STILL FIT TO DRIVE? – HOW CAR SICKNESS AFFECTS TAKEOVER AND DRIVING PERFORMANCE

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Myriam Metzulat, Dr. Barbara Metz (Wuerzburg Institute for Traffic Sciences, WIVW)
& Prof. Dr. Wilfried Kunde (University of Wuerzburg)

INTRODUCTION

INTRODUCTION

BACKGROUND & RESEARCH QUESTION

- With increasing automation new driver states emerge that potentially distract from the driving task or impair driving performance

CAR SICKNESS

- In automated driving the driver becomes a passenger → risk of car sickness increases *(Diels & Bos, 2016)*
- Negative effects of motion sickness on cognitive performance
  - increased reaction times *(Bos, 2015, Smyth et al., 2019; Metzulat et al. 2024)*
  - impaired hand-arm *(Smyth et al., 2019)* and hand- eye coordination *(Metzulat et al., Preprint)*
  - reduced performance of perception *(*e.g., *Kaplan et al., 2017)* and visuo-spatial ability *(Metzulat et al., Preprint)*
- Possible cognitive impairments due to car sickness could be safety critical when taking over in complex situations (e.g. obstacle avoidance)
- No studies regarding car sickness and driving only on effects of simulator sickness on driving
  - prolonged braking reaction times *(Reinhard, Tutulmaz, et al., 2019)*
  - reduced average speed *(Gálvez-García et al., 2020; Reinhard, Kleer, et al., 2019)*

HOW DOES CAR SICKNESS AFFECT TAKEOVER AND SUBSEQUENT DRIVING PERFORMANCE?

METHOD

METHOD

STUDY DESIGN

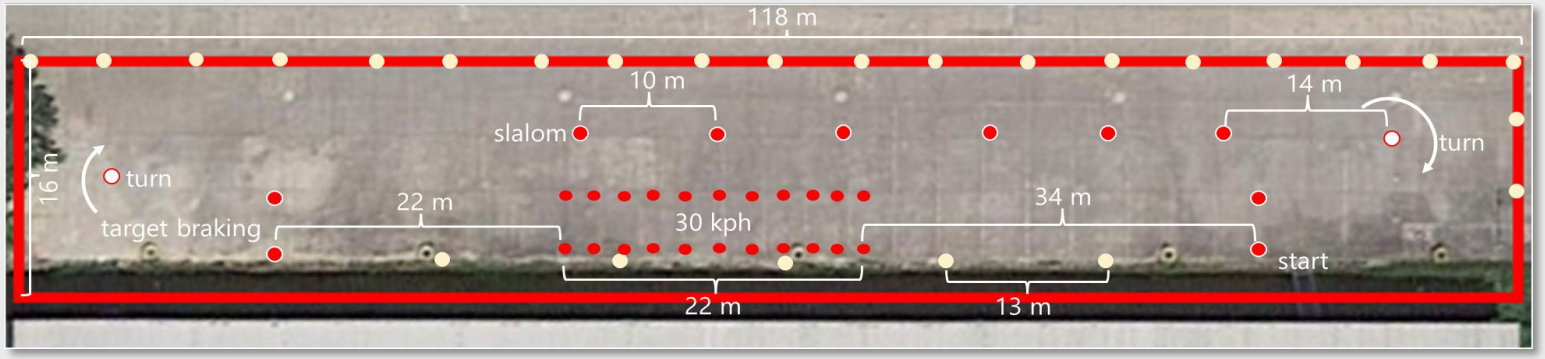
- With-in subject comparison: car sickness vs. baseline condition (without car sickness)
- 2 appointments for each condition with 4 rides and takeovers and 4 subsequent different driving tasks
- Sample:
  - N = 33 participants→ N = 66 sessions
  - Pre-screening and selecting according to subjective susceptibility to car sickness
  - n = 17 female, n = 16 male; mean age: 41.9 (SD = 15.5)

