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To cite this article: Taro Miyao and Shoichiro Takehara 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **501** 012031

IOP Conf. Series: Materials Science and Engineering **501** (2019) 012031 doi:10.1088/1757-899X/501/1/012031

An Experimental Study on Human Characteristics under Acceleration of Vehicle

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Abstract. Recently, environmental consideration, energy-saving performance and low fuel consumption become important, therefore personal mobility is actively developed. When vehicle become small, it is expected that human body behavior has a big influence on running performance. The influence is related to stability of vehicle and safety of its driver. Simulation is used as a method to investigate the interaction between vehicle and its driver, and the body behavior can be reproduced in advance. However, since it is necessary to consider the validity for the use of simulation, experiments to capture body behavior are indispensable. This research is aimed to obtain knowledge about dynamics of driver riding inside the vehicle. Therefore, subjects are placed on a simple truck simulating a vehicle. The truck is applied lateral acceleration and acceleration in the direction of travel, and the motion of subjects was recorded with the motion capture camera. From the measured data, human characteristics are examined by comparing the body behavior of subjects for each condition.

1. Introduction

Recently, personal mobility is actively developed because environmental consideration, energy-saving performance and low fuel consumption become important. Such vehicles are expected to be friendly to person and the environment, possible to transport comfortable and effective short/middle distance. In vehicles of various shapes, it is assumed that the occupant's posture is various. In addition, it is necessary for driver's physical characteristics to be considered for design and development, because it is assumed that human motion has influence on the motion at a light weight vehicle. In order to evaluate human characteristics and motion of vehicle occupants, experiments by actual vehicle running, vibration experiments of the seat with a vibration, and the like have been carried out. [1,2,3,4,5] These experiments are concerned with behavior under steady conditions, these are not concerned with behavior under unsteady conditions. Then, it is important to obtain data on body behavior when lateral acceleration and acceleration in the traveling direction are applied. The lateral acceleration is assumed at the time of lane change or turning of the vehicle, and the acceleration in the traveling direction is assumed when the vehicle starts or stops. The purpose of this research is to gain findings of the body motion of the vehicle occupant. Therefore, experiments on body behavior were conducted under unsteady conditions.

2. Methods

Subjects were 11 persons aged from 22 to 24 years old. The sheet used in the experiment was inflexibility in order to eliminate the influence on the body behavior by flexibility such as an automobile seat. Figure 1 shows the schematic diagram of experiment setup. Ten motion capture cameras were used for measurement. The vehicle was given three types of acceleration by changing the elongation of the rubber band. Comparison of body behavior due to acceleration difference was conducted. Experiments were carried out at 1.2[m/s^2] which is the general deceleration of the automobile and 0.8[m/s^2] and 1.4[m/s^2] which are the deceleration around it. (6) However, even with the same rubber band elongation, there was a difference in acceleration depending on the weight of the subject. In this study, the weight was set to 75 kg using a weight in order to eliminate the difference in acceleration. Experiments were carried out by instructing subjects to open eyes or close eyes, to inform the timing of departure or not to notify. Instructions for open eyes and closed eyes are to investigate the influence on the body behavior by the subject's visual information. Whether to notify the timing of departure or not is for comparing the body behavior at the time of a sudden start of the vehicle and the body behavior at the time of recognizing the timing of starting the vehicle. For the analysis of experimental results, five data without data loss were selected. In addition, this research is approved by the Ethics Committee of Sophia University. Each subject was explained about informed consent before experiments.

Table 1. Combination of experimental conditions

Experimental condition	Eyes	Departure signal
1	Opened	✓
2	Closed	
3	Opened	
4	Closed	✓

