Experiments of Earthquake Early Warning to Expressway Drivers using Plural Driving Simulators

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Abstract

To reduce casualties due to earthquakes, Japan Meteorological Agency (JMA) will introduce earthquake early warning (EEW) to general public on October 1, 2007. However, the possibility that EEW causes traffic accidents exists because EEW through car radio may not be transmitted to all the expressway drivers. Hence, the effects of early earthquake warning were investigated using plural driving simulators, connected together by a server. In the virtual experiments, three driving simulators were used, simulating three cars running together on an expressway. When EEW was transmitted to all the cars, the drivers reduced speed slowly and no trouble occurred. On the contrary, when EEW was transmitted to only one car, some drivers reduced speed suddenly, and accidents occurred in 2 cases out of 14 tests. These experiments show the necessity of public education how to react EEW on expressways. Turning on the hazard lights after receiving an EEW and then reduce speed gradually is suggested to avoid accidents.

Keyword: *driving simulator, earthquake early warning, traffic accident, expressway*

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1. Introduction

The Japan Meteorological Agency (JMA) plans to provide the earthquake early warning (EEW), which contains the arrival time of S-wave and the intensity of seismic motion estimated by the P-wave detection near the hypocenter [1]. It is expected that the preparations for strong shaking and tsunami can start based on an EEW and thus, emergency responses can be performed rapidly and efficiently.

The EEW has been under operation on a trial basis since August 2006. The EEW is transmitted to construction sites, railway companies and so on, where the EEW is expected to be utilized properly without confusions. Based on the results of trial operations, the JMA will introduce the EEW to general public on October 1, 2007 [2]. The EEW will be broadcasted by radio and TV. On the other hand, it is pointed out that some troubles may be caused when the EEW is issued to the general public. For example, it is anticipated that many evacuees may go down like ninepins at the exits of theaters and department stores.

The JMA compiled dos and don'ts after receiving the EEW [2]. The proper behaviors during automobile driving are mentioned in the dos and don'ts. The possibility that EEW causes traffic accidents exists because the EEW through car radio may not be transmitted to all the expressway drivers. Maruyama and Yamazaki [3] showed the effects of EEW to drivers on an expressway using driving simulator. In the study, no other vehicles were considered except for examinee's. It is important to consider the interaction among vehicles on an expressway when the EEW is issued. In this study, the effects of EEW are investigated using three driving simulators, connected together by a server. The reactions of drivers are observed under various receiving conditions of EEW.

2. Outline of the driving simulator experiments

Figure 1 shows the driving simulators used in this study [4]. Two regular driving simulators (Fig. 1) and one simple driving simulator that consists of only a steering wheel, brake and accelerator pedals were employed in the virtual tests. Figure 1 also shows the scenario course in the experiment. The examinees were instructed to drive at the speed of 80 km/h in the left lane. In the right lane, the simple driving simulator, driven by a trained person, was assigned as a pace maker during the experiment.

The condition of an EEW was determined using the locations of the hypocenter and seismometers in the 26 September 2003 Tokachi-oki earthquake. According to the results of numerical simulation by JMA, the time between receiving the EEW and the arrival of S-wave is about 10 seconds in Taiki Town, which is located about 100 km away from the epicenter.

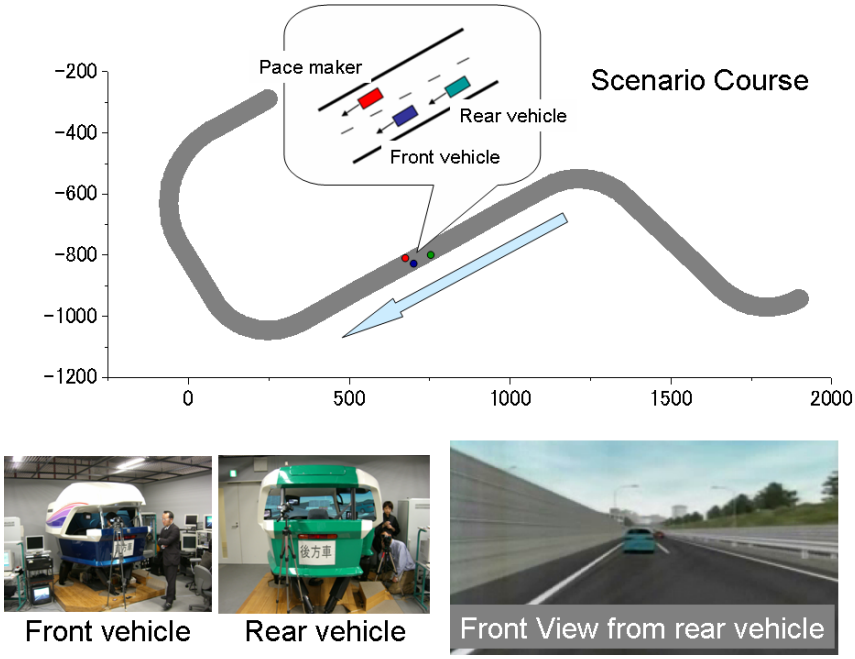


Figure 1 Driving simulators used in this study and scenario highway course

Hence, the 3-component acceleration record in K-NET Taiki Town was used as an input seismic motion in the experiment. The seismic response acceleration of a moving vehicle was calculated [5], and then the response acceleration was applied to the driving simulators.