METHOD

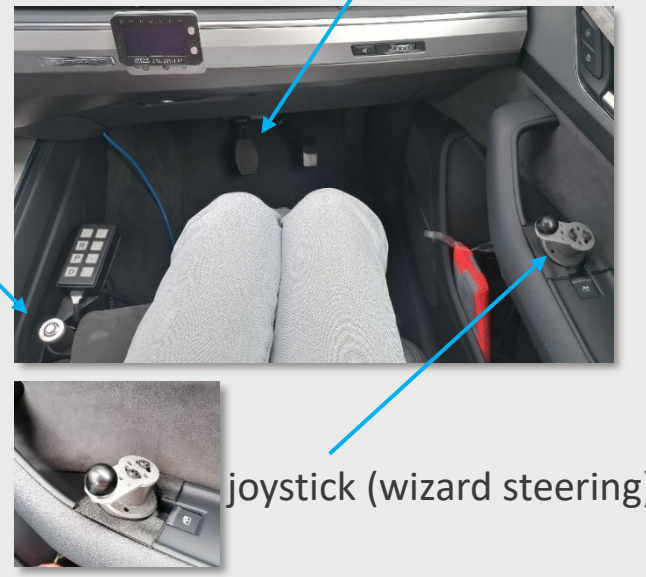
TEST SETTING

- Wizard-of-Oz vehicle: AUDI Q7
  - driving instructor's pedals on the front right hand side
  - joystick to steer the vehicle, mounted on the armrest in the door
  - participant on driver seat, experimenter on front passenger seat
  - wizard could trigger takeover request at any time

- closed-off area of the army base near WIVW
  (max. 30 kph)



Bird's eye view of the test track.



