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Comparison of Driver's Reaction Time Associated with Driving Speed on Actual Driving

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Abstract: It can be said that a collision happens when a car's stopping distance is longer than the car's headway distance. The stopping distance is some times prolonged unexpectedly. The stopping distance of the car comprises the braking distance and the reaction distance. One of the causes of the unexpected prolongation of the stopping distance is a lengthening of the reaction distance. The reaction time is the distance a vehicle travels from the time of the first appearance of an obstacle or a sudden change in the surroundings to the time when the brake system works. The authors measured the driver's reaction times (RTs) at the speed of 0km/h, 20km/h, 40km/h and 60km/h. The result of the experiment showed that the mean RTs for driving conditions were larger than that of a stopping condition. There are no differences between the mean RT of each speed condition. But there are differences between the standard deviation (SD) of RT. The result of other experiments showed that the RT while driving under hasty conditions was larger than that while driving under ordinary condition. Thus, the authors suggested that hasty driving must be deterred to avoid collisions.

Keywords: Driving behavior, Reaction time, Speed, Travel time

1. Introduction

According to a previous investigation through a questionnaire, many people thought that the principal cause for car accidents was over speed driving[1]. Traffic accidents (collisions) occur when a car's stopping distance becomes longer than the headway distance between the vehicle and the obstacles. It's known that the stopping distance is sometimes suddenly prolonged. One of the causes of this is the extension of the driver's reaction time (RT)[2]. This results in the greater distances traveled from the time of the first appearance of an obstacle or the sudden change in the surroundings to the time when the driver initiates the braking action[3]. But there are few people who are conscious of this fact.

It is supposed that the driver's RT is one of the most important human factors in accident prevention. For example, the result of our previous experiment was that the mobile phone restrained the driver's view and prolonged the driver's RT[4]. We suggested that this prolongation could be a cause of the collisions.

It was found that accident-prone drivers have a large standard deviation value in their RTs[5]. The mean value or RT did not relate to accident-proneness. The relationship between the standard deviation of RT and the vehicle speed is not yet clear. Therefore we aimed to measure the RT in several driving speed conditions and at stimulus locations. Next, we analyzed the mean and standard deviation of the RT. In experiment 1, the stimulus location was in the central area of the driver's view. In experiment 2, it was in the upper area of the driver's view.

2. Experiment 1: The driver's RT for Stimulation of the central area of the retina.

2.1 Purpose

The purpose of experiment 1 was to clarify the relationship among the mean of RT, the standard deviation of RT for the stimulus in the central area of the driver's view, and the vehicle speed.

2.2 Method

The authors developed a computer based experimental system that measured the speed and a driver's RT where by RT means the period from the time when the light-emitted diode (LED) on the windshield was turned on until the time when drivers pushed the button on a steering wheel. **Figure1** shows the equipment for the experiment 1.

The experimenter required the subject (the driver

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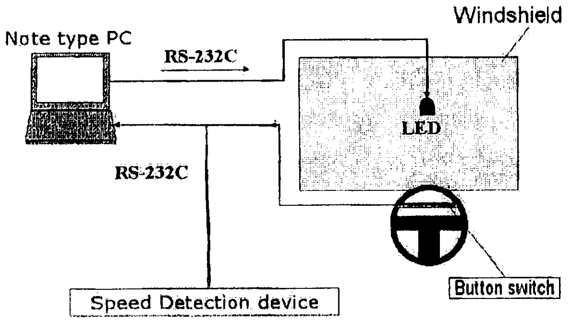


Fig.1 The equipment for the experiment 1.

of an experimental car) to push the button as soon as he noticed that the LED was turned on.

The experiment was conducted on a straight road. The car velocities were set as the stop condition (0km/h) and driving conditions (20km/h, 40km/h and 60km/h). The subject drove the experimental car without seeing a speed meter. The experimenter in the front passenger" seat verbally assisted the driver in keeping the speed.

The LED was set up in two positions, one on the windshield in front of the driver and the other on the windshield at 10 degrees on the left of the first LED position. The experiment for the central LED position was conducted first and the experiment for the LED at 10 degrees on the left was done at another time.