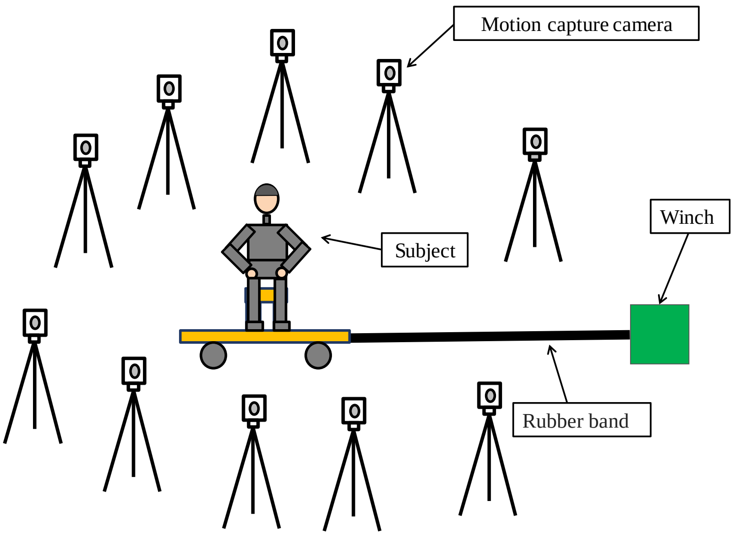
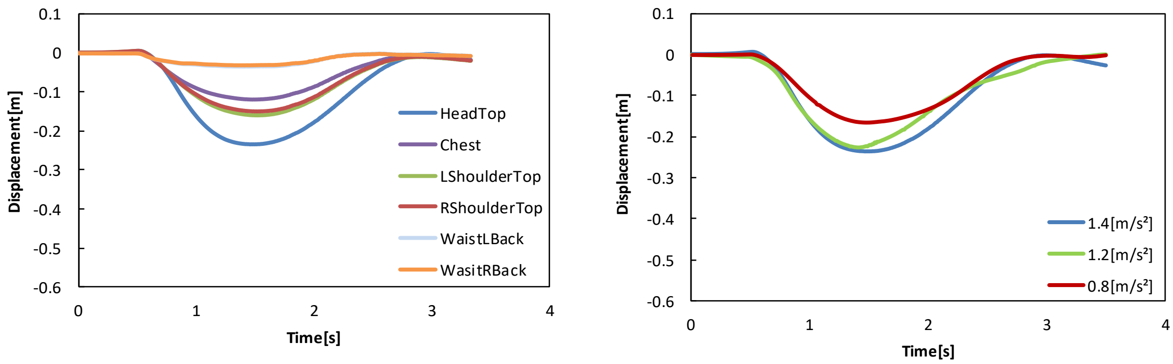


Figure 1. Schematic diagram of experiment setup

3. Result and discussion

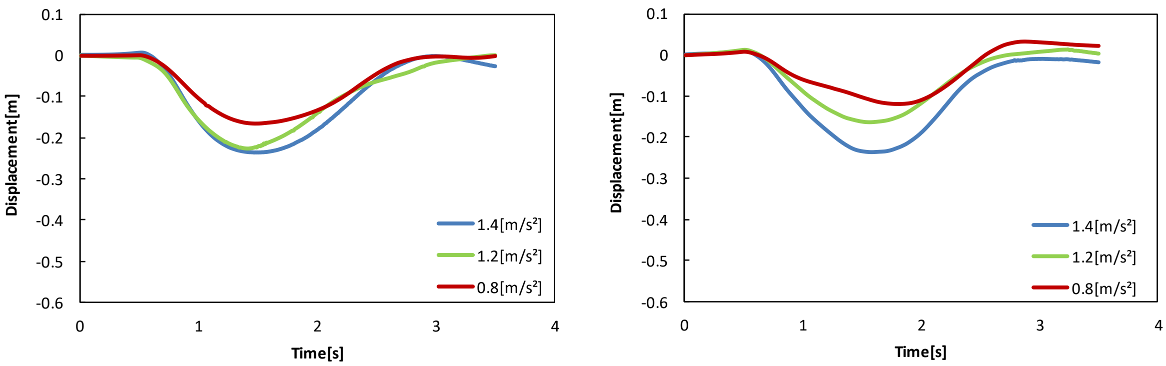
3.1 *Difference of displacement by acceleration, body part and subjects*

