

Study of Reproducibility of Pedal Tracking and Detection Response Task to Assess Driver Distraction

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ABSTRACT

We have developed a bench test method to assess driver distraction caused by the load of using infotainment systems. In a previous study, we found that this method can be used to assess the task loads of both visual-manual tasks and auditory-vocal tasks. The task loads are assessed using the performances of both pedal tracking task (PT) and detection response task (DRT) while performing secondary tasks. We can perform this method using simple equipment such as game pedals and a PC. The aim of this study is to verify the reproducibility of the PT-DRT. Experiments were conducted in three test environments in which test regions, experimenters and participants differed from each other in the US, and the test procedures were almost the same. We set two types of visual-manual tasks and two types of auditory-vocal tasks as secondary tasks and set two difficulties for each task type to vary the level of task load. As a result of these experiments, we found that differences in performances of PT and DRT among the different task types and the difficulties of the secondary tasks were similar across all the environments. This result suggests that the PT-DRT has a good reproducibility of relative assessments among various tasks, independent of test regions and experimenters. Owing to the good reproducibility and the ease of use, the PT-DRT could become a standard test method for various developers and researchers to fairly assess various tasks in various regions.

CITATION: Iwasa, T. and Hashimoto, T., "Study of Reproducibility of Pedal Tracking and Detection Response Task to Assess Driver Distraction," *SAE Int. J. Trans. Safety* 3(2):2015, doi:10.4271/2015-01-1388.

INTRODUCTION

The impact on driving from driver distraction caused by using infotainment systems has been an important topic of safe driving in recent years. In Japan and the US, guidelines for design of the human-machine interface for in-vehicle infotainment systems (IVIS) are prescribed [1,2,3]. These guidelines have recommended the occlusion method [4] and measurement of eye glance time in driving simulator tests to judge whether it is acceptable to use IVIS functions while driving. These methods mainly assess the visual load of visual-manual operation for IVIS, but do not assess the cognitive load involved in voice interface. The voice interface is expected to grow as a way to operate infotainment systems safely while driving because of improvements in voice recognition technology. Meanwhile, there have been reports that the cognitive load of the voice interface adversely affects driving performances [5,6]. The National Highway Traffic Safety Administration (NHTSA) in the US announced a plan to create guidelines for voice interfaces [7]. Therefore, it is assumed that methods to assess the impact of cognitive load on driving will become more important in the future.

The assessment methods must be sensitive to differences in task load. In product development, especially, ease of use and good reproducibility allowing us to obtain the same results even when different experimenters conduct the same tests in different regions, are key advantages. These would also be important if the methods are used in various regions by various developers and researchers as

standardized methods. Currently, to assess the impact of cognitive load, a method to measure the stability of a tracking task (PT) [8] and a method to measure the response time of a detection response task (DRT) [9] have been studied. We have reported a new assessment method, which is a combination of PT and DRT (PT-DRT) [10]. This method enables us to assess the driver's ability to simultaneously drive stably while paying attention to forward traffic in a usual situation and to quickly respond to emergencies, such as a lead vehicle applying its brakes. We also have pointed out its ease of use, because it is conducted with only simple and low-cost equipment, such as game pedals and a typical PC. The aim of this study is to verify the reproducibility of the PT-DRT, which is another key advantage.

METHOD

Test Environments and Participants

Experiments were conducted in 3 different test environments (Env. 1 - 3), all with different test regions and experimenters. The test regions for each environment were as follows: Env. 1: Torrance, CA; Env. 2: Powell, OH; Env. 3: Rockville, MD.

Twenty-four people living near the test site of each environment took part in the experiments. The participants were different in each environment (total: 72 participants). They were screened to ensure that they had valid US driver's licenses and documents [11].

(7,000 miles) per year for Env. 1 and 4,800 km (3,000 miles) per year for Env. 2 and 3. The 24 participants were composed of 3 males and 3 females in each year group (18 - 24, 25 - 39, 40 - 54 and 55 - 70). These samplings of participants were referred to the Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Device [3]. All of participants in Env. 1 and Env. 3 and 22 participants in Env. 2 had used cell phones while driving.

The participants were recruited through open recruitment. They were given full written and oral explanations of the purpose of the experiment, its procedures, its benefits, and its disadvantages, after which they indicated in writing their agreement to participate of their own free will. The experiments in Env. 1 - 3 were conducted with the approval of the Dynamic Research, Inc. Institutional Research Board; the Honda R&D Co., Ltd. Bioethics Committee; and Westat's Institutional Research Board.

PT-DRT

The PT-DRT simply simulates the process of following a vehicle. It consists of the PT, which corresponds to headway keeping task, and the DRT, which corresponds to responses to braking by a lead vehicle. The conditions of the PT and the DRT in these experiments were the same as in the previous study [10].

