Workshop on Multimodal Motion Sickness Detection and Mitigation Methods for Car Journeys

Pöhlmann, Katharina Margareta Theresa; Li, Gang; Dam, Abhraneil; Wang, Yu Kai; Wei, Chun Shu; Brietzke, Adrian; Papaioannou, Georgios

DOI
10.1145/3544999.3550156

Publication date
2022

Document Version
Final published version

Published in
Adjunct Proceedings of the 14th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2022

Citation (APA)
Pöhlmann, K. M. T., Li, G., Dam, A., Wang, Y. K., Wei, C. S., Brietzke, A., & Papaioannou, G. (2022). Workshop on Multimodal Motion Sickness Detection and Mitigation Methods for Car Journeys. In *Adjunct Proceedings of the 14th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2022* (pp. 157-160). Association for Computing Machinery (ACM). https://doi.org/10.1145/3544999.3550156

Workshop on Multimodal Motion Sickness Detection and Mitigation Methods for Car Journeys

Katharina Margareta Theresa Pöhlmann
katharina.pohlmann@glasgow.ac.uk
University of Glasgow
Glasgow, Scotland

Gang Li
University of Glasgow
Glasgow, Scotland

Abhraneil Dam
Virginia Polytechnic Institute & State University
Blacksburg, Virginia, USA

Yu-Kai Wang
University of Technology Sydney
Sydney, Australia

Chun-Shu Wei
National Yang Ming Chiao Tung University
Hsinchu City, Taiwan

Adrian Brietzke
Volkswagen AG
Wolfsburg, Germany

Georgios Papaioannou
Technische Universiteit Delft
Delft, Netherlands

ABSTRACT

The mass adoption of automated vehicles in the near future will benefit safety (of occupants and pedestrians), the environment (low emissions), and society (accessibility, on-demand travel). There are, however, still challenges that need to be addressed, with one of the most crucial being motion sickness. In automated vehicles, the interior could be transformed into a living room or a working space, allowing occupants to spend their time with non-driving activities. These changes are likely to provoke, and increase, motion sickness incidence. To that end, this workshop will explore the current state of motion sickness detection and mitigation methods from different angles (e.g., closed-loop detection, multimodal motion cues,etc.) through expert talks and reflections, followed by discussions. The workshop will develop an agenda for motion sickness research in automated vehicles, facilitate new research ideas and fruitful collaborations.

CCS CONCEPTS

• **Human-centered computing → User studies**.

KEYWORDS

Motion Sickness; Comfort; Automated Vehicles; Mitigation; Detection

ACM Reference Format:
Katharina Margareta Theresa Pöhlmann, Gang Li, Abhraneil Dam, Yu-Kai Wang, Chun-Shu Wei, Adrian Brietzke, and Georgios Papaioannou . 2022. Workshop on Multimodal Motion Sickness Detection and Mitigation Methods for Car Journeys. In *14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '22 Adjunct), September 17–20, 2022, Seoul, Republic of Korea.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3544999.3550156

AutomotiveUI '22 Adjunct, September 17–20, 2022, Seoul, Republic of Korea

ACM ISBN 978-1-4503-9428-4/22/09.
https://doi.org/10.1145/3544999.3550156

1 INTRODUCTION

Vehicle occupants spend a significant amount of time travelling as occupants, commuting to and from work or for other social reasons. While travelling, occupants often engage in non-driving related tasks (NDRTs; e.g., reading, watching movies, working), which often results in the occurrence of motion sickness. Motion sickness comprises of a multitude of symptoms, such as, dizziness, sweating, headaches, drowsiness, nausea and in extreme cases vomiting [8] and once experienced, symptoms are slow to diminish and persist for the course of the journey. Even mild symptoms can have negative effects on occupants' ability to use their time during transportation to engage in NDRTs [3, 38, 39]. With the advent of automated vehicles (AV), drivers become occupants in AVs and the number of active drivers is decreased. By reducing motion sickness effects and occurrence, this paradigm shift in transport will enable occupants to utilise their travel time productively by engaging in NDRTs. Highlighting the need for increased research towards not only detecting motion sickness but also developing mitigation strategies to ensure a comfortable experience for AVs occupants. This research must be multi-disciplinary, spanning different research domains, as the problem is broad and complex.

