Analysis of Driving Performance with Reaching Task

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Besides primary driving task, we used to have additional actions, for example, operating some buttons and looking for something. Such secondary actions have been the major cause of accidents. Using a driving simulator the effect of reaching tasks on driving performance was examined for emergency avoidance. From the experimental results, the driving performance was influenced by the body movements caused by the reaching tasks. However, estimated parameters of a driver model have no tendency according to the targets of the reaching tasks. It was considered that drivers control the vehicles not to be influenced by the reaching tasks.

Topics / reaching task, driving posture, driver model, driving performance, genetic algorithm

1. INTRODUCTION

A driving requires for a driver to repeat cognition, decision making, and operation. If workloads of the cognitions, the decision makings, and the operations for a driver become greater, they distract the driver from driving. If the workloads are higher than management limit of the driver, traffic accidents may occur because of human error.

The workloads that influence on the driver are classified into three as below [1]; 1) visual workloads, 2) mental workloads, and 3) execution workloads. The visual workloads are caused by visual searching. The mental workloads are psychological workloads concerned with consideration. The execution workloads are caused by pushing some buttons on any equipment in a car. When the drivers want to push any button, they look at the button and consider how to adjust the equipment. Then they push the button reaching their hand to the button.

There are many researches that deal with the mental workloads and the visual workloads while driving. However, it is important to clarify influence of the execution workloads on driving behaviors, because the execution workloads cause the visual and mental workloads.

Although Trains, airplanes, and ships are controlled by expert operators, the cars are operated by ordinary people. The ordinary drivers may have unexpected dangerous action while driving, for example, picking something up from a baggage on the passenger seat. In this case, first, the drivers confirm a position of the baggage with the visual workloads. Second, they have to select something in the baggage with the mental workloads. Finally, they reach their hand to the baggage changing their driving posture with the execution workloads. Therefore it is necessary for educating the risk, and for support system of the execution workloads.

In this research, physical loads with the visual workloads, the mental workloads, and the execution workloads are referred to as physical workloads (PWL). In preceding study, it was investigated influences of PWL on driving performances [2][3].

In this paper, it is focused on reaching actions. Influences of the reaching actions on emergency driving performances were investigated using driving simulator. To quantify the influence of the reaching actions, it is analyzed by using driver model.

2. RQUESTIONNAIRE ABOUT THE PWL TASKS

There are no detail data about traffic accidents caused by PWL tasks in Japan. Then questionnaires about the PWL tasks were sent out, 67 drivers returned the questionnaires living in Kagawa, Japan. The questionnaires were choice principles.

The ages of answerers are almost 30's to 40's years old. The 80 % of answerers have more than 10 years of driving experiences. The 80 % of them drive more than several times in every week.

The questions and results of every question are shown in Fig.1. In the question 1, the 80 % of them had the experience of PWL tasks. In the question 2 about reasons to execute PWL tasks, more than 50 % of them answered that it will be over soon. Moreover, there are some people answered that it's not danger. From these results, many drivers were inattentiveness for the PWL.

Therefore it is important to be known for all drivers by clarifying risks of executing the PWL. In the question 3 and 4, a half of valid response answered that they had near traffic accident experiences due to the PWL tasks, few people had experienced in a traffic accidents due to the PWL tasks. There are three workloads mentioned above. In the question 6, the

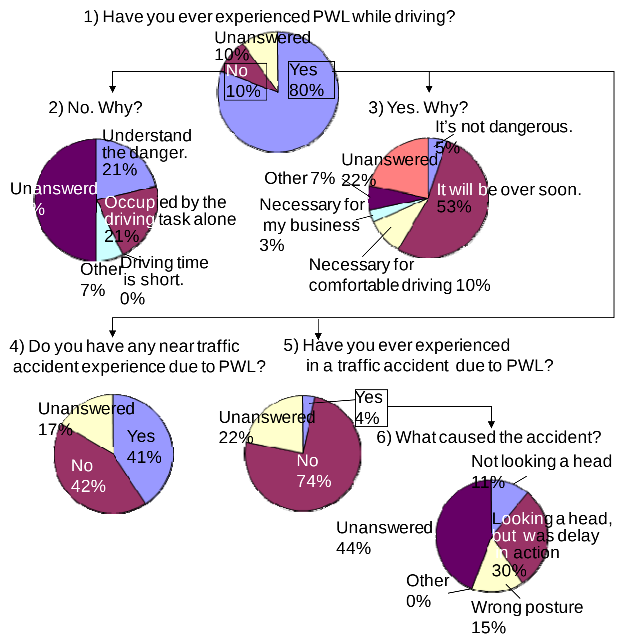

Fig. 1 Questionnaire about Experience of PWL tasks

choice of "not looking a head" is as the visual workloads. The choice of "looking a head, but was delay in action" was caused by the mental workloads. Moreover, the choice of "wrong posture" means that there are wrong influences of the PWL on the driving operation according to the wrong posture. Thus, it is important to prevention of the traffic accidents according to the visual, mental, and the execution workloads.

