Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

Non-driving related task engagement in highly automated vehicles: How to mitigate emerging motion sickness?

Claus Marberger [1*], Michael Schulz [2], Philipp Alt [2], Michaela Teicht [3], Arnd Engeln [3]

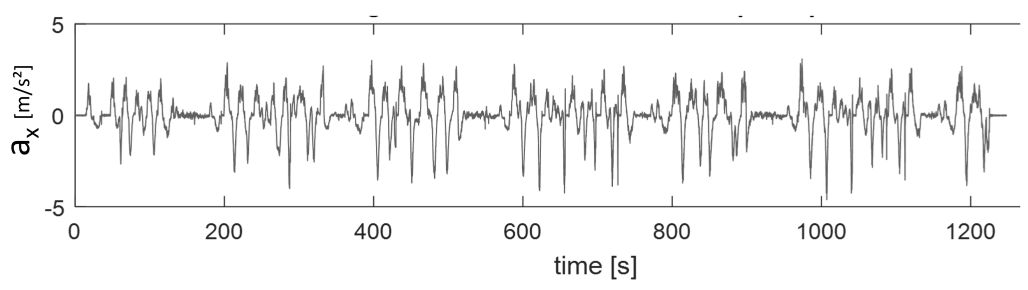
[1] Corporate Sector Research and Advance Engineering, Robert Bosch GmbH, Robert-Campus 1, 71272 Renningen, Germany
[2] Cross-Domain Computing Solutions, Robert Bosch GmbH, Robert-Allee 1, 74232 Abstatt, Germany
[3] Institute for Mobility and Digital Innovation, Hochschule der Medien, Nobelstr. 10, 70569 Stuttgart, Germany
[*] claus.marberger@de.bosch.com

1 | Introduction

- Passengers in highly automated vehicles may develop motion sickness when engaging in non-driving related tasks. What can we do about it?
- Published studies confirm effectiveness of selected countermeasures (e.g. Karjanto et al., 2018; Kuiper et al., 2020 or Bohrmann & Bengler, 2019) or indicate (unexpected) ineffectiveness of countermeasures (e.g. Golding et al., 2003)
- Objective of this study: Replication of existing findings and comparison of three countermeasures in terms of effectiveness to mitigate motion sickness in a highly controlled, yet realistic experimental setting

2 | Method

- N = 28 test participants (50/50 % female/male), aged between 23 and 47 years
- Pre-screened participants for increased susceptibility to motion sickness (mean susceptibility according to Golding (2006) representing the 75th percentile of population)
- Ride in automated vehicle on test track with highly reproducible fore-aft acceleration profile:



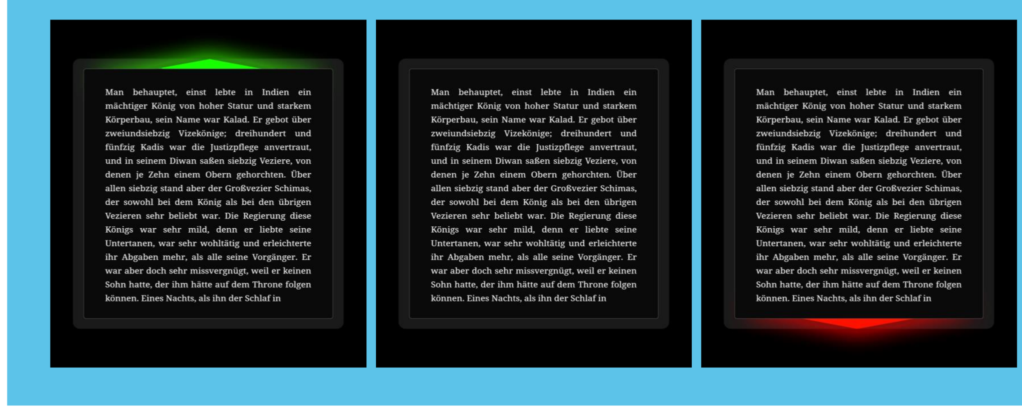
- Non-driving related task: Reading text on a handheld tablet
- Within-subject design with counterbalanced order of test conditions
- Independent variable: Type of countermeasure (see top right)
- Dependent variable: Differences between pre- and post-drive motion sickness scores measured by the Motion Sickness Assessment Questionnaire (MSAQ) according to Gianaros et al., 2001 (Delta MSAQ)