This workshop will summarise the current state of motion sickness research in AVs. At the same time, it will pave the way for future research by establishing a multi-disciplinary motion-sickness community, bringing together researchers from Automotive,Neuroscience, Human-Computer-Interaction (HCI), Psychology and others.

Motion sickness is considered to be the result of a mismatch between information about self-motion as perceived by different sensory systems [29, 33, 34] as well as postural instability [10, 34, 35, 40]. For example, when reading a book in a moving vehicle, occupants receive information from the vestibular system informing them of being in motion, whereas the visual system sends information of them being stationary. Multiple measurements of motion sickness have been developed over the years, such as various subjective rating scales and questionnaires (e.g., MSAQ, SSQ, MISC, FMS, etc.) [4, 9, 11, 19, 20], as well as physiological measures that accompany the experience of motion sickness (e.g., heart rate variability, skin temperature, EEG, etc.) [6, 12, 13, 27, 28, 32, 41]. These can further serve as detection methods for motion sickness [23–25, 42][23, 24, 42], that can be employed to define effective mitigation methods, and eventually prevent the onset of motion sickness or reduce the severity of the already experienced symptoms.

Mitigation methods are generally either passenger- or vehicle-centric. Optimising the velocity or acceleration profile of the vehicle [16, 22], suspension optimisation [17, 30],optimising seat configurations [18, 31] are vehicle-centric attempts to mitigate motion sickness. At the same time, passenger-centric methods involve presenting additional sensory input (e.g., visual input through a virtual reality (VR) headset or a displays placed in the car interior) [5, 7, 26], or administering neurostimulation to the passenger (e.g. TMS, tES or tDCs[24]). The validation of both has been explored using different experimental setups. From motion platforms [21, 24] and simulators [2, 14, 37] to on road studies using the Wizard of Oz method [1, 5, 26, 36] or AVs [15].

2 WORKSHOP GOALS

This workshop will (1) emphasise the importance of motion sickness research for the future of AVs, (2) develop a community at the intersection of various domains that will accelerate our progress towards understanding and tackling the issue of motion sickness in AVs, and (3) through this community, build an agenda for research that fosters collaborations through sharing of knowledge and hardware/software resources (motion platforms, toolkits) further accelerating the progress in this important field. The organisers will bring together researchers and practitioners of the AutoUI community and beyond with a wide variety of backgrounds in the design of motion sickness detection and mitigation methods. They will also strongly encourage researchers from industry to share their work. First, the workshop organisers and participants will present their current research to build a foundation and common knowledge. These will then serve as the building blocks for future discussions on widely-used motion sickness measures, study designs, detection, and mitigation methods. The workshop discussions are expected to generate new research ideas, forge future collaborations and, ultimately pave the way for research techniques that could fully mitigate the issue of motion sickness in AVs. The workshop will also build the foundation for a shared review paper.

3 WORKSHOP OVERVIEW AND TENTATIVE SCHEDULE

This workshop will include pre-recorded video presentations by organisers introducing their current work that can be viewed prior to the workshop, two keynotes as well as group discussions. The workshop will last for 4 hours with a short break resulting in two *Sessions*. Participants will leave this workshop with new collaborators and research ideas to work on motion sickness mitigation in AVs. Attendees will have the opportunity to submit questions online via a Slack channel dedicated to the workshop. This channel will allow organisers and participants to discuss their work prior to and after the workshop further facilitating collaborations. Participants can present their own work by submitting short abstracts prior to the workshop with some of them being selected by organisers for presentation.

A main goal of the workshop is to discuss the current challenges of motion sickness research to date. To that end, participants will have the opportunity to submit their suggestions via Slack. Closer to the workshop date, they will be informed to vote on which challenges they want to be discussed at the workshop and which group discussion they want to attend. We are expecting around 30-40 participants to take part in this workshop.