The LED was turned on at the same random interval sequence for each speed condition. The RTs were measured 20 times under each stimulus position and speed. An experimental design was 8 (subjects) × 4 (speed conditions) × 2 (LED positions). The drivers (subjects) were eight males who were between 22 and 25 years of age.

2.3 Result and Discussion

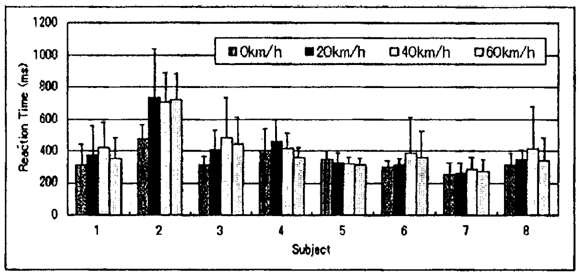
Figure 2 shows the mean and standard deviation of RT of each subject and each experimental condition.

[The Mean RT]

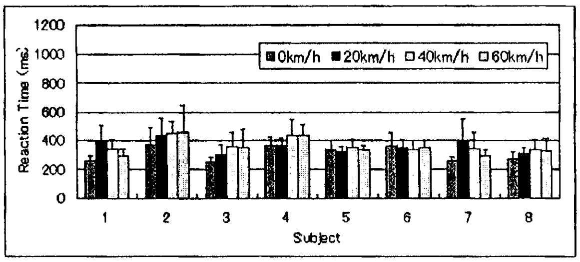
At the center LED position, the mean RT at 0km/h was 339ms (SD:64ms); at 20km/h 400ms (SD:138ms); at 40km/h 429ms (SD:122ms); at 60km/h 396ms (SD:130ms).

At the 10 degrees on the left LED position, the mean RT at 0km/h was 315ms (SD:48ms); at 20km/h 354ms (SD:43ms); at 40km/h 367ms (SD:46ms); at 60km/h 360ms (SD:52ms).

A two-way analysis of variance (ANOVA) led to the main effect of the speed condition ($F(3,18)=7.814$, $p<.01$), but did not reveal the



(A) LED on Center



(B) LED at 10 degrees left from center

Fig.2 The RT of each subject under each condition.

main effect of the LED's position ($F(1,6)=1.807$, *n.s.*). A multiple comparison with Ryan's proccedure showed that the mean RTs at driving conditions of 20km/h, 40km/h and 60km/h were larger than the mean RT at 0km/h condition.

[The SD of RT]

At the center LED position, the mean of the standard deviation of a driver's RT at 0km/h was 81ms (SD:34ms); at 20km/h 126ms (SD:82ms); at 40km/h 162ms (SD:77ms); at 60km/h 118ms (SD:47ms). At the 10 degrees on the left LED position, the mean of the standard deviation of a driver's RT at 0km/h was 60ms (SD:30ms); at 20km/h 81ms (SD:40ms); at 40 km/h 83ms (SD:22ms); at 60km/h 82ms (SD:50ms).

A two-way ANOVA led to the main effect for the condition of speed ($F(3,21)=3.035$, $p<.10$), and led to the main effect of LED's position ($F(1,7)=14.626$, $p<.01$).

The mean RTs in driving conditions were larger than these in the stopping conditions. This differences suggests that driving required more processing loads for the subjects. But there were no significant differences in either the mean RT or the SD of RT in all the driving conditions. In this experiment, the stimulus was located in front of the driver so that they could see it at a central vision.

We could not find any differences in driving conditions because the stimulus was noticed too easily. We found that the standard deviation of RT at the 10 degrees left position was smaller than that at the

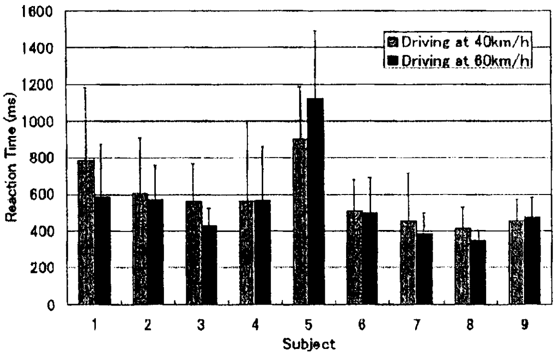


Fig.3 The RT of each subject (Experiment 2).

central position.