Figure2 shows results of lateral experiments in condition1 by subject1. Figure2(a) shows displacement of six markers in acceleration of 1.4 [m/s^2]. Figure2(b) shows the displacement of the head top in acceleration of 0.8 [m/s^2], 1.2[m/s^2], 1.4[m/s^2]. The displacement of the head top is larger than the displacement of other portions (Figure2(a)). In addition, the displacement of head top increases as acceleration increases (Figure2(b)). Based on the above results, the experimental results were analyzed by displacement of the head top in acceleration of 1.4[m/s^2]. Figure3 shows the displacement of the head top of two subjects in condition1. The difference of head top at acceleration 1.2[m/s^2] and 1.4[m/s^2] is smaller as compared with the difference at acceleration 0.8[m/s^2] and 1.2[m/s^2] (Figure3(a)). This is thought to be because at low acceleration, the influence by acceleration is smaller than the influence by notify the timing of departure and vision, but beyond a certain acceleration, the influence by acceleration became larger than that by notifying the timing of departure and visual feedback. On the other hand, the difference of head top at acceleration 0.8[m/s^2] and 1.2[m/s^2] is smaller as compared with the displacement difference at acceleration 1.2[m/s^2] and 1.4[m/s^2] (Figure3(b)). Thus, as the acceleration increases, the displacement of the head top increases, but it can be confirmed that the influence of the acceleration on the displacement of the head top varies depending on subjects. Figure4 shows the displacement of the head top of the subject1 in the traveling direction in condition1 and condition2. It can be found that the head top displacement of the acceleration 1.4[m/s^2] is larger in condition1 than in condition2. This result shows that the subject showed different behavior if the experimental conditions were different. Therefore, findings consistent with experiences such as head displacement increased as acceleration increased was obtained. However, it was confirmed that the influence was affected by individuals and conditions.



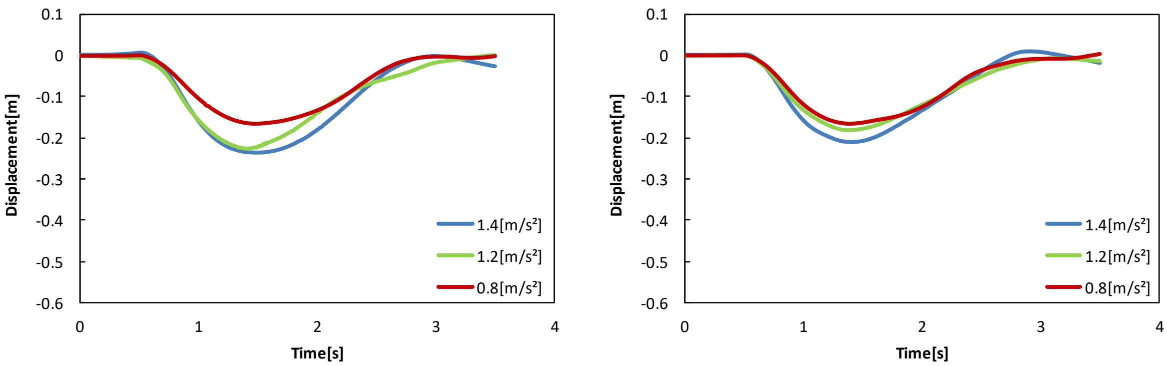
(a) Displacement of each marker (b) Displacement of head top

Figure 2. Time history of displacement (Subject1)



(a) Subject1 (b)Subject2

Figure 3. Time history of head displacement for each acceleration (Condition1)



(a) Condition1 (b) Condition2

Figure 4. Time history of head displacement for each acceleration (Subject1)