3 | Countermeasures

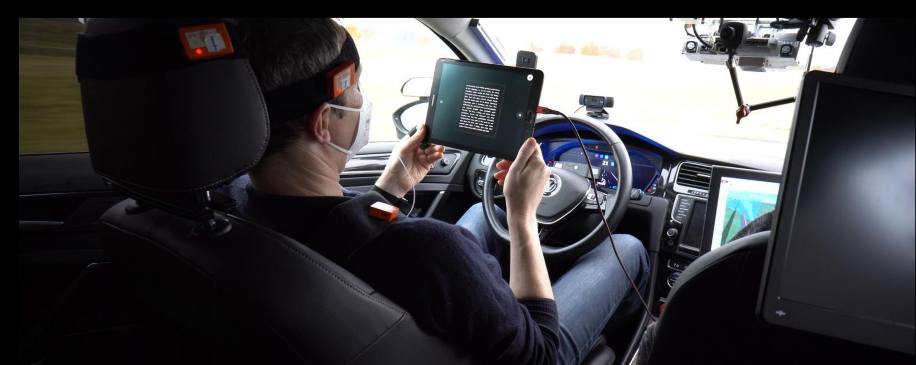
No countermeasure (control condition)

Dynamic seat adjustments (during accelerations)

Visual anticipatory cues (preview of 1.3 s)



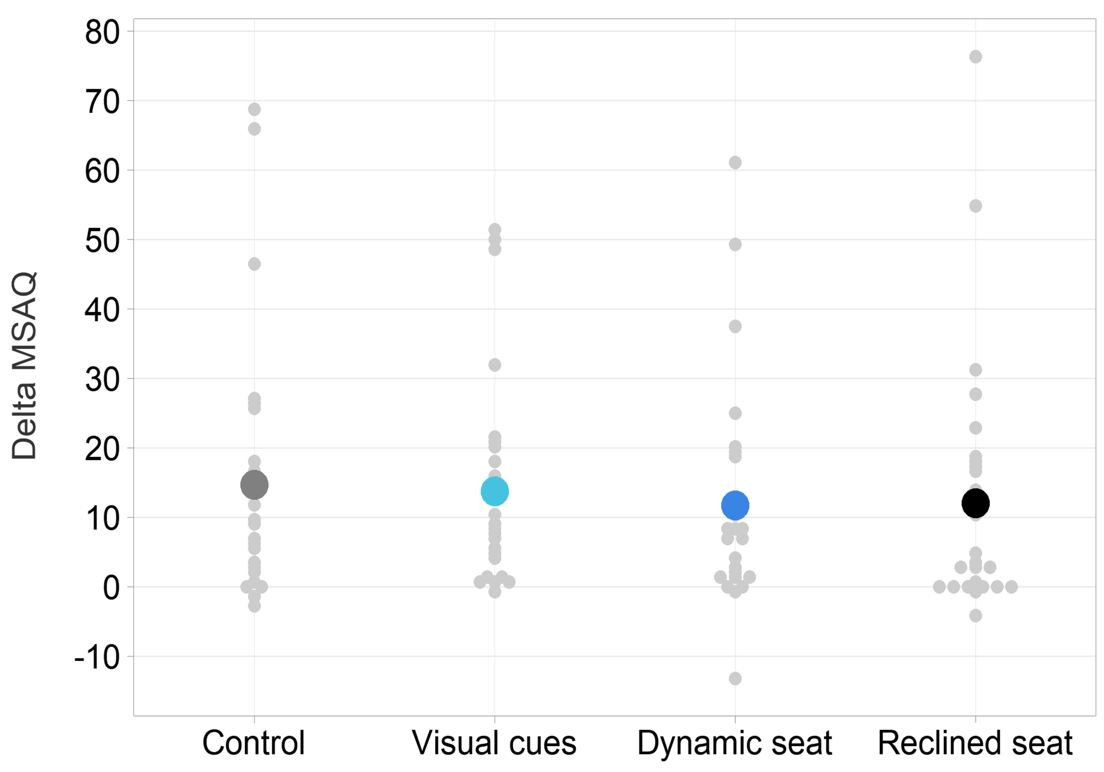
Reclined seating (increase of backrest angle by 15°)