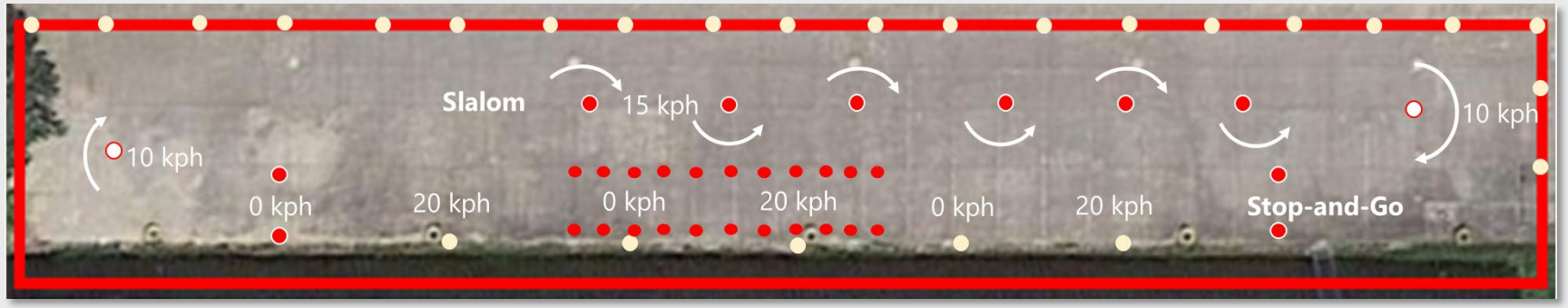
AUDI Q7

METHOD

STUDY DESIGN

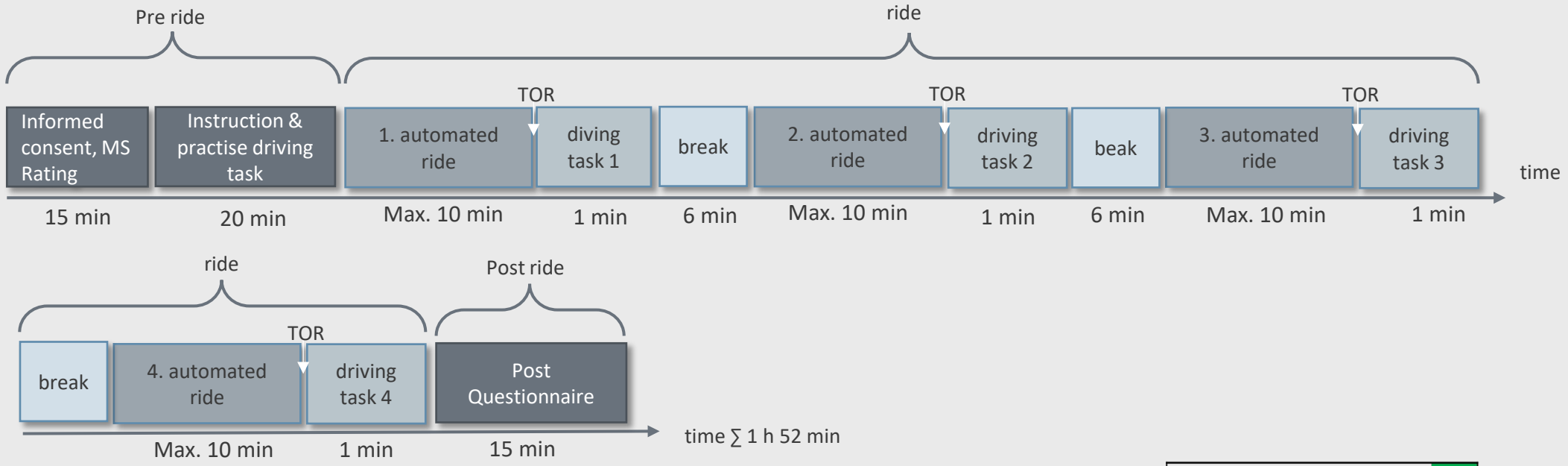
Car sickness condition	Baseline condition
▶ simulated automated ride by wizard ▶ dynamic driving manoeuvres: stop-and-go, turning and slalom ▶ non-driving related task: maze game ▶ TOR while being driven	▶ car was standing still ▶ non-driving related task: maze game ▶ wizard drove off few meters → TOR while being driven

▶ Equal number of participants started with baseline and car sickness condition



METHOD

PROCEDURE



- During automated ride motion sickness assessment every 30 s with Misery Scale (0 -10; MISC; Bos et al., 2005)
- Break to recover from car sickness between driving tasks
- Order of driving task randomized and balanced over participants

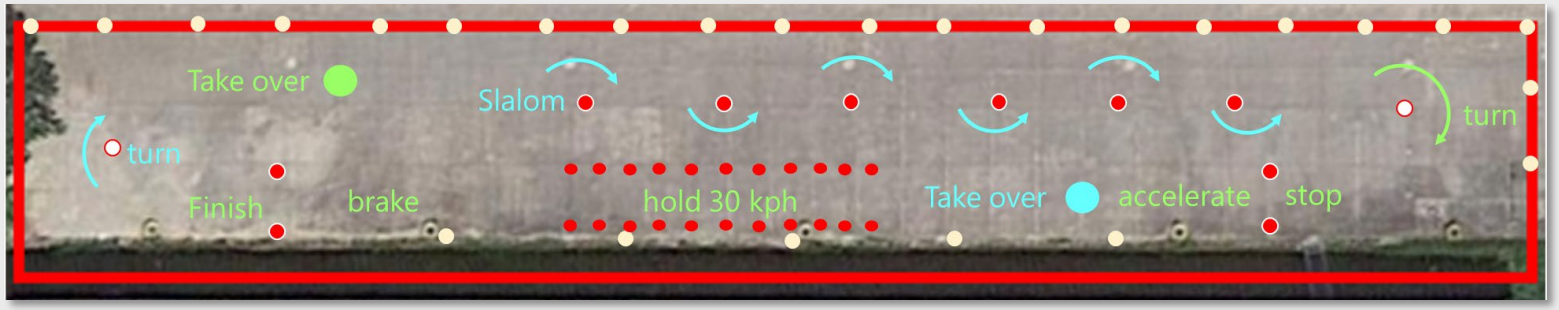
No problems		0
Some discomfort, but no specific symptoms		1
Discomfort with specific symptoms, but no nausea	vague	2
	little	3
	rather	4
(dizziness, cold/warm, headache, sweating, blurred vision, yawning, tiredness, burping, stomach/throat awareness...)	severe	5
nausea	little	6
	rather	7
	severe	8
	retching	9
vomiting		10

METHOD

TAKEOVER & DRIVING TASKS

- trigger of the takeover at certain car sickness level of 7 (MISC), if level is not reached within 10 min → takeover
- visual and acoustic signal “Please takeover” & countdown of 10 seconds
- participant had to confirm takeover with a button press for 2 seconds

Driving task	Instruction	Measure
Target braking	Accelerate to 30 kph, maintain 30kph, stop with exterior mirrors as close as possible to finish line	Distance to target position Speed + acceleration
Slalom 25 kph	1. With target speed of 25 kph	Number of hit cones Speed + acceleration
Slalom free	2. With freely chosen speed	
Emergency braking	Stop as quickly as possible when an acoustic warning is heard.	Reaction time, baking pressure