Three types of experiments were conducted in this study. The EEW was given neither the front vehicle nor the rear vehicle in Experiment 1 (14 pairs of drivers). The EEW was transmitted to the both vehicles in Experiment 2 (13 pairs). In Experiment 3, the EEW was given only to the front vehicle, and it was not given to the rear vehicle (14 pairs). The EEW was assumed to be transmitted by car radio, and it announced to the drivers that an earthquake has just occurred and strong motion will arrive soon.

3. Results of questionnaire survey after the experiments

After the experiment, questionnaire survey was conducted to each examinee. Figure 2 shows the degree of recognition of the earthquake motion during the experiments. When the EEW was not transmitted to the drivers, about 40 % of examinees in Experiment 1 and about 70 % of examinees in Experiment 3 (rear vehicle) could not recognize the earthquake occurrence. Similar tendency was also pointed out under the actual earthquake environment [6].

On the other hand, the examinees recognized the earthquake motion when the EEW was provided. If failures of road embankment or cracks of road surface are generated due to an earthquake, drivers that are unaware of the earthquake may run into the failures. The drivers that know the earthquake occurrence in advance by EEW can avoid such kind of traffic accidents. The EEW seems to be very effective in this regard.

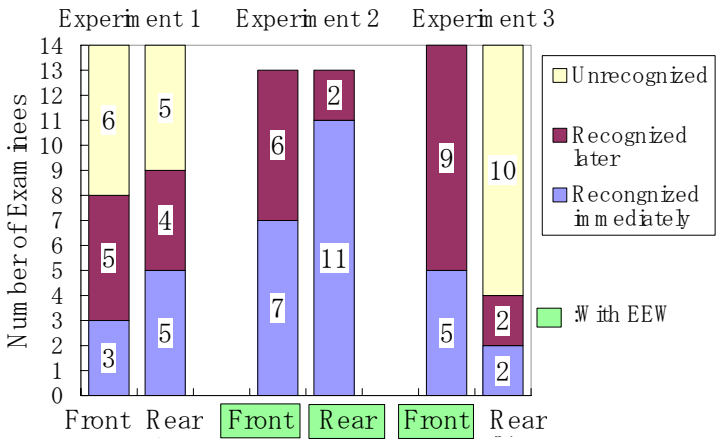


Figure 2 Degree of recognition of earthquake occurrence during the experiment

In Experiment 3, the examinees of the front vehicle can recognize the earthquake occurrence owing to EEW, however, the examinees of the rear vehicle may be unaware of the earthquake. The difference of earthquake recognition between the two drivers will affect drivers' behaviors during an earthquake. Figure 3 shows the reactions of the examinees during strong seismic motion. In Experiment 1, more than half of the examinees kept on driving as usual even under strong shaking. On the contrary, many of the examinees in Experiment 2 reduced speed or stopped the car during strong shaking. Because of the EEW, the examinees in Experiment 2 recognized the earthquake. Hence, they reduced speed or stopped their vehicles to make ready for strong shaking. The results of Experiment 1 indicate that the drivers that are unaware of an earthquake may drive as usual. As for the rear vehicle in Experiment 3, less than half of the examinees kept on driving as usual though they did not recognize the earthquake. Because the examinee on the rear vehicle tried to keep the distance from the front vehicle, he reduced speed or stopped the vehicle without recognizing the earthquake.

4. Results of the experiments

In the experiments, the moving speed of vehicle, the positions of brake and accelerator pedals, the angle of steering wheel and so forth were recorded to evaluate drivers' reactions during an earthquake. Figure 4 shows examples of moving speeds of vehicles and positions of brake pedals observed in Experiments 2 and 3. When the EEW was given to the both examinees (Experiment 2), the front vehicle reduced speed gradually and the rear vehicle put on the brake in phase to keep the distance from the front vehicle. When the EEW was given only to the front vehicle (Experiment 3), the examinee on the front vehicle put on the brake before the