3.1 Session 1

The workshop will start with a brief introduction of the organisers as well as its aims. Then, a Q&A session will follow, in which organisers will answer questions regarding their work and allow for an open discussion based on organisers' pre-recorded presentations. Participant presentations and short Q&A sessions will follow. The inclusion of both organiser and participant presentations will give a broader overview over the current research landscape, and motivate the engagement of the participants. After the presentations, a short overview of the current challenges selected for the group discussions will be given. This is done to give participants a final overview over the topics discussed in smaller groups in the second session and allows them to make their final decision regarding which group discussion they want to participate in. These topics could include but are not limited to:

(1) Advantages and disadvantages of measures and detection methods of motion sickness used in current research,
(2) Advantages and disadvantages of various study designs that are currently being applied (simulators, Wizard of Oz, VR,...),
(3) Advantages and disadvantages of currently employed mitigation methods for prevention, reduction and recovery of motion sickness,
(4) Passenger-centric vs. vehicle-centeric mitigation methods.

Session 1 will conclude with a short keynote by a leading researcher in the field (Assoc. Prof. Riender Happee). Between sessions there will be a 15 min break for participants and organisers to recuperate before the second session.

3.2 Session 2

The second session will focus on group activities to discuss the current challenges of motion sickness research and possible ways to overcoming these. Session 2 will start with a quick summary regarding Session 1 with the opportunity to ask any remaining questions. Afterwards, the groups will be formed to discuss the chosen topics. Each sub-group will focus on one of the research challenges identified prior to the workshop.

After participants have had a chance to debate the topics in their own sub-groups, the entire workshop group will come back together for a final discussion. Each sub-group will give a quick presentation about the outcome of their discussion (~ 5min each). A group discussion will summarise the outcomes of the workshop, the

Table 1: Workshop Timeline

Timeline		
Before Workshop	**First Session**	**Second Session**
Pre-recorded Presentation by organizers Introducing their Research	Introduction of Organizers (10min)	Recap of first Session (10min)
Submission of Short Abstracts of Participants to Present at the Workshop	Open Discussion and Q&A Session with Participants (30min)	Group Discussions of Research Challenges (40min)
Participant Introduction to Slack Groups	Pre-selected Participant Presentations (3 min presentation and 2 min Q&A; 30min in total)	Final Discussion in entire Group and Group Presentations (45min)
Submission of Discussion Topics "Crucial Challenges of Motion Sickness Research to Date" by Participants	Overview of the pre-selected Topics for the Group Discussions of Research Challenges (10 min)	Keynote (25min)
	Keynote (25min)	
	Break (15 min)	

current state-of-the-art, and the future of motion sickness research. The workshop will conclude with the last keynote by one of the leading motion sickness researchers (Dr Cyriel Diels).

4 WORKSHOP OUTCOMES

The organisers hope that this workshop will facilitate new fruitful collaborations between attendees, and will lead to new research ideas that will help advance motion sickness research. Our universal goal is to create a motion sickness free travel experience for occupants of AVs. Furthermore, we expect this workshop to serve as the basis for an overview paper on detection and mitigation methods for motion sickness in AVs focusing on prevention, reduction and recovery methods.

5 AUTHOR BIOGRAPHIES

Katharina Pöhlmann is a Post-doctoral Researcher in the School of Computing Science at the University of Glasgow (UofG) working on the ViAjeRo project (https://viajero-project.org/). She earned her PhD in Psychology at the University of Lincoln. Her research focuses on using VR as a tool for motion sickness mitigation in AVs focusing on multi sensory cue integration to mitigate motion sickness.

Gang Li is a Post-doctoral Researcher in the School of Psychology at the UofG also as part of the ViAjeRo project. He is committed to pioneering the integration of multimodal biosensing approaches with non-invasive brain stimulation techniques together to understand the neural mechanisms of VR-induced motion sickness so as to improve people's cognitive control abilities and improve the utility of consumer VR.