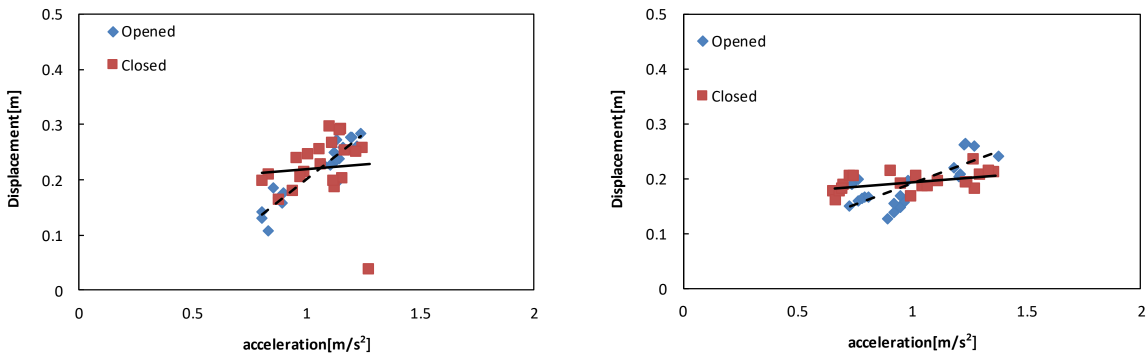
3.2 *Relationship between acceleration and head displacement*

The relationship between the input acceleration of the two subjects and the displacement of the head is discussed in more detail. In figure5 to 8, the vertical axis shows the maximum displacement of the head, and the horizontal axis shows the maximum acceleration in the same experiment. In addition, the approximate straight line obtained by the least squares method is also shown. First, condition1 and condition4 are compared (Figure5). It can be found both subject1 and subject2 show that the inclination of the approximate straight line is smaller when eyes closed than eyes opened. Since it is impossible to obtain visual information when eyes closed, it is considered to be to control the head by stiffening the body in preparation for movement.

Second, condition2 and condition3 are compared (Figure6). It can be found that the slopes of approximate straight lines of subject1 and subject2 at the time of eyes opened and at the time of eyes closed are almost equal. This result shows that head displacement is considered to be proportional to acceleration under this condition.

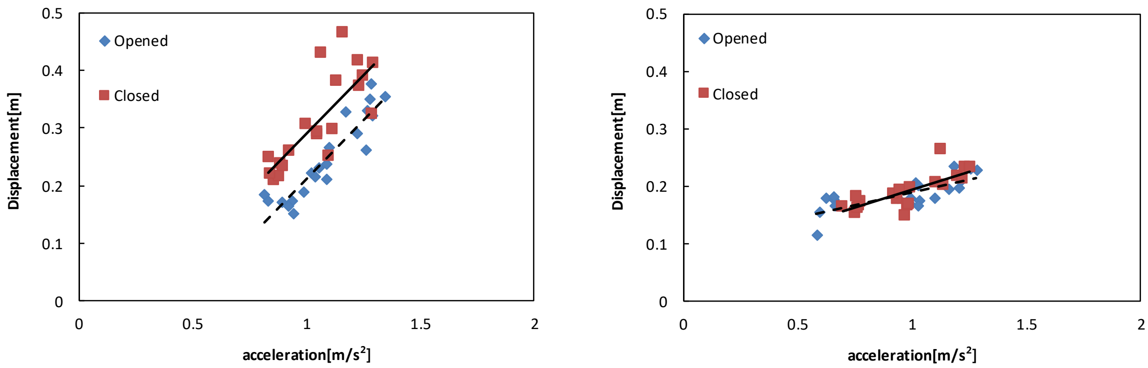
Third, condition1 and condition3 are compared (Figure7). Subject1 is different from subject2, and it can be found that the inclination of the approximate straight line with notified the timing of departure is smaller than that without notified the timing of departure. This may possibly reduce the influence by stiffening the body before if there is notified the timing of departure. In addition, it can be found that displacement is bigger than that with notified the timing of departure without notified the timing of departure. This is thought to be because the reaction was delayed.

Finally, condition2 and condition4 are compared (Figure8). In both subjects, it can be found that the slope of the approximate straight line without notified the timing of departure is larger than the approximate straight line with notified the timing of departure, and the displacement is also large. It seems that this was caused by the same reason as before. Therefore, even for the same subject, variations in the inclination of the approximate straight line could be found by conditions. Even in the same condition, it was also found that the inclination of the approximate straight line is different for each subject. These results suggest that recognition of movement and visual information are influenced feedback to body behaviors. Furthermore, it is considered that the body behavior varies from subject to subject because this feedback varies depending on the personality owned by subjects themselves.