4 | Results

General effects on motion sickness mitigation

- Distribution of individual Delta MSAQ scores (coloured circles indicate the mean value):



- No statistically significant differences in increase of MSAQ scores (Delta MSAQ) between test conditions ($\chi^2(3) = 4.79$, $p = 0.188$, $N = 28$)

Inter-individual differences

- Individual impact of countermeasures compared to the control condition (in terms of differences between Delta MSAQ scores):

ID	Visual cues	Dynamic seat	Reclined seat
1	-2.08	-4.86	-5.56
2	-0.69	0.00	0.00
3	-6.25	-5.56	-18.06
4	4.17	-9.72	-13.89
5	-17.36	-16.67	-34.72
6	10.42	13.89	6.25
7	-16.67	-6.94	-9.72
8	6.25	4.17	4.17
9	2.08	-2.78	-6.94
10	-1.39	-0.69	-2.08
11	2.78	0.00	0.00
12	-4.17	6.94	4.86
13	9.03	13.19	-2.78
14	-11.81	-38.89	-2.78
15	-8.33	-24.31	-8.33
16	20.14	-12.50	-11.81
17	-22.92	-14.58	-13.19
18	-2.08	5.56	-2.78
19	1.39	2.08	27.78
20	3.47	0.69	0.69
21	-17.36	-31.25	7.64
22	6.94	4.86	1.39
23	-5.56	-6.25	-6.25
24	10.42	0.69	-6.94
25	3.47	14.58	8.33
26	-0.69	15.97	7.64
27	6.25	0.69	0.00
28	3.47	9.72	2.08

- All countermeasures seem to mitigate motion sickness for some participants, but increase it for others compared to the control condition

5 | Discussion

- On average, no effect of any countermeasure: Study does not replicate effects from reference studies (see introduction):
  - Visual cues: inappropriate HMI modality?
  - Dynamic seat adjustment and reclined seating: inadequate implementation of countermeasure?
- Large interindividual differences in how participants respond to a countermeasure:
  - Personalized effectivity?
  - Impact of placebo effect?
  - Reliability of individual response?

Bohrmann, D., & Bengler, K. (2019). Reclined posture for enabling autonomous driving. In T. Ahram, W. Karwowski, S. Pickl, R. Taiar (eds), *Human Systems Engineering and Design II. IHSED 2019. Advances in Intelligent Systems and Computing, vol 1026* (pp. 169–175). Springer, Cham.
Gianaros, P. J., Muth, E. R., Mordkoff, J. T., Levine, M. E., & Stern, R. M. (2001). A questionnaire for the assessment of the multiple dimensions of motion sickness. *Aviation, space, and environmental medicine, 72*(2), 115–119.
Golding J. F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual differences, 41*(2), 237–248.
Golding, J. F., Bles, W., Bos, J. E., Haynes, T., & Gresty, M. A. (2003). Motion sickness and tilts of the inertial force environment: active suspension systems vs. active passengers. *Aviation, space, and environmental medicine*, *74*(3), 220-227.
Karjanto, J., Yusof, N. M., Wang, C., Terken, J., Delbressine, F., & Rauterberg, M. (2018). The effect of peripheral visual feedforward system in enhancing situation awareness and mitigating motion sickness in fully automated driving. *Transportation Research Part F: Traffic Psychology and Behaviour, 58*, 678–692.
Kuiper, O. X., Bos, J. E., Diels, C., & Schmidt, E. A. (2020). Knowing what's coming: Anticipatory audio cues can mitigate motion sickness. *Applied Ergonomics, 85*, 103068.