Abhraneil Dam is PhD student in the Grado Department of Industrial and Systems Engineering at Virginia Polytechnic Institute and State University in Blacksburg, VA. He is planning to conduct his dissertation work around the issue of motion sickness in occupants of AVs.

Yu-Kai Wang is currently a Senior Lecturer and core member of the Australia Artificial Intelligence Institute within the Faculty of Engineering and Information Technology at University of Technology Sydney, Australia. His current research interests include computational neuroscience, human performance modelling, Brain-Computer Interface and human-agent interaction.

Chun-Shu Wei is an assistant professor (Hwa Tse Roger Liang Junior Chair Professor) at National Yang Ming Chiao Tung University, Taiwan. He received his Ph.D. degree in Bioengineering from University of California San Diego, and worked as a Post-doctoral Researcher at Stanford University. His research interests include cognitive engineering, computational neuroscience, brain-computer interface, machine learning and biomedical data analysis.

Adrian Brietzke is a research engineer for interior and comfort. He studied Automotive Mechanical Engineering at UAS Ostfalia in Wolfsburg in cooperation with Volkswagen AG working on seating in terms of comfort and optimized climate functions. Further he is a PhD candidate with the topic of motion sickness in cars at the Technical University of Chemnitz in cooperation with Volkswagen AG.

Georgios Papaioannou is an Assistant Professor at TU Delft within the Intelligent Vehicles group. He received his Ph.D. degree from the National Technical University of Athens, Greece, in 2019 . His research interests include motion comfort, seat comfort, human body modelling, automated vehicles, optimisation and control.

ACKNOWLEDGMENTS

The opinions and conclusion of this announcement and the workshop are not necessarily those of the associated organisations.
This research is sponsored by European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 835197).

REFERENCES

[1] Juffrizal Bin Karjanto, Nidzamuddin Md. Yusof, Chow Wang, Frank Delbressine, Matthias Rauterberg, Jacques Terken, and Alberto Martini. 2017. Situation awareness and motion sickness in automated vehicle driving experience: a preliminary study of peripheral visual information. In *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct*. 57–61.
[2] Marten Bloch. 2018. *Alleviating motion sickness through presentations on interior panels of autonomous vehicles.* Master's thesis. University of Twente.
[3] JE Bos, MA Hogervorst, K Munnoch, and D Perrault. 2008. Human performance at sea assessed by dynamic visual acuity. In *ABCD Symposium'Human Performance*

in the Maritime Environment', 31 January 2008 Pacific 2008 International Maritime Conference, Sydney, Australia.

[4] Jelte E Bos, Scott N MacKinnon, and Anthony Patterson. 2005. Motion sickness symptoms in a ship motion simulator: effects of inside, outside, and no view. *Aviation, space, and environmental medicine* 76, 12 (2005), 1111–1118.

[5] Hyung-Jun Cho and Gerard J Kim. 2022. RideVR: Reducing Sickness for In-Car Virtual Reality by Mixed-in Presentation of Motion Flow Information. *IEEE Access* (2022).

[6] Patricia S Cowings, Steve Suter, William B Toscano, Joe Kamiya, and Karen Naifeh. 1986. General autonomic components of motion sickness. *Psychophysiology* 23, 5 (1986), 542–551.

[7] Ksander N de Winkel, Paolo Pretto, Suzanne AE Nooij, Iris Cohen, and Heinrich H Bülthoff. 2021. Efficacy of augmented visual environments for reducing sickness in autonomous vehicles. *Applied Ergonomics* 90 (2021), 103282.

[8] Cyriel Diels and Jelte E Bos. 2016. Self-driving carsickness. *Applied ergonomics* 53 (2016), 374–382.

[9] Peter J Gianaros, Eric R Muth, J Toby Mordkoff, Max E Levine, and Robert M Stern. 2001. A questionnaire for the assessment of the multiple dimensions of motion sickness. *Aviation, space, and environmental medicine* 72, 2 (2001), 115.

[10] JF Golding. 2016. Motion sickness. *Handbook of clinical neurology* 137 (2016), 371–390.

[11] John F Golding. 1998. Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. *Brain research bulletin* 47, 5 (1998), 507–516.

