

Abstract

This paper proposes a method of evaluating the degree of safety of a verbal interface that is used while driving. Recently there have been concerns about driver distraction when a person uses voice commands to operate their in-vehicle multimedia systems while driving, since such distraction has the potential to cause or contribute to a crash. With our evaluation method, the reaction time from the instant that an in-vehicle LED (positioned in the driver's peripheral vision) is turned on to the time that the subject presses a button is measured. We found from the histogram made by the many reaction time data

that the number of the delayed reaction time trials increased as a result of the subjects' using a verbal interface compared with the condition that the subjects were only driving. It suggested that the rate of the delayed reaction time trials was available as the evaluation index. Based on the data obtained with an actual vehicle, we found that our method produces more useful results than other methods that use the average reaction time as an index. Additionally, we show that we can find the point at which the subjects' reactions are delayed during a verbal task by processing the delayed reaction time trials.

Keywords

Driver distraction, Index of safety, Verbal interface, Secondary task, Reaction time

1. Introduction

The development of in-vehicle technologies has led to more and more vehicles featuring multimedia systems that can be used while driving, and this has led to concerns about driver distraction. Ranney¹⁾ writes, "Driver distraction may be characterized as any activity that takes a driver's attention away from the task of driving. An examination of crash data reveals that any distraction has the potential to cause or contribute to a crash."

Additionally, Ranney classified driver distraction into four categories: visual distraction (e.g., looking away from the roadway), auditory distraction (e.g., responding to a ringing cellular phone), biomechanical distraction (e.g., manually adjusting the radio), and cognitive distraction (e.g., being lost in thought).

Much research has been done into biomechanical distraction and, specifically, the use of cellular phones while driving. In this research, variances in the lateral position and the time needed to react to a front-mounted light were often used as evaluation indices.²⁻⁴⁾ For researching visual distraction, glance frequency and duration were often used as evaluation indices.

Our goal was to evaluate the level of distraction when drivers use their voices to interact with invehicle multimedia systems while driving. In this case, we have to consider both auditory distraction and cognitive distraction, because the driver not only has to listen and speak, but also memorize and recall the commands needed to use such a system.

In this paper, we propose a new method of evaluating the level of distraction when using a verbal interface while driving. With our method, the driver performs a reaction time task as a secondary task. Although the task is similar to the peripheral detection task (PDT)⁵⁾, it differs in that we adopted the rate of the delayed reaction time trials as the evaluation index.

2. Evaluation method

With our evaluation method, the reaction time from the instant that an in-vehicle LED is turned on to the time that the subject presses a button is measured. **Figure 1** shows the position of the LEDs and switches. Four LEDs are installed such that they are in the subject's peripheral vision. For the test, one of the four LEDs is turned on, and the subject indicates which LED is lit by pressing one of two (upper or lower) buttons. The upper and lower LEDs are positioned very close together, so the subject cannot distinguish which LED is lit without giving them sufficient visual attention. The LED pairs are installed to the left and right of the driver, so that he or she does not concentrate on one side only.

Once the subjects have repeated this reaction time task many times while performing another task such as driving or using voice commands, we can obtain a reaction time histogram like that shown in **Fig. 2**. In this histogram, the left-hand part is the distribution of the subjects' standard reaction times, and is usually a normal distribution. The right-hand part,



right LED's left LED's

switches

Fig. 1 Position of LEDs and switches.

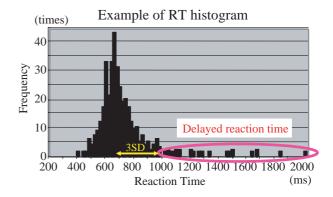


Fig. 2 Reaction time histogram while driving.

on the other hand, shows the delayed reaction time. We found the histogram that the number of delayed reaction time trials increased more when a verbal interface was being used while driving than when the subjects were only driving. Since the length of the reaction time is directly related to safety, we assumed that we could use the rate of the delayed reaction time trials as an index of safety.