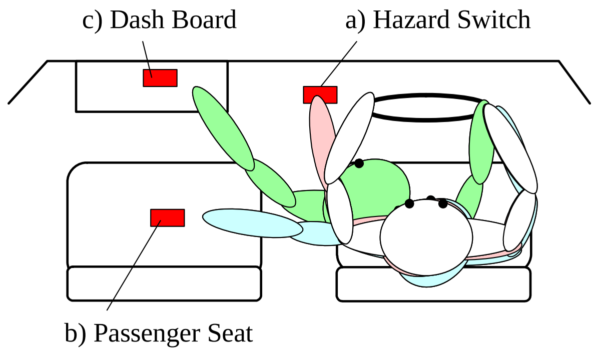

Fig. 2 Targets of Reaching Tasks

3. PWL TASKS

Additional actions during driving were researched with questionnaire and monitored while DS driving. Table 1 shows the results of researched additional actions. The actions were classified by eye movements and body movements. Level 0 is driving actions. Level 1 contains actions against driver oneself, these actions less influence on the driving behavior. Level 2 to 4 were divided by amplitude of the eye movements with or without the body movements. Level 5 to 6 were the actions cause major body movements, classified with or without the eye movements.

The tasks for experiments are three targets of reaching tasks. They are a) hazard switch, b) passenger seat, and c) dashboard, as shown in Fig.2. The Cartesian coordinates (x, y, z) of those points are (100, 250, 100) at a) hazard switch, (700, -350, -400) at b) passenger seat, and (700, 300, -100) [mm] at c) dashboard. In this regard, x, y, and z axes point to the left, ahead, and upward, respectively.

Table.1 Classification of Additional Actions while driving

Level 0	Driving Operation		Acceleration and brake pedal operation, steering wheel operation, shift lever operation, turn signal switch operation, wiper switch operation, look around a car, <u>push the hazard switch</u>, turn the air conditioner dial
Level 1	Driver Only		Rub own eyes, make hair adjustment, place hand to face, blow nose, smoke cigarette
Level 2	Near Driver	Minor Eye Movements	Confirm a switch position before pushing the switch, looking at the car navigation system display
Level 3		Minor Body and Eye Movements	Fasten seat belt, eat and drink, talk on a cellular phone, take a map from the door trim
Level 4		Major Eye Movements	Light a cigarette, put a cigarette out, take a cup from the cup holder, take a cellular phone, change CDs in the car audio, <u>look for something on the passenger seat</u>, control the switches at the car audio or the car navigation system, look at a map and read a book
Level 5	Not Near Driver	Major Body Movements	(Not include eye movements due to practice and experience) Take something on the rear seat, <u>grope something in the dashboard</u>
Level 6		Major Body and Eye Movements	Take something on the rear seat, grope something in the dashboard, reach an object from the underfoot, take care of a baby on the passenger seat