[12] Ashton Graybiel and James R Lackner. 1980. Evaluation of the relationship between motion sickness symptomatology and blood pressure, heart rate, and body temperature. *Aviation, space, and environmental medicine* (1980).

[13] Timotej Gruden, Nenad B Popović, Kristina Stojmenova, Grega Jakus, Nadica Miljković, Sašo Tomažič, and Jaka Sodnik. 2021. Electrogastrography in Autonomous Vehicles—An Objective Method for Assessment of Motion Sickness in Simulated Driving Environments. *Sensors* 21, 2 (2021), 550.

[14] Timotej Gruden, Nenad B Popović, Kristina Stojmenova, Grega Jakus, Nadica Miljković, Sašo Tomažič, and Jaka Sodnik. 2021. Electrogastrography in Autonomous Vehicles—An Objective Method for Assessment of Motion Sickness in Simulated Driving Environments. *Sensors* 21, 2 (2021), 550.

[15] Rebecca Hainich, Uwe Drewitz, Klas Ihme, Jan Lauermann, Mathias Niedling, and Michael Oehl. 2021. Evaluation of a Human–Machine Interface for Motion Sickness Mitigation Utilizing Anticipatory Ambient Light Cues in a Realistic Automated Driving Setting. *Information* 12, 4 (2021), 176.

[16] Zaw Htike, Georgios Papaioannou, Efstathios Siampis, Efstathios Velenis, and Stefano Longo. 2021. Fundamentals of motion planning for mitigating motion sickness in automated vehicles. *IEEE Transactions on Vehicular Technology* (2021).

[17] Matthias Jurisch, Christian Holzapfel, and Claudia Buck. 2020. The influence of active suspension systems on motion sickness of vehicle occupants. In *2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC)*. IEEE, 1–6.

[18] Kazuhito KATO, Kousuke SUZUKI, and Chikanori HONDA. 2021. Reduction of Carsickness using a Headrest with Support to Suppress Head Motion. *Comfort Congress*.

[19] Robert S Kennedy, Norman E Lane, Kevin S Berbaum, and Michael G Lilienthal. 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology* 3, 3 (1993), 203–220.

[20] Behrang Keshavarz and Heiko Hecht. 2011. Validating an efficient method to quantify motion sickness. *Human factors* 53, 4 (2011), 415–426.

[21] Ouren X Kuiper, Jelte E Bos, Cyriel Diels, and Eike A Schmidt. 2020. Knowing what's coming: Anticipatory audio cues can mitigate motion sickness. *Applied Ergonomics* 85 (2020), 103068.

[22] Scott Le Vine, Alireza Zolfaghari, and John Polak. 2015. Autonomous cars: The tension between occupant experience and intersection capacity. *Transportation Research Part C: Emerging Technologies* 52 (2015), 1–14.

[23] Gang Li, Mark McGill, Stephen Brewster, Chao Ping Chen, Joaquin Anguera, Adam Gazzaley, and Frank Pollick. 2021. Multimodal Biosensing for Vestibular Network-Based Cybersickness Detection. *IEEE Journal of Biomedical and Health Informatics* (2021).

[24] Gang Li, Francisco Macía Varela, Abdullah Habib, Qi Zhang, Mark McGill, Stephen Brewster, and Frank Pollick. 2020. Exploring the feasibility of mitigating VR-HMD-induced cybersickness using cathodal transcranial direct current stimulation. In *2020 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*. IEEE, 123–129.

[25] Chin-Ten Lin, Chun-Hsiang Chuang, Yu-Kai Wang, Shu-Fang Tsai, Te-Cheng Chiu, and Li-Wei Ko. 2012. Neurocognitive characteristics of the driver: A review on drowsiness, distraction, navigation, and motion sickness. *Journal of Neuroscience and Neuroengineering*, 61–81.

[26] Mark McGill, Alexander Ng, and Stephen Brewster. 2017. I am the passenger: how visual motion cues can influence sickness for in-car VR. In *Proceedings of the 2017 chi conference on human factors in computing systems*. 5655–5668.