If the delayed reaction time were a result of auditory or cognitive distraction, we could find the point in time where the reaction starts to be delayed by analyzing the delayed reaction time trial. The horizontal axis of the upper-right figure in Fig. 3 shows the time required to complete a verbal task, while the line segments indicate those trials for which the reaction times were delayed. After drawing all the line segments for the delayed reaction times, we can plot a histogram for an appropriate interval like that in the lower-right part of Fig. 3. The time corresponding to the peak in this histogram is that at which the greatest number of delayed reaction time trials occurred. In other words, it is probable that the reaction will be delayed at that time.

In the following section, we introduce the results of our experiments to verify the validity of our method.

3. Experiment

3.1 Subjects

Four male subjects, all in their thirties, participated in this experiment. Two of the subjects were already experienced in the verbal task, explained later, and were fully accustomed to the use of the system. The other two subjects had no previous experience with the verbal task, so performed three practice sets for each condition in advance.

3.2 Apparatus

The experiment was done using an actual vehicle. Figure 1 shows the position of the LEDs and buttons used for the reaction time task. Pairs of LEDs were installed on the dashboard, 25 cm apart, and the buttons were installed on the gearshift. A program running on the personal computer controlled the reaction time and verbal tasks, and recorded the instants at which the LED was turned on when the button was pressed. The view through the windshield was recorded using a VCR. The subjects' eye movements were monitored by a non-contact eye-tracking system and the results were superimposed on the scene being recorded by the VCR.

As the driving course, we used the regular roads within our company's facility. The speed limit was 25 km/h, such that approximately eight minutes was needed to complete one lap of the course. There was little other traffic to negotiate, and there were four slow curves and twelve right or left turns.

3.3 Conditions

The experiment conditions were as follows.

- (1) Stop and perform a reaction time task. [stop]
- (2) Drive and perform a reaction time task. [no verbal task]
- (3) Drive and perform a reaction time task and verbal task1 [FR]

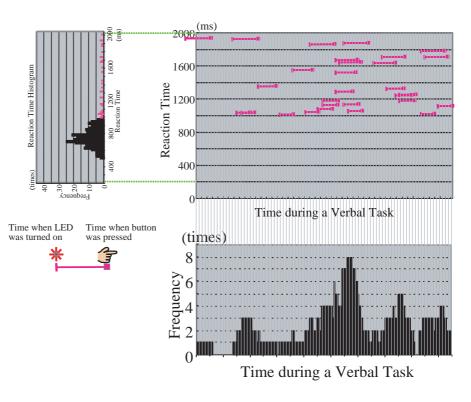


Fig. 3 Analysis for the time tending to delay the reaction.

(4) Drive and perform a reaction time task and verbal task2 [DDR]

The duration of the [stop] condition was four minutes, while the other conditions required approximately eight minutes.

REACTION TIME TASK - One of the four LEDs was turned on, and then the subjects responded by pressing either the upper or lower button according to the LED that was lit. An LED was lit every six seconds, and was turned off as soon as the subject pressed a button. If the subject failed to press a button, the LED was turned off two seconds after being turned on.

VERBAL TASKS - As an example of the verbal task to be evaluated, we adopted two kinds of cognitive tasks that consisted of listening, memorizing, recalling and speaking. These tasks were called delayed digit recall (DDR) and free recall (FR). **Figure 4** shows a time chart for the delayed digit recall task. The experimenter read aloud one-digit numbers at fixed intervals and, upon hearing one number, the subject repeated the previous number aloud. In this experiment, speech synthesis software running on the personal computer was used to present the number, and the reading interval was 2.3 seconds.

Figure 5 shows the time chart for the free recall task. An experimenter read aloud five nouns at fixed intervals, and the subject then repeated them one by one as a series of beeps was sounded. The subjects were permitted to answer in a different order from the order in which the nouns were originally read. In the same way as for DDR, speech synthesis software running on the personal computer was used to present the nouns. The reading interval was 1.6 seconds and the beeps were sounded at intervals of 2.2 seconds.

3.4 Procedure

Each of the four subjects participated in this experiment eight times, each time on a different day and with different orders of conditions. After we had eliminated the erroneous data, we classified the delayed reaction time data according to the factor contributing to the delayed reaction by using the VCR. Only the reaction time data for which the delay was caused by the verbal task was selected and processed.