METHOD

MEASURES

Subjective Measures

- Fitness to drive (Woerle et al., 2023)
- Criticality of takeover and driving task (Neukum et al., 2003)
- Mental workload (NASA-TLX) and difficulty for driving task
- Subjective experience of driving

Car sickness

- Misery Scale (MISC; Bos et al., 2005)

Objective measures

- Takeover time (time until button press)
- Driving performance:
  - Behavioural data
  - Driving data

RESULTS

SUBJECTIVE MEASURES

CAR SICKNESS & FITNESS TO DRIVE

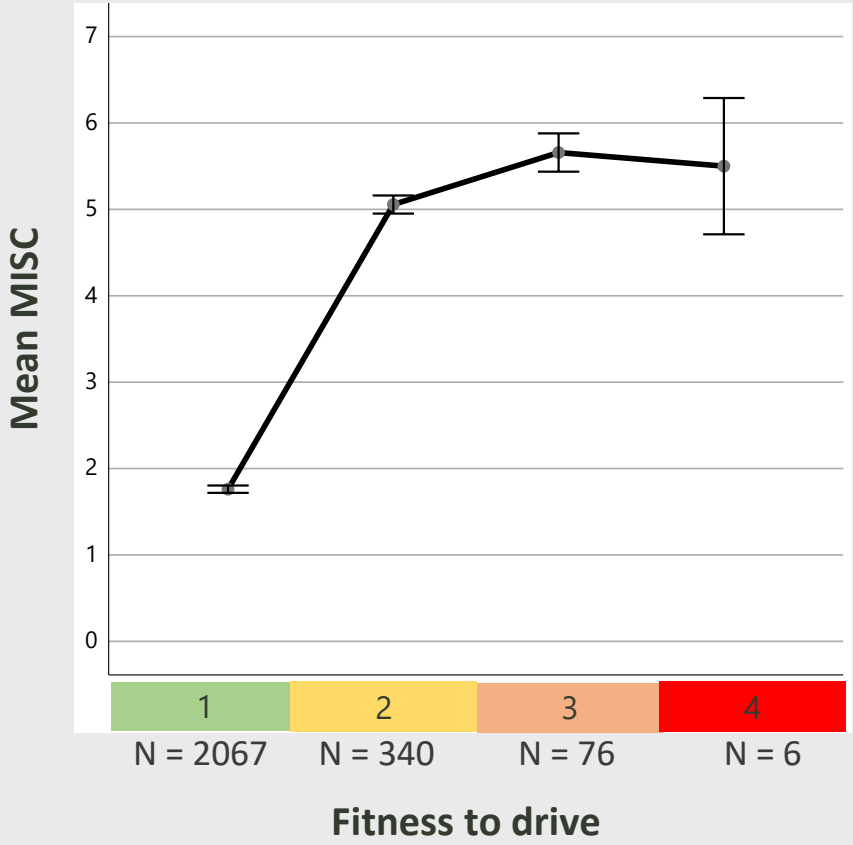
- In 79% of automated rides the takeover was triggered at a MISC-level of 6 or higher

There were significantly higher motion sickness ratings for lower levels of the subjective fitness to drive compared to unrestricted fit to drive.
[$F(3, 2485) = 365.866$, $p < .001$]

How do you rate your current fitness to drive?	
1	Unrestricted fit to drive
2	Rather fit to drive with slight impairments
3	Rather not fit to drive, major impairments
4	Absolutely unfit to drive

Woerle et al., 2023

The subjective fitness to drive decreased together with an increase of the subjective car sickness level.
[*rmCorr*elation(2455) = .601, $p < .001$]