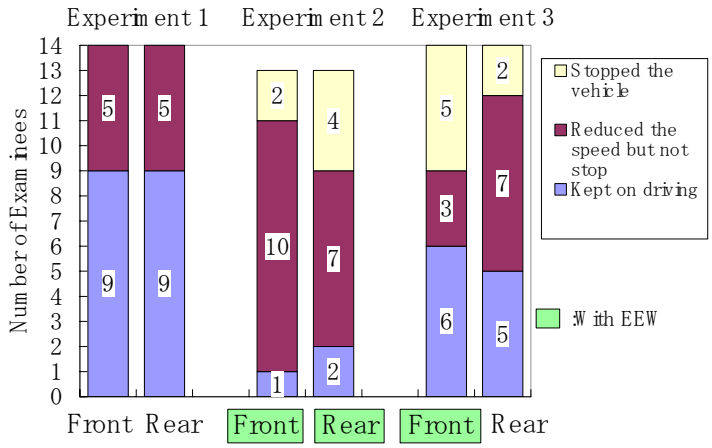
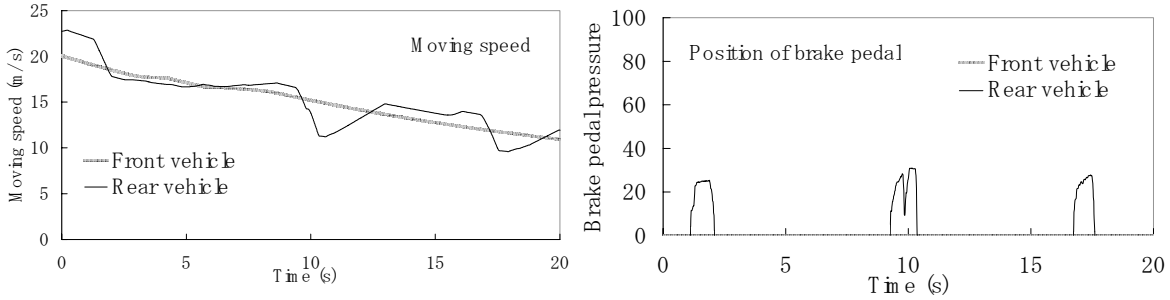
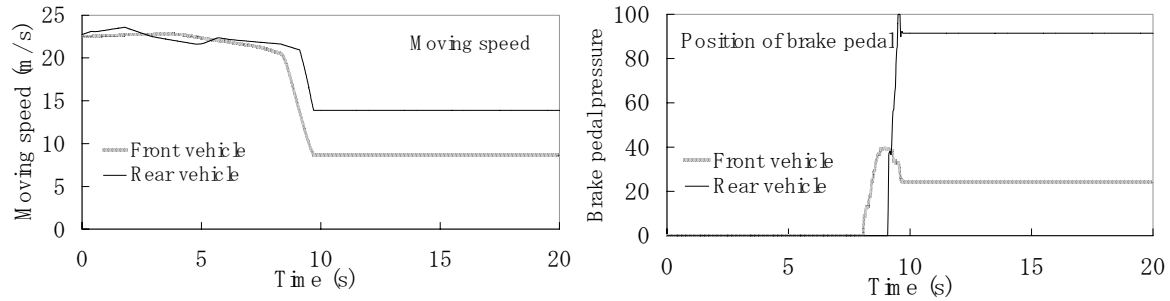


Figure 3 Reactions of the examinees during strong shaking



(a) Experiment 2



(b) Experiment 3

Figure 4 Examples of moving speeds and positions of brake pedals in Experiments 2 and 3

S-wave arrival (t = 10 s). Although the examinee on the rear vehicle tried to stop immediately, he eventually crashed to the front vehicle.

In Experiment 3, two pairs of examinees caused traffic accidents out of 14. Because the EEW was given to the front vehicle, the examinee tried to be ready for strong shaking by reducing the moving speed. On the other hand, the examinee of the rear vehicle, without receiving an EEW, kept on driving as usual. The disagreement in the drivers' reactions during an earthquake caused traffic accidents in this case.

Four examinees on the front vehicle turned on hazard light before reducing the moving speeds in Experiment 3. In these cases, the rear vehicles could respond properly even though

they did not receive an EEW. The intention to reduce speed of the front vehicle was conveyed to the rear vehicle by turning on hazard light. When the EEW is transmitted to general public through radio and TV, some drivers may receive the EEW and the others may not receive it at the present stage. Turning on the hazard lights by EEW receivers is considered to be the most effective way to make the other drivers ready for an unknown hazard (a coming earthquake) on an expressway.

5. Conclusions

In this study, a series of virtual driving tests were conducted to realize the reactions of drivers under the earthquake early warning. When an EEW is given only to a part of vehicles running in close distances, the disagreement among drivers' reactions during an earthquake may cause traffic accidents. Such kind of expected events were actually occurred in the experiments using three driving simulators connected together by a server. Turning on the hazard lights by drivers that received the EEW is considered to be the effective way to make the drivers without receiving the EEW ready for unexpected hazards. Before the EEW is provided to general public through mass media, it is important to instruct drivers to turn on the hazard lights before reducing speed when receiving the EEW on an expressway.

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