Adjunct Proceedings of the 9th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '17), September 24–27, 2017, Oldenburg, Germany.

Experimental Setup of Motion Sickness and Situation Awareness in Automated Vehicle Riding Experience

Nidzamuddin Md. Yusof
Eindhoven University of Technology
Eindhoven, Netherlands
n.yusof@tue.nl

Jacques Terken
Eindhoven University of Technology
Eindhoven, Netherlands
j.m.b.terken@tue.nl

Juffrizal Karjanto
Eindhoven University of Technology
Eindhoven, Netherlands
j.karjanto@tue.nl

Frank Delbressine
Eindhoven University of Technology
Eindhoven, Netherlands
fdelbres@tue.nl

Shivam Kapoor
Eindhoven University of Technology, Eindhoven, Netherlands
s.kapoor@student.tue.nl

Matthias Rauterberg
Eindhoven University of Technology
Eindhoven, Netherlands
g.w.m.rauterberg@tue.nl

AutomotiveUI '17 Adjunct, September 24–27, 2017, Oldenburg, Germany

ACM ISBN 978-1-4503-5151-5/17/09…$15.00
https://doi.org/10.1145/3131726.3131761

Abstract

Automated vehicle users are likely to engage in non-driving tasks while traveling. Most of these activities require their visual attention and prevent them from getting information from outside vehicle. This leads to motion sickness symptom because of conflicts to what they see and what they feel during traveling. In this paper, an experiment is designed to study the effect of enhancing situation awareness by providing haptic feedback to mitigate the motion sickness inside a vehicle

Figure 1: The Instrumented Car

while doing a non-driving task. A preliminary study (N=10) shows that the experimental setup has promising results that can provide insightful information between situation awareness and motion sickness for future car designers.

Author Keywords
Automated vehicles driving; motion sickness dose value; situation awareness; motion sickness; haptic feedback information.

CCS Concepts
• General and reference~Experimentation • Human-centered computing~Field studies • Hardware~Haptic devices

Introduction

Automated vehicles raise numerous complex challenges in the forthcoming years as automated driving technology evolves. They enable a transition of humans drivers to eventual passengers that can perform non-driving tasks, such as reading, socializing with other passengers, watching movies, or working [11]. Such activities usually tend the automated vehicle users’ focus off the road, which leads to an incapability to predict the immediate movement of the automated vehicle. This lack of outside visual information substantially reduces situation awareness (SA) of the users.

SA is defined in various ways of concept, depending on the theoretical and methodological approaches. [3] mentioned in a simple way that SA is “knowing what is going on around you.” In the context of fully automated vehicle driving experience, SA would involve the user being aware of what is happening in the environment and surroundings of the automated vehicle while performing non-driving tasks. Furthermore, automated vehicle users’ will be subjected to experience certain forces, which are induced by braking, cornering and accelerating of the vehicle. They normally try to compensate the feeling of forces acted on their body by visually understanding the situation and act accordingly. However, when they have no ability to foresee the direction of movement of the vehicle, they cannot act accordingly and motion sickness (MS) symptoms, such as physical discomfort, dizziness, and nausea, might occur.

MS is a result of a conflict between the passenger’s vestibular and visual inputs, diminished ability to foresee the direction of movement of the vehicle and deprivation of control over one’s movements [1]. In addition, an aggressive driving manner involving multiple occurrences of acceleration and braking is more probable to cause MS [2][9]. The previous study found that automated vehicle user would prefer a defensive or much less induced acceleration driving styles [13]. Yet, engaging non-driving tasks, even with that kind of driving style, can cause MS since human bodies are not habitual to low-frequency oscillation of movement, especially in an urban area [5].

The general idea to overcome this situation is using human senses to provide sufficient situation awareness to predict or anticipate the action of the automated vehicle and act accordingly on time. In this paper, experimental and analytical methods of research are described and discussed in order to scrutinize the role of SA in mitigating MS insightfully. The research aims to examine whether providing haptic feedback information in advance about the automated vehicle’s movement in a certain direction to the passengers increases SA and

Figure 2: Sitting position while watching video inside the instrumented car.

Figure 3: Haptic feedback device attached on the left forearm.

reduces MS when compared to providing no information at all.

Design, Prototype, and Apparatus

Haptic Feedback

A haptic feedback device, which consists of several mini vibration motors and controlled by Arduino board, is designed. Participants will wear the device on both of their forearms. This device provided haptic feedback information cues by vibrating the forearm corresponding to the direction the car will be turning in, either left or right. This way the participants were informed in advance about the oncoming change in the direction of movement of the vehicle and as an attempt to try to improve the passenger's SA.