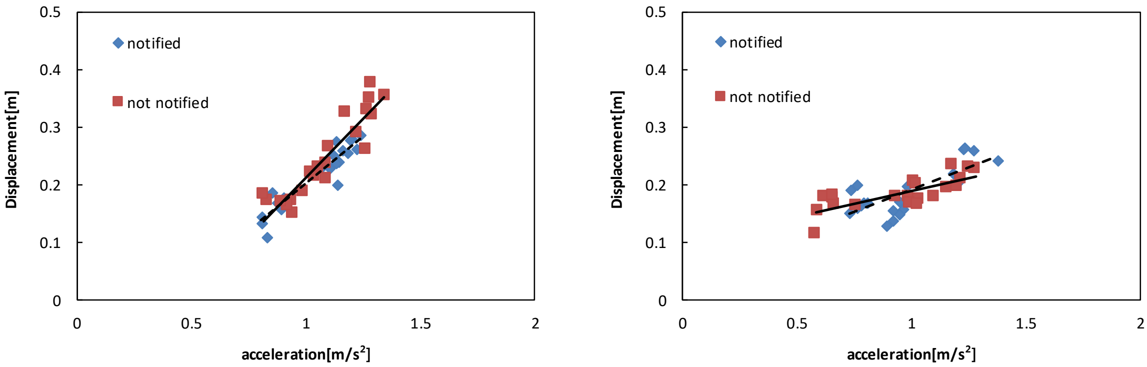
(a) Subject1 (b)Subject2

Figure 5. Comparison between condition1 and condition4



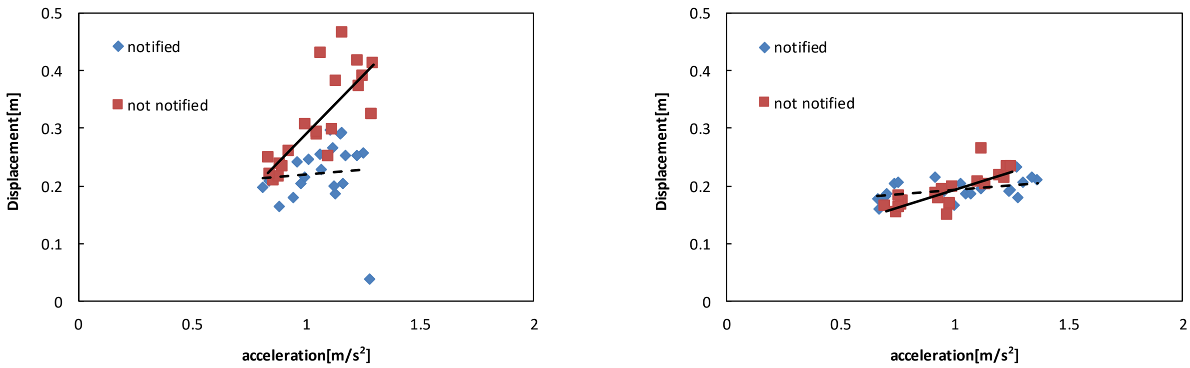
(a) Subject1 (b)Subject2

Figure 6. Comparison between condition2 and condition3



(a) Subject1 (b)Subject2

Figure 7. Comparison between condition1 and condition3



(a) Subject1 (b)Subject2

Figure 8. Comparison between condition2 and condition4

4. **Conclusion**

In this study, lateral acceleration is applied to the vehicle and the body behavior of the vehicle occupant was recorded. At the time of experiments, subjects were instructed whether to notify the timing of departure and whether to open eyes or close eyes. Characteristics of the body behavior were examined using these results. It is considered that the body is controlled in advance in preparation for movement with notified the timing of departure. On the other hand, without notified the timing of departure, it can be thought that the response was delayed because it could not prepare for the movement. In addition, results that the displacement increased proportionally with the acceleration was obtained. However, differences were found displacement and slope of approximate straight line depending on experimental conditions and subjects. Therefore, it is suggested that the individuality possessed by each person may influence feedback to the body behavior from external factors such as recognition to move and visual information.

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