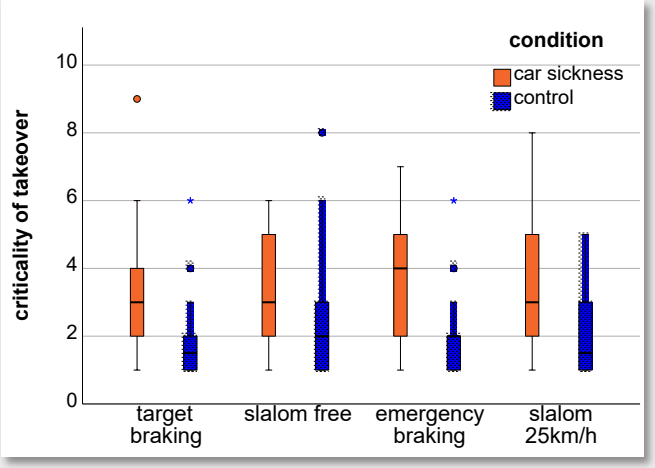


SUBJECTIVE MEASURES

CRITICALITY, MENTAL WORKLOAD, DIFFICULTY

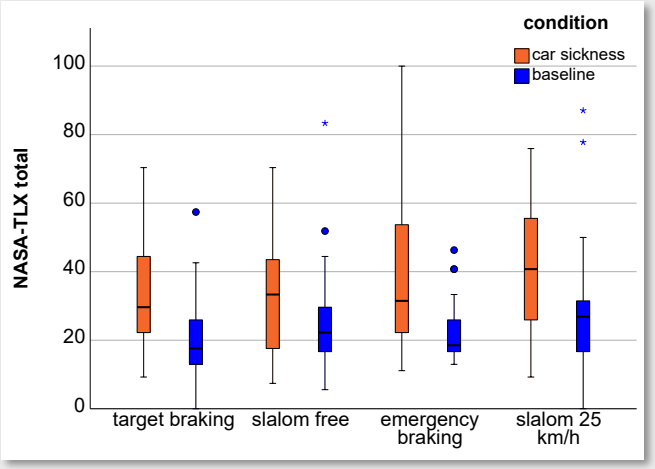
- The **criticality of takeover** was assessed **significantly higher** with car sickness than without over all 4 takeovers.
  [$F(1, 30) = 26.991$, $p < .001$]

- The **criticality of driving tasks** was assessed **significantly higher** with car sickness than without over all driving tasks.
  [$F(1, 30) = 19.115$, $p < .001$]



- The **mental workload** (NASA-TLX) was assessed **significantly higher** with car sickness than without over all driving tasks.
  [$F(1, 30) = 29.361$, $p < .001$]

- The **difficulty of driving task** was assessed **significantly higher** with car sickness than without over all driving tasks.
  [$F(1, 30) = 23.529$, $p < .001$]