Instrumented Car

Due to interior space and possibility of various seat arrangements, a Renault Espace, a multiple purpose vehicle (MPV), will be used for this study. This vehicle is transformed into an instrumented car, equipped with various sensors, such as pulse sensor and accelerometer, and all data is synchronized in a data acquisition (DAQ) device. A laptop will be used to show all data when conducting the experiment. This instrumented car's interior layout is customized and can be seen in Figure 4.

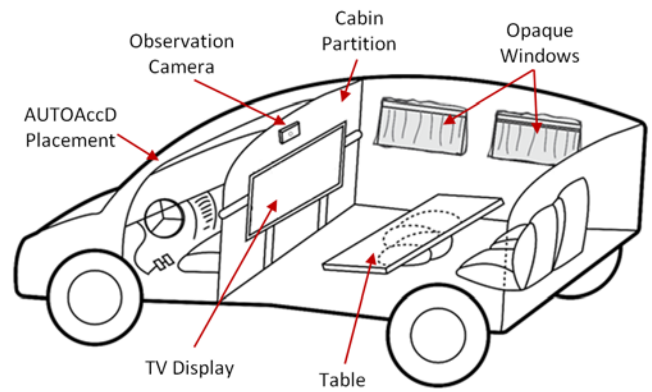

Figure 4: Interior cabin layout of the instrumented car.

In order to simulate an automated vehicle riding experience, the rear cabin is designed with a table, and a TV display is mounted on the cabin partition where participants could perform non-driving tasks. Furthermore, in order to maximize the passenger's feeling of being inside an automated vehicle and to provide a 'no driver' perception to the passengers, the rear cabin was completely isolated using a partition that separates the frontal area where the driver is present. In addition, a special device, the Automatic Acceleration and Data controller (AUTOAccD), will be used to help experimenter to simulate automated driving style [8].

Planned Study Design

The main objectives of this study are: 1) Is the information provided from haptic feedback can increase the situation awareness of automated vehicle user, where no visual information is given? 2) Is enhancing the situation awareness will reduce or mitigate the motion sickness symptom? 3) Do this information increase users’ mental workload when they are engaging in the non-driving task?

To answer these questions, the targeted participants for this experiment are the people that fall within the range of 25- to 100-percentile of Motion Sickness Susceptibility Questionnaire (MSSQ) scores [6]. All selected participants will be subjected to two experimental conditions, with (haptic condition (HC)) and without (baseline condition (BC)) haptic feedback prototype. In avoiding carry-over effect, the pseudo-randomized order will be applied. During the experiment, they will engage with a non-driving task, by watching a video on the TV display. For measuring the consistency of experiment sessions, instrumented car data (speed and acceleration) will be collected, and the concept of Motion Sickness Dose Value (MSDV) will be applied, based on [10] and according to [7]. For the measurement of motion sickness level, the Motion Sickness Assessment Questionnaire (MSAQ) will be used before and after experiment sessions [4]. For the measurement of situation awareness level, Situation Awareness Rating Technique (SART) will be used [12]. Rating Scale Mental Effort (RSME) will be used to assess the mental workload. After the experiment sessions, participants can give their opinions about the experiment in general.

Preliminary Results

The setup of experiment has been analyzed after conducting 10 sessions of the experiment, involving 10 participants (4 male and 6 female) between the ages of 18 and 36. As mentioned before, they were selected based on their MS susceptibility which was rated using the MSSQ.

The mean value of the MSDV for all 10 sessions in BC was $6.65ms^{-1.5}$ (SD = $1.17ms^{-1.5}$) and in HC was $6.09ms^{-1.5}$ (SD = $0.71ms^{-1.5}$). On the same hand, the mean of exposure time of the experiment was 535.6s (SD = 6.0s) in BC and 532.7s (SD = 9.6s) in HC. Furthermore, the mean value of the answer of MSAQ was calculated, and the score of before and after each experiment was compared, with 0% representing no MS and 100% representing unbearable MS. In BC, the level of MS raised from 15.1% (SD = 5.9%) to 22.8% (SD = 22.9%); in HC, the level of MS raised from 14.8% (SD = 5.1%) to 19.4% (SD = 8.0%). The mean SART score was also calculated, in both BC and HC, with a total range from -5 (lowest SA) to 13 (highest SA). Without haptic prototype feedback, the mean rating score was 2.7 (SD = 2.7); with haptic prototype feedback, the mean score was 5.1 (SD = 2.5). In addition, the RSME score reduced from 38.3 in BC to 23.1 in HC was 23.1.