The PT is a task in which participants control the size of a white square (PT target) on a display in front of them using the gas pedal of a set of game pedals (Figure 1). The PT target represents the rear view of a lead vehicle. The PT-DRT program has variables corresponding to the acceleration and velocity of the lead vehicle and the participant's vehicle. The size of the PT target changes based on the distance between the lead vehicle and the participant's vehicle, calculated from these variables. Expansion of the PT target means a decrease in the headway distance and a reduction means an increase in that distance. In these experiments, the headway distance at which the PT was started was 20 meters from the participant's eye point. The expansion rate of the PT target was set so that it would be same as that under actual driving conditions. Once the PT was started, the acceleration of the lead vehicle was changed according to a function composed of the following 2 sine waves, $f_1(t)$, $f_2(t)$ and 1 rectangle wave, which generates a series of accelerations of -0.4 m/s^2 for 3 seconds and then $+0.4 \text{ m/s}^2$ for 3 seconds with random intervals between 6 - 12 seconds.

$$f_1(t) = 0.2 \cdot \sin\left(2\pi \cdot \frac{1}{5}t - 2\pi \cdot \text{rnd}_1\right)$$

$$f_2(t) = 0.075 \cdot \sin\left(2\pi \cdot \frac{3}{40}t - 2\pi \cdot \text{rnd}_2\right)$$

(rnd: Random value between 0 - 0.99)

The acceleration of the participant's vehicle was varied from -0.04 m/s^2 to $+0.06 \text{ m/s}^2$ linearly as a function of the angle of the gas pedal with a 1-second delay. If the brake pedal was pressed, the participant's vehicle did not decelerate. The participants were instructed to stably maintain the size of the PT target at its initial size.

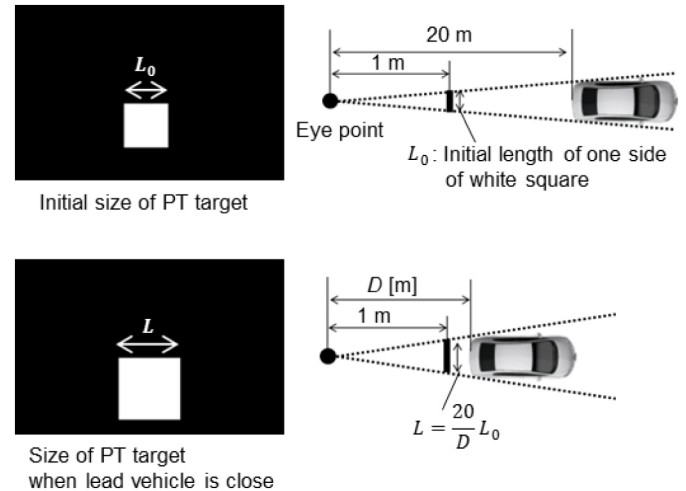


Figure 1. Graphic image of PT target

The DRT is a task in which participants press a brake pedal as soon as they perceive that a red square (DRT target) appears within the PT target (Figure 2). Once the brake pedal is pressed, the DRT target disappears. The intervals between one response and the next appearance of the DRT target were randomly set between 4 and 12 seconds. The participants were instructed to interrupt the PT and press the brake pedal as soon as possible when the DRT target appeared, and then resume the PT immediately. They were also instructed that the PT-DRT was the primary task.

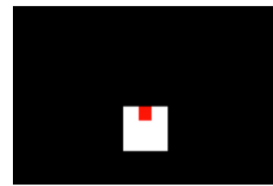


Figure 2. Graphic image of DRT target

Apparatus

Figure 3 shows the arrangement of the equipment for the experiments. The PT-DRT image was displayed on a 22- or 23-inch LCD placed 1 meter in front of the participant's eye point. The LCD was placed so that its center would be at the same height as the eye point of the average US male. Game pedals (Logitech Driving Force GT) were used for the PT-DRT. The participants adjusted the placement of the pedals to their comfort levels before testing began.

The image of the secondary task was displayed on a 7- or 8- inch resistive touchscreen. This was placed in front and to the right of the participant, where a touchscreen navigation system would typically be placed. A 10-key pad, typically used with PCs, was placed to the left of the touchscreen for performing secondary tasks.

Video cameras were placed to record and analyze eye glance behavior and how participants operated. In Env. 3 only, participants wore eye-tracker glasses (Applied Science Laboratories Mobile Eye-XG Eye Tracking Glasses). The details of eye glance behavior are not discussed in this paper.