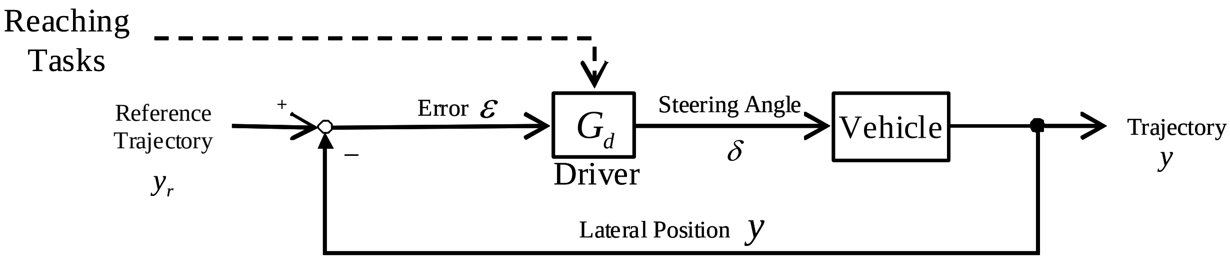

Fig. 3 Driver-Vehicle Model with Reaching Tasks

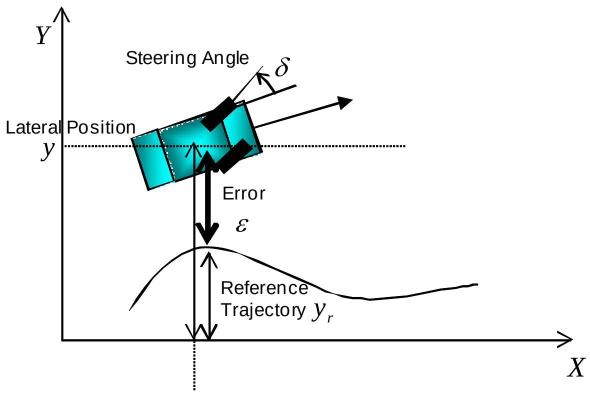

Fig. 4 Driver Preview Model

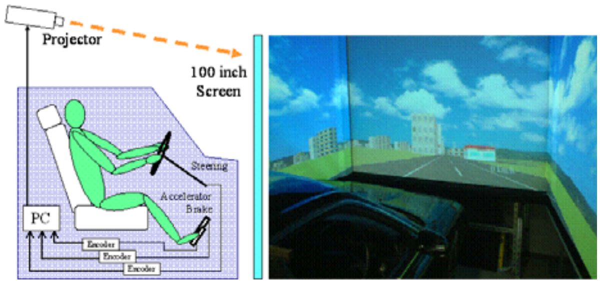

Fig. 5 Driving Simulator

4. DRIVER MODEL

The driver-vehicle model to clarify the influence of the reaching tasks on the driving behavior is shown in Fig.3. As the whole, we adopt a driver-vehicle model that keeps a distance between the target lateral position yr and a car lateral position y to the minimum (see Fig.4). A transfer function of the driver G_d is shown as below.

$$G_d = K\frac{T_h s + 1}{T_k s + 1} \qquad (1)$$

where K is a gain, T_k and T_h denote time constant for first order lag and lead element, respectively.

The parameters K, T_k and T_h will change according to the reaching tasks. In other words, the gain K becomes large and the time constant of lag T_k becomes small. Because a manipulability of an end effecter of driver's arm is high, if the drivers stretch their arms to the target [4].

5. EXPERIMENT OF STEERING AVOIDANCE

5.1 Experimental Equipment

It is used to evaluate an avoidance performance with the reaching tasks in an emergency situation. A driving simulator was utilized for experiments (shown in Fig. 5.) The accelerator, brake pedal and steering wheel were connected to the computer by encorders. The traffic scene was calculated by computer based on driving operation, and then projected onto a 100 inch screen. The vehicle dynamics are calculated by CarSim (Virtial Mechanics Corp.).

5.2 Experimental Procedure

In this section, we evaluate the avoidance ability using steering with the reaching tasks. The situation is supposed the urgent case of sudden car emergency from left side of the straight street (see Fig. 6 (a)). The long straight street includes six crosses. There is a car that may run into the street at the center of the short straight street among the crosses. One car among five cars runs into the road. As shown in Fig. 6 (b), when own car runs through the line A, a car approaches from Point P and

