at different set intervals. When the brake was applied, this circuit was broken so that both the buzzer and the clock stopped. In this way the time interval between the onset of the buzzer and the braking-reaction was noted, with an accuracy of 1 sec. The interval between the signals was often set so that it was greater than an hour, and since the car was mainly used for traveling to and from work, the

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cy of the measurements were dependent on the reliability of the reaction time. Thus the standard deviation of the brake reaction time should be negligible. What of the brake reaction time spread? The spread of the reaction time should be less than the reaction time spread. Thus, $\sigma^2_{BRT} + \sigma^2_{RT}$, reaction time $\sqrt{4\%}$ of the total variance when $BRT = 1.5$.

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interval between two signal occasions was sometimes more than a week.

It was found that a certain amount of familiarizing with the signal was necessary. On the first signal occasion, the driver often enough had a short moment's confusion before he realized that a braking reaction was called for. This could, of course, result in an increase in brake reaction time. To compensate for this, the first three signal occasions were used only for allowing the driver to become accustomed to the buzzer as a signal for braking and the corresponding three brake reaction time measurements were not included in the final results. In all cases the brake reaction time curve had reached an asymptote after the third signal.

(EXPECTED) EXPERIMENT I

The main question studied was: What distribution of brake reaction times will be obtained from an approximately representative sample of drivers who are expecting an "accident situation" within 10 km.?

Procedure

All cars and trucks were stopped with the exception of taxis and emergency-service vehicles (ambulances, police cars, etc.). All drivers who passed the measuring station and who had earlier stopped at the interview station, braked in response to the signal. The signal was not given, however, in the case of those drivers who had turned off the main road before reaching the signal station and in those cases where even a slight reduction of speed could lead to an accident because of other vehicles traveling close behind. Such cases, however, occurred infrequently and there is no reason to believe that they could have affected the results.

Results

Brake reaction times were obtained for 321 drivers; the distribution is given in Figure 1. (The reaction time of the experimental assistant

who registered these times has been subtracted.) The median brake reaction time was .66 sec.; the range was from .3 to 2.0 sec. Also included in Figure 1 is the distribution of the assistant's reaction time.

(UNEXPECTED) EXPERIMENT II

The main object of this part of the study was to see how brake reaction time in response to a completely unexpected signal compares with brake reaction time in response to a somewhat anticipated signal.

Procedure

Brake reaction time was measured on several occasions for each of a small group of drivers, ten measurements being made using Method I ("anticipation") and ten using Method II ("surprise").

The five drivers who comprised the group of subjects each had at least seven years driving experience. Four of these were in the 25-35 age range; the fifth was 50 years old.

Results

The individual brake-reaction-time medians obtained with the two methods are given in Table 1, along with ranges. Also given are the means of the two sets of individual medians.

DISCUSSION

Every subject in Experiment II had a longer brake reaction time when the signal occurred completely unexpectedly. The differences between the individual medians of brake reaction time in the two situations ranged from .1 to .35 sec.

The range of values obtained under the anticipation condition was about the same for each subject and the total range over all the measurements for this condition was not more than .4 sec. (.4-.8 sec.). Even with the surprise method and its changing traffic conditions, the range of values was remarkably small.