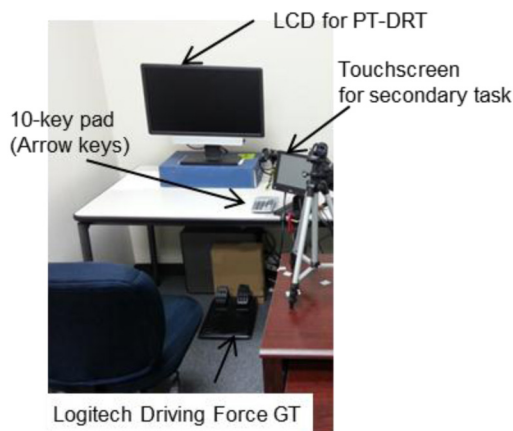


Figure 3. Experimental setup

Secondary Tasks

We set 2 types of visual-manual tasks and 2 types of auditory-vocal tasks. We set 2 difficulties for each task type. A total of 8 tasks were performed by the participants. These tasks were used in a previous study [10].

Visual Touch

Five single-digit numbers from 1 to 9 and a numeric keypad of 1 through 9 were displayed on the touchscreen (Figure 4). The participants looked at the 5 numbers and searched for the largest number or the third-largest number among them. When they found the target number, they responded by touching it on the numeric keypad. Searching for the largest number was defined as an easy task (Touch-1) and searching for the third-largest number was defined as a difficult task (Touch-3). The 5 numbers were changed automatically at 12-second intervals, accompanied by a notification sound. If participants did not respond within 12 seconds, 5 new numbers were displayed with the sound. The 5 numbers were arranged randomly, without repetition.

Five single-digit numbers

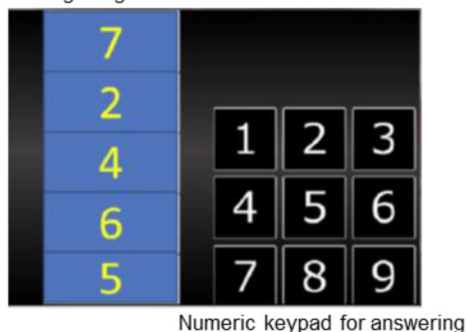


Figure 4. Visual Touch screen image

Auditory Speech

The participants performed a similar task for the Visual Touch using auditory-vocal modality. Five single-digit numbers were read aloud from a PC, and the participants responded aloud with the largest number or the third-largest number among them. Responding with the largest number was defined as an easy task (Audio-1) and

responding with the third-largest number was defined as a difficult task (Audio-3). Five different numbers were read aloud every 12 seconds. They were not displayed on the touchscreen.

Surrogate Reference Task (SuRT)

Multiple circles with the same diameter (distractors) and a circle with a different diameter from that of the distractors (target) were displayed on the touchscreen. The display area of the touchscreen was divided vertically into multiple areas of equal size. The participants selected the area that included the target using the arrow keys of the 10-key pad [11]. When the participants pressed the right or left key first, one area was highlighted. The participants moved the highlighting to the area that included the target by pressing the right or left keys, and then selected it by pressing the up key. Once the up key was pressed, the distractors and the target were shuffled and the next task was started. In the easy task (SuRT-E), the diameter of the target was more than twice that of the distractors, and the display area was divided into 2 areas. In the difficult task (SuRT-D), the diameter of the target was only slightly larger than that of the distractors, and the display area was divided into 6 areas (Figure 5).

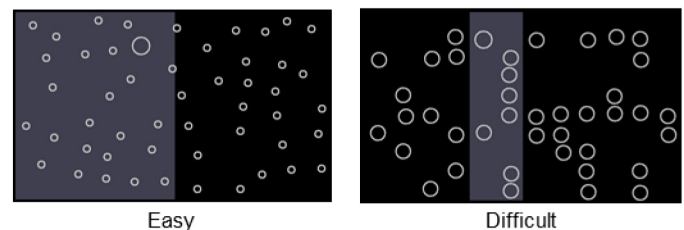


Figure 5. Easy and difficult tasks of SuRT

N-Back

The participants listened to a string of single-digit numbers read aloud from a PC. They verbally repeated N numbers back after they heard each number [9,12]. In the easy task (0-Back), they repeated 0 numbers back. In other words, they simply repeated each number after hearing it. In the difficult task (1-Back), they repeated 1 number back after they heard each number.

Experiment Design and Procedure

To verify whether or not there were differences among the test environments in the performance of the PT and the DRT for each task type and each difficulty of the secondary tasks, the study employed a three-way repeated measures design, with one between subjects factor (3 environments) and two within subjects factors (4 task types and 2 difficulties).

The participants were given an explanation of the content of the experiment, after which they signed a consent form. They were given an explanation of the PT-DRT, and then they performed eight to ten 1-minute practice trials. After the practice trials, they performed three 1-minute trials without any secondary tasks (Baseline). After that, they performed the PT-DRT with each of the 8 secondary tasks. The order of the secondary tasks was counterbalanced among participants.