3. Experiment 2: The driver's RT for upper central area stimulus

3.1 Purpose

In experiment 1, there was no significant difference in RT for the central area stimulus in all the driving conditions. In experience 2, we tried to measure RT for a stimulus that was located farther from the central area.

3.2 Method

We used the same measurement equipment as in experiment 1, but installed the LED at a 15 degrees elevation from the center of the driver's visual field. Conditions of vehicle speed were at 40km/h and 60km/h. The reasons the authors omitted the 0km/h, 20km/h conditions were that the 20km/h condition was not considered an ordinary speed on most roads, and there was no significant difference on RTs and SDs beween the 20km/h condition and the 40km/h, 60km/h and stopping conditions.

The subjects were nine men between 23 and 25 years of age.

The experimental design was 9(subjects) × 2(speed conditions).

3.3 Result and Discussion

Figure 3 shows the mean and standard deviation of RT of each subject.

[The mean RT]

The mean RT of all subjects at 40km/h was 582ms (SD:162ms), and at 60km/h 553ms (SD:230ms). A t-test did not show a significant difference between those ($t(8)=0.741$, *n.s.*).

[The SD of RT]

The mean SD of RT at 40km/h was 254ms (SD: 113ms), and at 60km/h 188ms (SD:107ms). The SD of the RT under the 40km/h driving condition was larger than that of the 60km/h driving condition ($\mathbf{t}(8)=2.497$, $\mathbf{p}<.05$).

There was no difference in mean RT between two velocities. But, at the speed of 40km/h, the SD of the RT was larger than that at 60km/h. Most subjects reported that they became anxious about other vehicles at 40km/h driving because other traffic ran at around 60km/h. We supposed that the speed difference with the surrounding traffic gave the drivers stress and they looked frequently in the rearview mirrors while at 40km/h.

There is a report that when a driver drove a vehicle at a spontaneous speed, the Rt of the driver was shorter than that of spontaneous speed[6]. This suggests that the RT was influenced by the conditions required to maintain a speed other than the driver's spontaneous speed.

4. Experiment 3: The RT of the driver under hasty driving conditions

4.1 Purpose

The purpose of experiment 3 was to compare the RT at ordinary driving speeds and the RT in faster speeds.

4.2 Method

The experiment was conducted on a straight road. The distance of the experimental course was 3km. First, the subjects were required to drive at their ordinary speed (ordinary condition). At the conclusion of the first drive, the experimenter showed the subject his travel time. Then, the subjects were required to drive in a shorter time than the first drive (hasty condition). Under each condition, the experimenter required the subject to push the button as soon as the noticed that the LED was turned on. A computer recorded the RT of the driver. The LED was set up in a helmet at a 10 degree left position in front of the driver's face. **Figure 4** shows the equipment for experiment 3.

The LED was turned on at the same random in-

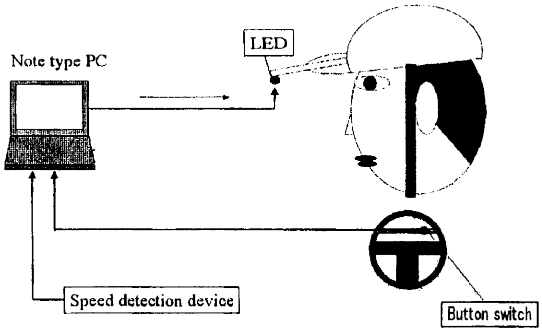


Fig.4 The equipment for the experiment 3.

terval sequence at each speed condition. The experimenter measured the RTs 20 times. The drivers (subjects) were 14 males between 22 and 37 years of age.

4.3 Result and discussion

The mean travel time under ordinary conditions was 271s (SD:31s) and under hasty conditions 235s (SD:22s). Traveling times under hasty conditions were shorter than those under ordinary conditions ($t(13)=433$, $p<.01$). The average speed under ordinary conditions was 38.8km/h (SD:4.5km/h) and under hasty conditions 43.6km/h (SD:3.5km/h). The average speed under hasty conditions was higher than that under ordinary conditions ($t=3.55$, $p<.01$).

The results of the measurement of travel time and average speed show that the subjects were rushed.