young to middle age

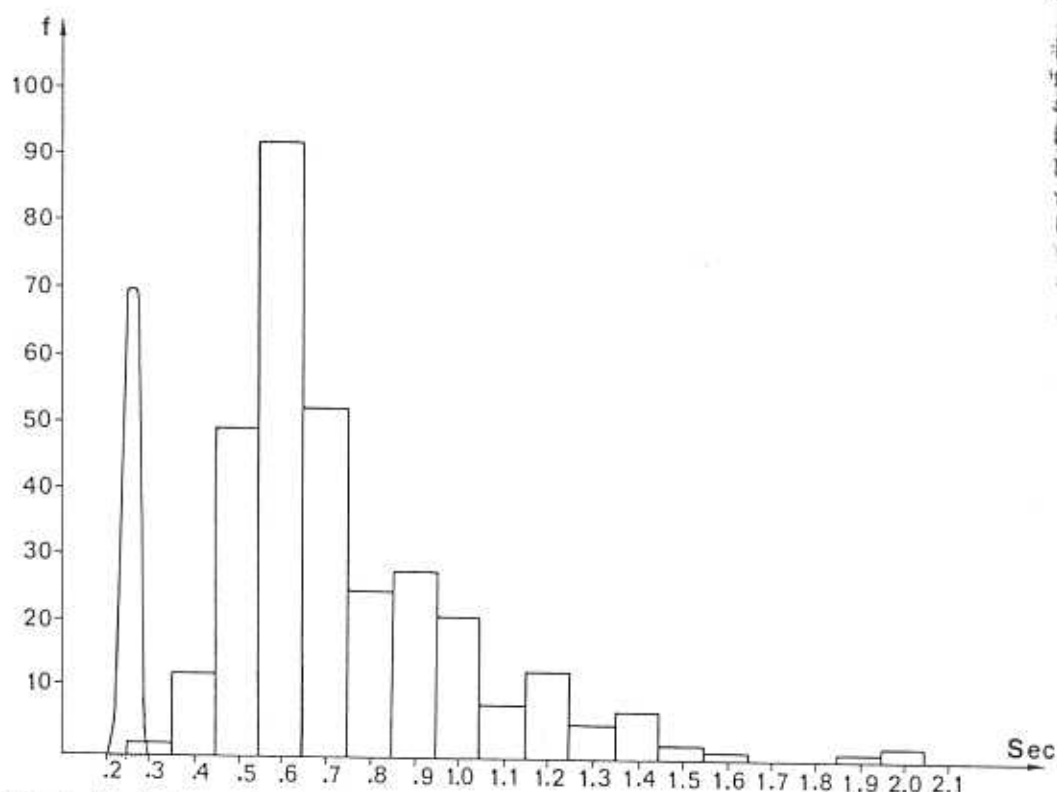


Figure 1. The brake-reaction-time distribution for 321 drivers on the road and the reaction-time distribution of the experimental assistant responsible for the measurements.

From these results it can be seen that it is possible to obtain a correction factor which can be applied to measurements made under conditions where some degree of anticipation is unavoidable (Method I). To calculate this factor the group mean of the individual medians obtained using Method II was divided by that obtained using Method I. This quotient was

then used as a multiplicative correction factor. That is, the correction factor = $.73/.54 = 1.35$.

Applying the correction factor to the results of Experiment I, provided an estimated brake reaction time of .9 sec. or longer in 50% of all sudden accident situations. On 10% of the occasions, brake reaction time was estimated to be 1.5 sec. or longer, and in a few cases brake

TABLE 1

Brake Reaction Time for the Five Subjects as Measured in the Surprise Situation (*s*) and the Anticipation Situation (*a*)

Situation	<i>n</i>		Median		Range	
	<i>s</i>	<i>a</i>	<i>s</i>	<i>a</i>	<i>s</i>	<i>a</i>
Subject						
A	10	10	.85	.6	.7-1.1	.5-.7
B	10	10	.6	.5	.6-1.0	.5-.8
C	10	10	.9	.55	.7-1.0	.5-.8
D	10	10	.7	.55	.6-.7	.5-.6
E	10	10	.6	.5	.5-.9	.4-.6
Total (M)	5	5	.73	.54	.5-1.1	.4-.8

SURPRISE

MD

RANGE

reaction time was estimated to be greater than 2 sec.

In Experiment II the 75th percentile was .9 sec. The corresponding figure corrected for surprise would be 1.2 sec. This .3-sec. increase of brake reaction time would, with a speed of 100 km/h, mean an increase of the stopping distance by nearly 10 m. The distribution of brake reaction time obtained here is caused by interindividual differences. It is not improbable to assume that the intraindividual distribution over various occasions could have the same form and range.

The correction factor calculated here is valid only for simple reactions. There is reason to believe that in more complicated situations the factor would be larger. But the methodology developed—the use of a small group for calculation of a correction factor to be applied on the results of a larger group—could be useful in several other situations in which it is difficult to

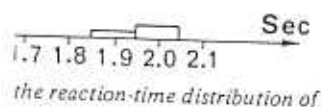
make experiments with a large representative sample.

ACKNOWLEDGMENTS

These investigations were made possible by a grant from the Official Swedish Council for Road Safety Research. We are especially grateful to Lars Bäckström who functioned as our human photocell with amazing precision.

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Range	
a	
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.0	.5-.8
.0	.5-.8
.7	.5-.6
.1	.4-.6
.1	.4-.8