[27] Igor B Mekjavic, Michael J Tipton, Mikael Gennser, and Ola Eiken. 2001. Motion sickness potentiates core cooling during immersion in humans. *The Journal of physiology* 535, 2 (2001), 619–623.

[28] Gerard Nobel, Ola Eiken, Arne Tribukait, Roger Kölegård, and Igor B Mekjavic. 2006. Motion sickness increases the risk of accidental hypothermia. *European journal of applied physiology* 98, 1 (2006), 48–55.

[29] Charles M Oman. 1990. Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian journal of physiology and pharmacology* 68, 2 (1990), 294–303.

[30] Georgios Papaioannou, Jenny Jerrelind, Lars Drugge, and Barys Shyrokau. 2021. Assessment of optimal passive suspensions regarding motion sickness mitigation in different road profiles and sitting conditions. In *2021 IEEE International Intelligent Transportation Systems Conference (ITSC)*. IEEE, 3896–3902.

[31] Georgios Papaioannou, Donghong Ning, Jenny Jerrelind, and Lars Drugge. 2022. A K-Seat-Based PID Controller for Active Seat Suspension to Enhance Motion Comfort. *SAE International Journal of Connected and Automated Vehicles* 5, 12-05-02-0016 (2022).

[32] Nenad B Popović, Nadica Miljković, Kristina Stojmenova, Grega Jakus, Milana Prodanov, and Jaka Sodnik. 2019. Lessons learned: gastric motility assessment during driving simulation. *Sensors* 19, 14 (2019), 3175.

[33] James T Reason. 1978. Motion sickness adaptation: a neural mismatch model. *Journal of the Royal Society of Medicine* 71, 11 (1978), 819–829.

[34] James T Reason and Joseph John Brand. 1975. *Motion sickness*. Academic press.

[35] Gary E Riccio and Thomas A Stoffregen. 1991. An ecological theory of motion sickness and postural instability. *Ecological psychology* 3, 3 (1991), 195–240.

[36] Spencer Salter, Cyriel Diels, Paul Herriotts, Stratis Kanarachos, and Doug Thake. 2019. Motion sickness in automated vehicles with forward and rearward facing seating orientations. *Applied ergonomics* 78 (2019), 54–61.

[37] Sarah'Atifah Saruchi, Mohd Hatta Mohammed Ariff, Hairi Zamzuri, Noor Hafizah Amer, Nurbaiti Wahid, Nurhaffizah Hassan, and Khairil Anwar Abu Kassim. 2020. Novel motion sickness minimization control via Fuzzy-PID controller for autonomous vehicle. *Applied Sciences* 10, 14 (2020), 4769.

[38] Joseph Smyth, Stewart Birrell, Alex Mouzakitis, and Paul Jennings. 2018. Motion sickness and human performance–exploring the impact of driving simulator user trials. In *International Conference on Applied Human Factors and Ergonomics*. Springer, 445–457.

[39] Joseph Smyth, Paul Jennings, Alex Mouzakitis, and Stewart Birrell. 2018. Too sick to drive: How motion sickness severity impacts human performance. In *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*. IEEE, 1787–1793.

[40] Thomas A Stoffregen and L James Smart Jr. 1998. Postural instability precedes motion sickness. *Brain research bulletin* 47, 5 (1998), 437–448.

[41] Chun-Shu Wei, Shang-Wen Chuang, Wan-Ru Wang, Li-Wei Ko, Tzyy-Ping Jung, and Chin-Teng Lin. 2011. Implementation of a motion sickness evaluation system based on EEG spectrum analysis. In *2011 IEEE International Symposium of Circuits and Systems (ISCAS)*. IEEE, 1081–1084.

[42] Chun-Shu Wei, Li-Wei Ko, Shang-Wen Chuang, Tzyy-Ping Jung, and Chin-Teng Lin. 2011. EEG-based evaluation system for motion sickness estimation. In *2011 5th International IEEE/EMBS Conference on Neural Engineering*. IEEE, 100–103.