

Effects of Visual Display Conditions on Ride Comfort Evaluation in Autonomous Vehicles

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In automated vehicles, various types of information may be displayed on the windshield and side windows. Previous studies have reported that ride comfort is affected by mechanical vibration and audiovisual stimuli synchronized with the vibration. Therefore, even when the vibration acceleration is the same, visual information different from the driving scene may affect vibration discomfort and ride comfort evaluation. In this paper, a driving simulator experiment was conducted to investigate these changes.

Twenty healthy university students aged 20 years or older participated. Each participant sat in a driving simulator with three displays and a six-degree-of-freedom motion system for approximately 9 min. To simulate fully automated driving, the experimenter operated the vehicle at approximately 60 km/h using an external controller. The test course had 25 vibration exposure sections. Five vibration conditions were presented in random order using different bump heights. After passing through each vibration section, the participants evaluated their discomfort using a five-point scale from “Not uncomfortable” to “Very uncomfortable”.

Four visual conditions were used, as shown in Fig. 1. The driving scene was presented on all displays in Condition 1. The nature video was presented on the center display in Condition 2, on the side displays in Condition 3, and on all displays in Condition 4. The nature video was selected based on a previous study. In Conditions 1 and 3, the participants were instructed to look at the preceding vehicle. In Conditions 2 and 4, they were instructed to look at the nature video on the center display. After the subjective evaluation experiment, the triaxial translational acceleration on the seat surface was measured. The measurement was conducted in another run under the same conditions. The driving sound and the sound of the nature video were mixed using a sound mixer. The sound level was adjusted to approximately 62 dB (L_{Aeq}) at the participant's ear position. The study was approved by the Bioethics Committee of the Faculty of Engineering, Kindai University.

A scale was constructed using the category judgment method based on the discomfort ratings and measured vibration accelerations. The obtained category boundaries are shown in Fig. 2. Compared with Condition 1, boundary values tended to be higher overall in Condition 2. In Condition 3, the two category boundaries at relatively high acceleration were higher than those in Condition 1. In Condition 4, the category boundaries for lower discomfort were higher than those in Condition 1. However, the boundaries for higher discomfort were lower than those in Condition 1.

A previous study reported that discomfort tended to decrease when participants could see the road condition in advance compared with when they could not see it. In Condition 4, the participants could not see the road surface. Except in the low-acceleration range, Condition 4 tended to be evaluated as more uncomfortable than Condition 1. The boundary values in Condition 1 were generally lower than those in Condition 2. They were also lower than those in Condition 3 for the higher discomfort categories. These results suggest that the synchronized visual stimuli may increase vibration discomfort when the driving scene is presented on all displays. In Conditions 2 and 3, the driving scene was presented on fewer displays because the nature video was presented on some displays. This may have reduced discomfort.

This study used a driving simulator to examine the effects of presenting visual information that differed from the driving scene on ride comfort. When the driving scene was presented on all displays, the category boundaries tended to be lower than when the nature video was presented on some displays. However, when the nature video was presented on all displays, the category boundaries for higher discomfort tended to be lower than those in Condition 1. These results suggest that the visual presentation conditions may affect vibration discomfort. In addition, completely blocking the driving scene may increase occupant discomfort, particularly at higher vibration acceleration levels.



Fig. 1 Visual presentation conditions

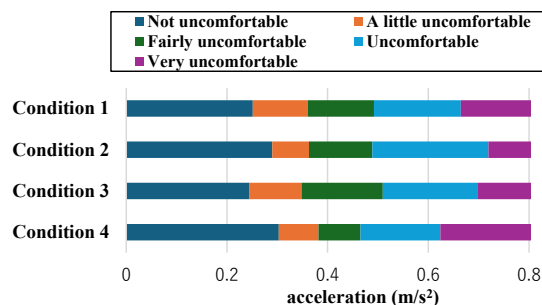


Fig. 2 Category boundaries for each condition