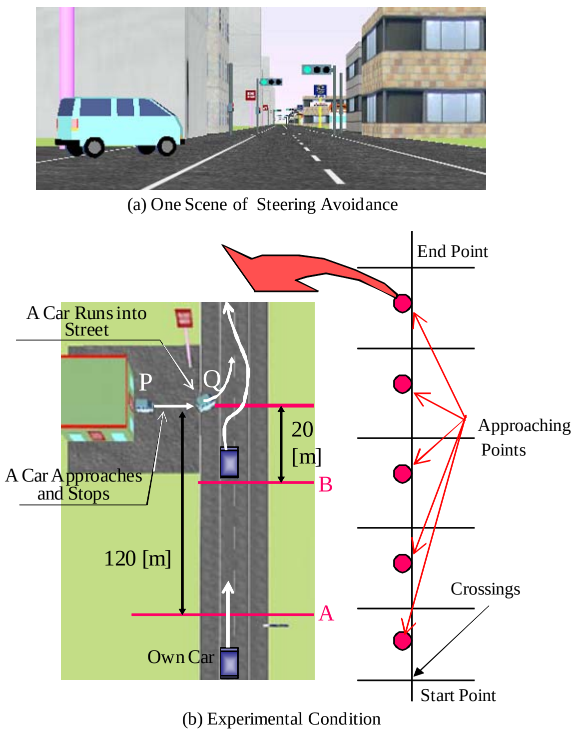

Fig. 6 Outline of Steering Avoidance

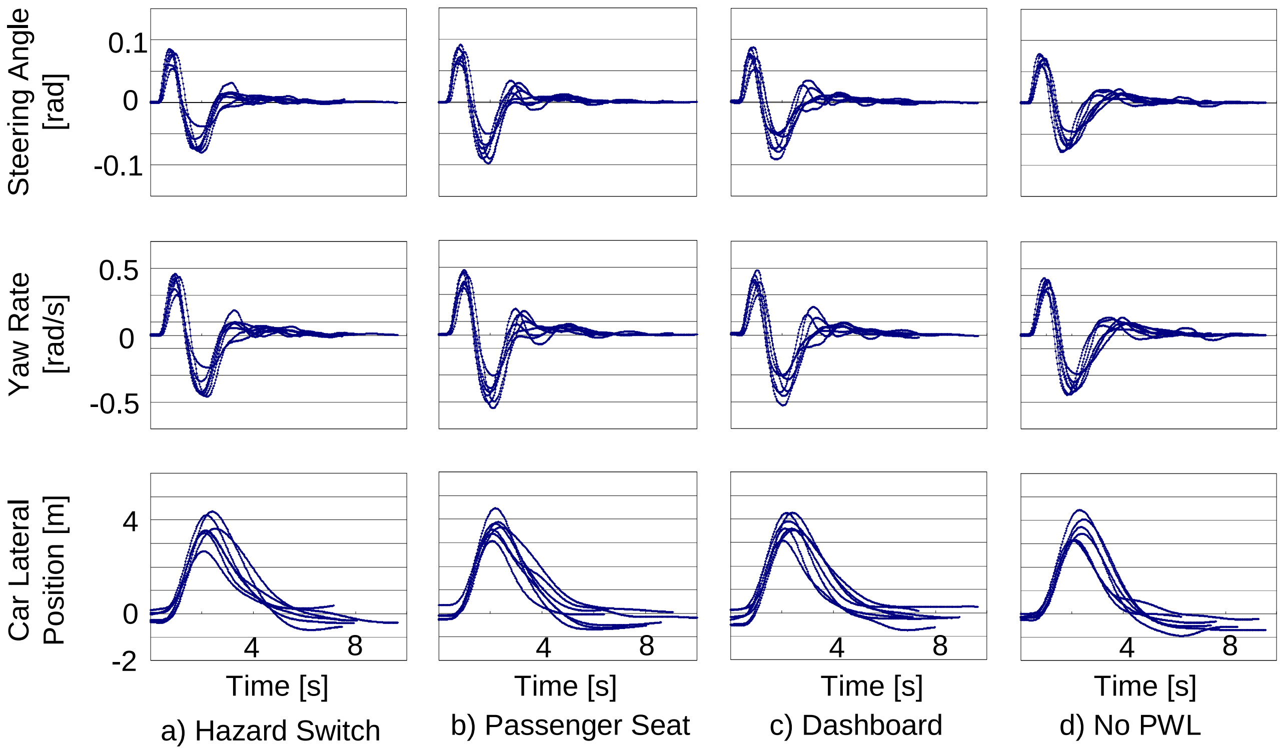

Fig.7 Vehicle Behavior in Emergency Avoidance for All Subjects

stop beside the street (Point Q). A car runs into the street suddenly at one of the every five P-Q line at random when own car runs through line B. The distance from line B and line P-Q is 20 [m]. Own car runs at constant 60 [km/h]. The driver can avoid only by the steering toward to coming lane. The targets of the reaching tasks are a) hazard switch, b) passenger seat, and c) dashboard. During experimental driving, subjects were stretching their hand to the target. Seven subjects of 18 to 26 years old are employed.

6. Experimental Results

Fig.7 (a), (b), (c) show the time series of steering angle, yaw rate, and car lateral position, after own car runs through line B. They are averaged for each subject. Moreover, Fig.7 (d) shows the results with no reaching task. When a car runs into the street, the drivers steer to the right for the avoidance. There are overshoots of the steering angle after the avoidance compared with the case of no task. The amount of overshoots becomes larger in order of the (a) hazard switch, (b) passenger seat, (c) dashboard. The peak times of the overshoot become smaller according to distance of the targets. There are not differences in the lateral positions for each target. However, the wave shapes of the steering angles and the yaw rate were vibrating. These results show the reaching tasks make steering behavior unstable.

7. PARAMETER ESTIMATION OF DRIVER MODEL

The lateral acceleration in emergency avoidance looks like two kinds of sine wave (shown in Fig.8.) Then, the target course of the driver model was second order integral of the lateral acceleration. It is necessary to estimate these parameters, because a time for avoidance *dlcT* and a maximum side deviation in avoidance *dlcB* shown in Fig.8 are different among the drivers and trials as well as the parameters K, T_k, and T_h.