4. Results and discussion

Figure 6 shows the reaction time histogram for the [no verbal task] condition and the [FR] condition for one given subject. By adding the verbal task, the peak for the normal reaction time shifted to the right and the number of delayed reaction time trials increased. This means that the average reaction time and the rate of the delayed reaction time were increased as a result of adding the verbal task.

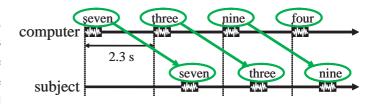


Fig. 4 Time chart of delayed digit recall.

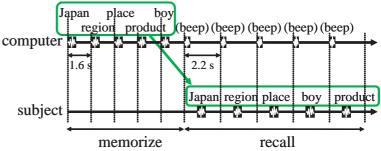


Fig. 5 Time chart of free recall.

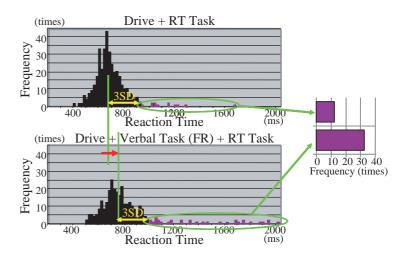


Fig. 6 Comparison of reaction time histogram.

Figure 7 shows the rate of the delayed reaction time for all the subjects (average and standard deviation). It shows that the rate of the delayed reaction time increased due to the subjects' performing the verbal task. The difference between the [no verbal task] condition and the [FR] condition was statistically significant (p<0.05). The difference between the [DDR] condition was also statistically significant (p<0.05).

Figure 8 shows the average reaction time for all the subjects. It shows that the average reaction time increased due to the verbal task. However, the difference between the conditions was not statistically significant.

From these results, we could conclude that our method and the use of the rate of the delayed reaction time trials as an index was better than the method using the average reaction time.

The following paragraphs present the processed results for the delayed reaction time trials for the DDR and the FR.

Figure 9 shows an example of the processed result

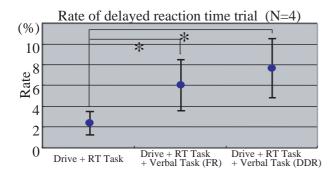


Fig. 7 Rate of delayed reaction time trial (N = 4). *:p < 0.05

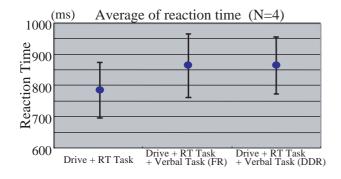


Fig. 8 Average of reaction time (N = 4).

for the FR for a given subject. The blue and green circles indicate the times at which the personal computer presented the nouns. The first eight seconds are used for memorizing, and the remainder is used for recall. This particular subject tended to have a delayed reaction during the recall time. It should be noted that all the subjects were much the same.

Figure 10 shows an example of the processed result for the DDR of a certain subject. To determine the time at which the subject responded, the voice data is drawn over the histogram. The first part of the voice data corresponds to the computer presenting the number, while the second part is the subject answering. In all subjects, there was a peak at or near the time point when they answered.

The fact that most of the subjects had the same tendency shows clearly the validity of our method.

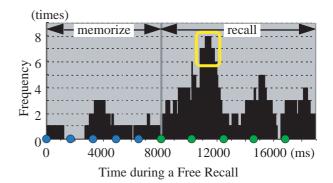


Fig. 9 The probable time to be delayed the reaction at during a free recall task.

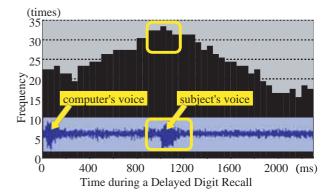


Fig. 10 The probable time to be delayed the reaction at during a delayed digit recall task.

5. Conclusion

We have developed a new method for evaluating the level of safety of verbal interfaces while driving. This evaluation method has the following characteristics.

• As the evaluation index, we use the rate of delayed reaction time trials. The use of this index proved to be better than the method using the average reaction time as an index.

• The time that it is probable the reaction will be delayed at during a verbal task can be found by processing the delayed reaction time trial.

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