Discussion and Conclusion

Participants that are having an MSSQ percentile rating below 25 were not selected for the experiment since they were not susceptible enough to MS and therefore would prove to be irrelevant for conducting the experiment. In addition, MSDV needed to ensure consistency in the experiments since it is important to induce the same MS in all participants by driving in the same style and on the same route in order to get realistic results. The calculated MSDV showed that the experiment was consistent and the period of the experiment (during the riding part) has almost the same exposure time.

Comparing the mean scores of MSAQ in both conditions, both results showed growth in MS level. However, in HC, the MSAQ score is raised less than in BC. Added to that, the mean SART score increase by 2.6 points. These results showed that providing early information about the direction the car will be turning in did increase SA of participants and lessen the MS symptoms. Moreover, based on RSME result, the implementation of the prototype did reduce the mental workload in gaining SA. However, these results are based on the small number of participants. A larger number of participants could provide a more extensive comprehension of the correlation between the changes in SA and its effects on MS.

In conclusion, this paper presents a brief explanation of experimental setup to study the correlation between SA and MS by means of haptic feedback. Preliminary results showed the experimental setup is reliable and consistent for each conducted sessions.

Acknowledgements
The authors would like to express their gratitude to Universiti Teknikal Malaysia Melaka and Ministry of Higher Education, Malaysia for the funding of the Ph.D. programs of Nidzamuddin Md. Yusof and Juffrizal Karjanto.

References
1. Cunningham, M. and Regan, M.A. 2015. Autonomous Vehicles : Human Factors Issues and Future Research. *Proceedings of the Australasian Road Safety Conference* (2015).
2. Diels, C. and Bos, J.E. 2016. Self-driving carsickness. *Applied Ergonomics*. 53, (2016), 374–382. DOI:https://doi.org/10.1016/j.apergo.2015.09.009
3. Endsley, M.R. 2000. Theoretical Underpinnings Of Situation Awareness : A Critical Review. *Situation Awareness Analysis and Measurement*. M.R. Endsley and D.J. Garland, eds. LEA. 3–32.
4. Gianaros, P.J., Muth, E.R., Mordkoff, J.T., Levine, M.E. and Stern, R.M. 2001. A Questionnaire for the Assessment of the Multiple Dimensions of Motion Sickness. *Aviation Space and Environmental Medicine*. 72, 2 (2001), 115–119.
5. Golding, J.F. 2006. Motion sickness susceptibility. *Autonomic Neuroscience: Basic & Clinical*. 129, (Oct. 2006), 67–76. DOI:https://doi.org/10.1016/j.autneu.2006.07.019
6. Golding, J.F. 1998. Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. *Brain Research Bulletin*. 47, 5 (1998), 507–516. DOI:https://doi.org/10.1016/S0361-9230(98)00091-4.
7. ISO 1997. The International Standard ISO 2631-1 Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration.
8. Karjanto, J., Md. Yusof, N., Terken, J., Delbressine, F., Hassan, M.Z. and Rauterberg, M. 2017. Simulating autonomous driving styles: Accelerations for three road profiles. *MATEC Web of Conferences*. 90, (Dec. 2017), 1–16. DOI:https://doi.org/10.1051/matecconf/20179001005.
9. Karlsson, N. and Tjärnbro, H. 2012. Motion sickness in cars: Physiological and psychological influences on motion sickness. Bachelor’s Thesis. Chalmers University of Technology, Gothenburg, Sweden (2012).
10. Lawther, A. and Griffin, M.J. 1987. Prediction of the incidence of motion sickness from the magnitude, frequency, and duration of vertical oscillation. *The Journal of the Acoustical Society of America*. 82, 3 (1987), 957–66. DOI:https://doi.org/10.1121/1.395295.
11. Schoettle, B. and Sivak, M. 2014. Public Opinion About Self-Driving Vehicles in China, India, Japan,

The U.S., The U.K., and Australia. UMTRI-2014-30 (2014), 1–35. DOI:https://doi.org/UMTRI-2014-30.

12. Taylor, R.M. 1990. Situational Awareness Rating Technique (SART): The development of a tool for aircrew systems design. *Situational Awareness in Aerospace Operations (AGARD-CP-478)*. 3/1 –3/17.
13. Yusof, N.M., Karjanto, J., Terken, J., Delbressine, F., Hassan, M.Z. and Rauterberg, M. 2016. The Exploration of Autonomous Vehicle Driving Styles: Preferred Longitudinal, Lateral, and Vertical Accelerations. *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '16)* (Ann Arbor, MI, USA, 2016), 245–252.