To evaluate the parameters is a least square problem as shown below;

$$\textit{minimize} \quad J = \left[\frac{1}{N}\sum_{i=1}^{N}\left\{T_k\dot{\delta}_{[i]} + \delta_{[i]} - K\left(T_h\dot{y}_{r(i*\Delta t)} - T_h\dot{y}_{[i]} + y_{r(i*\Delta t)} - y_{[i]}\right)\right\}^2\right]^{\frac{1}{2}} \quad (2)$$

where Δt is a sampling time, and N is a sampling number. The variable $\delta_{[i]}$, $\dot{\delta}_{[i]}$, $y_{[i]}$, and $\dot{y}_{[i]}$ are the steering angle, a difference of the steering angles, the lateral position, and the difference of the lateral positions at *i*-th sampling, respectively. The variables $y_{r(i*\Delta t)}$, $\dot{y}_{r(i*\Delta t)}$ denote the target lateral position and a difference of the target positions at the time of i*dt, respectively.

The genetic algorithm (GA) was used for this estimation. The GA uses real values and changes domain of the parameter adoptive [5].

When the value of equ.(2) became 0.01 [rad], the estimations were finished.

In a preliminary estimation, variances of the

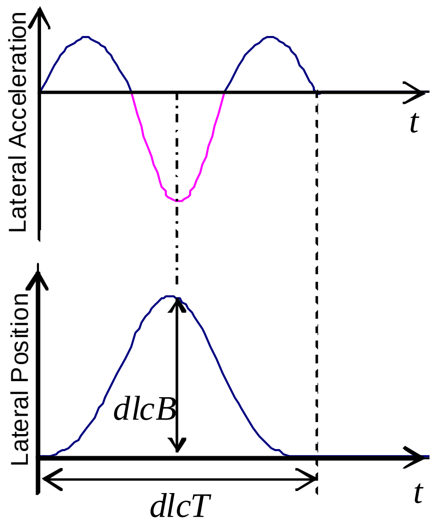

Fig. 8 Target Course of Driver Model

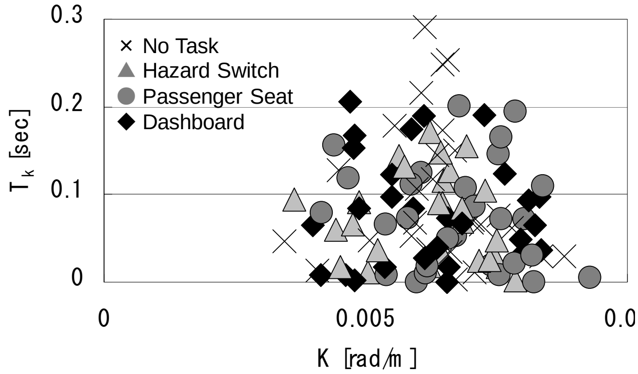

Fig. 9 Relationship among the parameters of the driver model according to the reaching tasks

variable T_h and *dlcT* are small. Then, in the actual estimation, the T_h and *dlcT* were 1.5 [sec] and 2.5 [sec] as constant values, respectively.

Moreover, the variable *dlcB* was constant 4.0 [m], because it may influence the gain *K*.

8. DISCUSSION

Fig.9 shows the relationship between the parameters of the driver model K and Tk. As the whole, the plots were within a fixed area of the figure. There is no tendency of the parameters according to the reaching tasks. However, in Fig. 7 there are qualitative tendency in the time series of the steering angles, that there are overshoots of the steering wheels and the peak time of the overshoots became small according to the distance to the reaching targets. In follows, it is discussed why these qualitative tendencies did not appear in the parameters of the driver model.

Mechanical impedances around the steering wheel axis changes according to the posture of the driver's arm [6]. In other words, maneuverability of the steering wheel changes according to the arm posture. The changed maneuverability affects the operation of the steering wheel and the vehicle behavior. It is considered that the drivers control the vehicle to be not influenced by the maneuverability. As the results, the parameters of the driver model changed little.

9. CONCLUSION

In this paper, first, the dangerousness of the PWL was shown with the questionnaire, the PWL tasks were classified. The targets of the reaching tasks were a) hazard switch, b) passenger seat, and c) dashboard according to the classification. The driving behaviors with the reaching tasks were examined using the DS. As the results, there were overshoots of the steering wheel and the peak times of the overshoots were small according to the distance to the reaching targets.

It was not clarified the influence of the reaching tasks on the parameters of the driver model. It is considered that the mechanical impedances around the steering wheel according to the driving posture and the control strategies should be divided. It is necessary to be carried out experiments in a single lane change course in not emergency, because the driver model in an emergency used to be the program operation.

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