

Effects of occupant behaviour on head pitch rotation in a SAE Level 3 autonomous vehicle driving simulator

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1. Introduction

With the increasing integration of Advanced Driver Assistance Systems into modern vehicles, the transition to autonomous vehicles (AVs) is accelerating (Rana & Hossain, 2021). While AVs have the potential to significantly reduce automotive accident severity, current safety systems do not adequately address the safety of occupants in SAE Level 3+ AVs (Bouzekri, Martinie, & Palanque, 2022; Subit, Vézin, Laporte, & Sandoz, 2017). Conventional safety systems, reliant on impact dummies, cannot fully represent the behavioural aspects and out-of-position movements of occupants (Subit, Vézin, Laporte, & Sandoz, 2017). Improving occupant protection in AVs necessitates a deeper understanding of human-machine interaction, occupant behaviours, and positioning during emergency scenarios. One approach is to conduct personalized cognitive explorations of occupants in a dynamic environment, coupled with a controlled virtual environment. This study aims to investigate the correlation between head pitch rotation and occupant activities during a short driving scenario on a driving simulator.

2. Methods

Ten participants behavior and physiology were studied during a 10-minute ride in a Level 3 AV simulator. The simulator used a 6-DOF hexapod (Fig. 1), and a virtual environment (30 fps) created by Unreal Engine and CARLA (Dosovitskiy *et al.* 2017). A motion cueing algorithm was developed to transform the horizontal

acceleration from the virtual environment into vertical acceleration on the driving simulator to enhance the sense of immersion. Participants were fitted with sensors to measure head pitch rotation (100 Hz), and they were filmed throughout the experiment. The simulated AV drive included standard and strong braking events. Participants had the seat belt on, they were seated in a standard position, and were freely allowed to engage in various activities of their choice, including using their phones or the radio. Sixteen braking events occurred, with 8 between 0.2 and 0.4 g (standard) and 7 between 0.4 and 0.6 g (strong). Two of the standard braking events and one of the strong braking events were preceded by the same audible alerts. The effect of different activities on participant's head pitch rotation variation (max – min) during each braking events was investigated. An N-way ANOVA test was used to assess the significant differences between groups and parameters. All participants gave their consent and signed the necessary forms.

3. Results and discussion

Three types of non-driving activities were identified: looking at the road ahead "A", using devices such as a phone or tablet "B", and using devices before braking and then looking at the road when braking starts (C). Although no significant difference was found, the head pitch rotation (Fig. 1) shows that the median head pitch rotation during standard braking without an alert for A, B, and C are 7.96°, 4.64°, and 11.33°, respectively. Under strong braking conditions without an alert, the

median head pitch rotation for A, B, and C are 6.37°, 6.8°, and 14.77°, respectively. The median head pitch rotation for A and C are 6.21°, and 10.59°, respectively, in the event of an audible alert during standard braking. Under strong braking with audible alert, the median head pitch rotation for A is 8.32°. This indicates that that with an alert, no participant kept engaged with their device. Activity A occurred 18 times with an alert and 61 times without. Activity B occurred 28 times without an alert, as participants always looked at the road when alerted. Activity C occurred 9 times with an alert and 37 times without.

This study examined the impact of passenger activities on head pitch rotation during braking events in a Level 3 AV simulator. Findings revealed that there is no significant difference between the 3 activities, which is in contradiction with in-car experiments (Mackenzie *et al.*, 2022) which showed a noteworthy difference in head rotation between the activities mentioned. Additionally, there was no significant effect of age, gender, or BMI on head pitch rotation. These findings emphasize the importance of considering simulators to study passenger head pitch rotation. Next step will be to conduct another experiment with a larger sample size while analyzing muscular, respiration, and heart activities. Additionally, another experiment will be conducted using a 1 DOF 4 meters long sled to apply full horizontal acceleration to compare with the driving simulator.

4. Conclusions

This study investigated the correlation between head pitch rotation and occupant activities during braking events in a Level 3 AV simulator. Ten participants' behavior and physiology were studied during a 10-minute ride. The simulator included standard and strong braking events, and participants were allowed to engage in various activities of their choice. The results showed that there was no significant difference in head pitch rotation between the three activities (looking at the road ahead, using devices, and using devices before braking and then looking at the road). These findings suggest that simulators can be a valuable tool for studying passenger head pitch rotation in AVs.

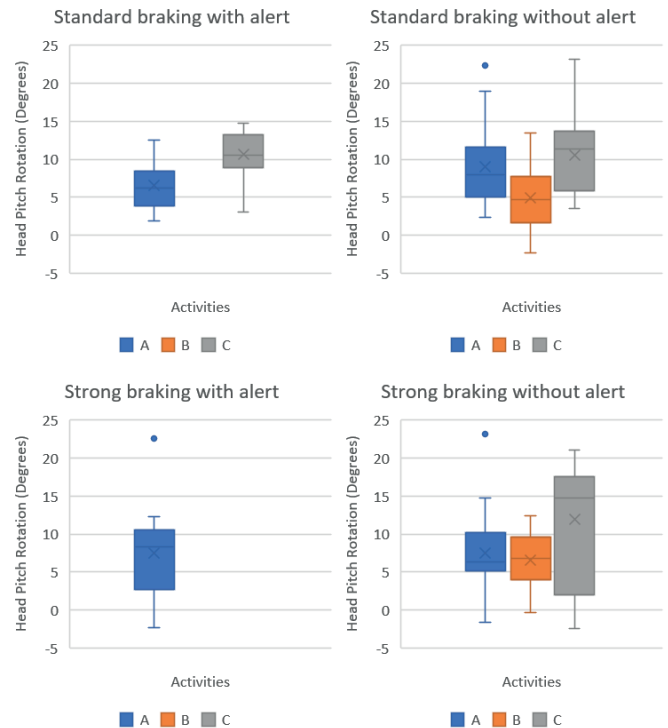


Figure 1. Head pitch rotation for each activity under Standard braking (with & without alert), and Strong braking (without alert)

Activity: (A) looking at the road; (B) using devices such as a phone; (C) using devices before braking and then looking at the road when braking starts.

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Conflict of Interest Statement

This study had no conflict of interest.

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