Fugure 5 shows the mean RT measured under each condition. The mean RT under ordinary conditions was 407ms (SD:54ms) and under hasty conditions 476ms (SD:61ms). The mean RT of all subjects under hasty conditions was longer than that under ordinary conditions ($t(13)=3.57$, $p<.01$).

Figure 6 shows the SD of all subjects under each condition. The mean of SD under ordinary conditions was 126ms (SD:103ms) and under hasty conditions 241ms (SD:180ms).

The t-test shows the tendency of the SD under hasty conditions to be longer than that under ordinary conditions ($t(13)=1.96$, $p<.10$).

Braking distance was lengthened at a higher driving speed. When the driver was rushed, the speed of the vehicle would become higher than at ordinary speeds. Driving under hasty conditions lengthened the RT of the driver. Longer reaction time lengthens reaction distance. The lengthening of reaction distance lengthened stopping distance. Therefore, driving under hasty conditions could increase the possibility of an accident.

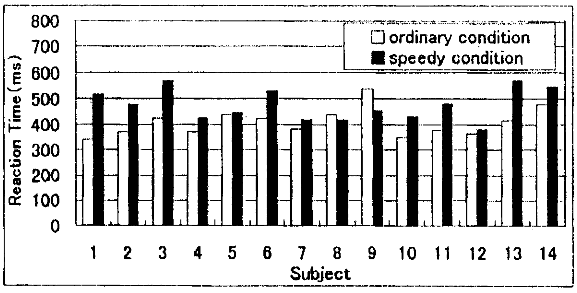


Fig.5 The mean RT of each subject (Experiment 3).

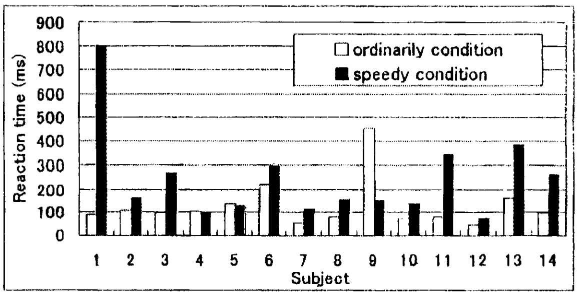


Fig.6 The SD of each subject (Experiment 3).

5. General Discussion

The result of experiment 1 showed that the mean RTs under all driving conditions were larger than in the stopping condition. This difference suggests that subjects must process more information while actually driving.

In experiment 1, there were no significant differences in the mean RT and the SD of RT under all driving conditions. In experiment 1, it was supposed that the subject could drive a vehicle without any shift of a fixate point to find the stimulus since the stimulus position was in the central area of the subject view. Therefore the subject could easily check the stimulus while driving.

But in experiment 2, the stimulus was presented at a farther position from the central area of the subject's view. It was assumed that they could not see the direction of travel and the stimulus, simultaneously. They would frequently move their eyes from the direction of travel to the stimulus and vice versa. The task was a little more difficult than in experiment 1.. Therefore, the SD of RTs showed a difference between the two velocity conditions in experiment 2. The SD of RT at 40km/h was larger than that at 60km/h in experiment 2. It was assumed that this result was due to the traffic circumstances of the experiments. The authors did the experiments on a wide and straight road without busy traffic. Other vehicles traveled at around 60km/h. At 40km/h, the subjects sometimes looked in the rearview mirrors to see other vehicles. It was supposed that this produced the large SD. The authors believe that this would not apply on crowded or narrow roads. Drivers must be aware of many other things and will be processing too much information at a high driving speed.

The RT under hasty conditions was larger than that under ordinary conditions in experiment 3. Higher speed conditions lengthened the driver's RT and stopping distance. These lengths would prolong the vehicle's stopping distance. If the prolonged stopping distance was longer than the vehicle's headway distance, a collision would occur. Thus, the hasty driver must be deterred to avoid a collision.

6. Conclusions

There was no significant difference in mean RT under different driving conditions. But the SD of RT at 40km/h was larger than that at 60km/h for a near central view area stimulus. We inferred that this result was due to traffic circumstances.

The RT under hasty conditions was larger than that under ordinary conditions. Thus, the authors suggested that hasty driving must be deterred to avoid a collision.

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