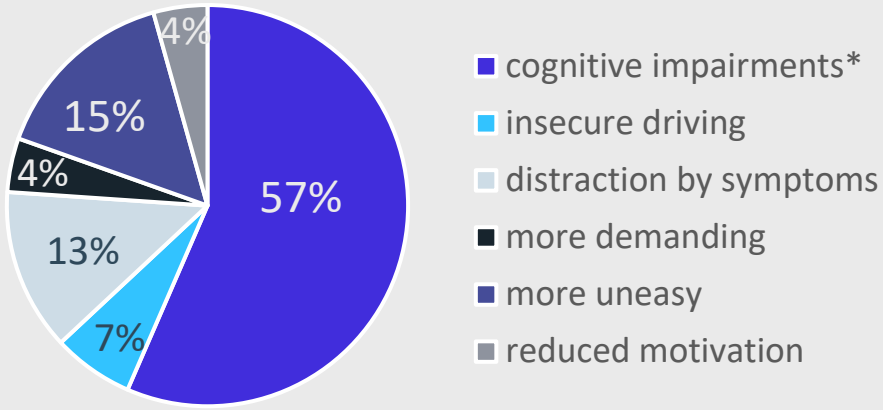


SUBJECTIVE MEASURES

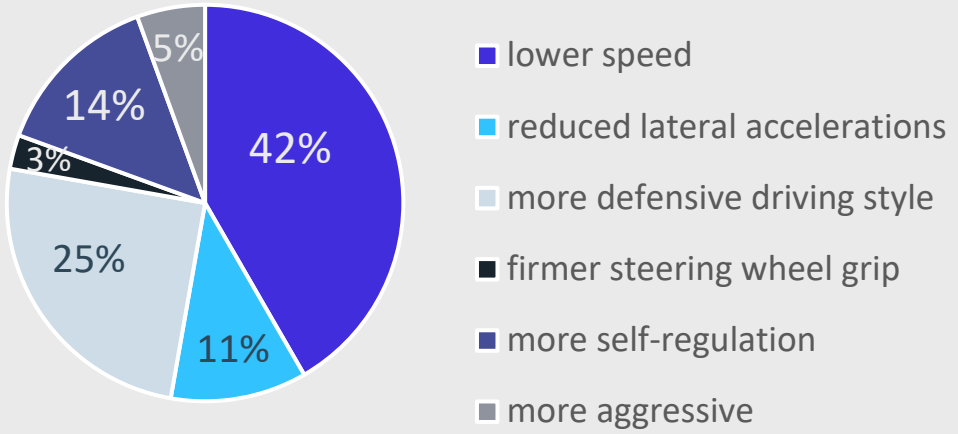
EXPERIENCE OF DRIVING

- 73% felt impaired through car sickness while driving
- 70% stated that they had changed or adapted their driving behavior due to car sickness

Impairments through car sickness



Adaptions due to car sickness



*reduced concentration, attention, orientation & perception, prolonged reaction

OBJECTIVE MEASURES

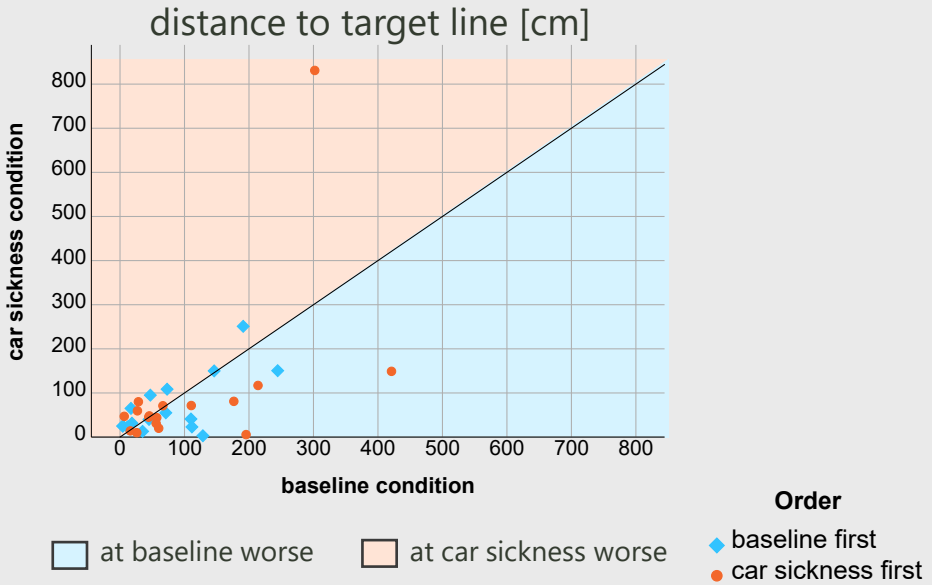
TAKEOVER TIME, BEHAVIOURAL PERFORMANCE DATA

Mean time [s] between TOR and action

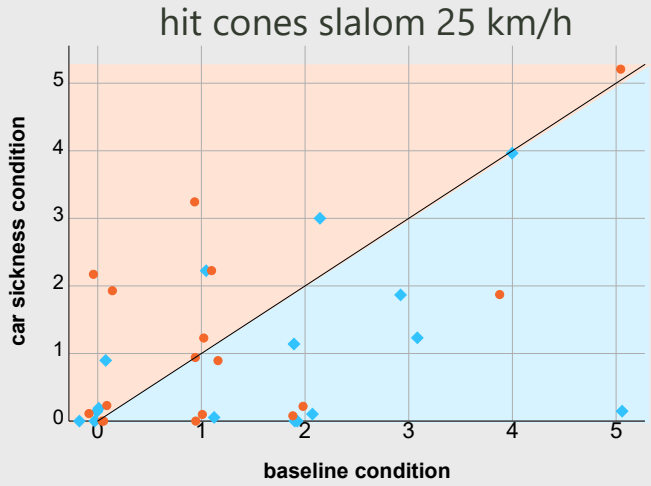
time

Action	Baseline		Car sickness	
	M	SD	M	SD
NDRT end	1.17	0.47	1.23	0.68
Takeover*	2.48	0.65	2.61	0.70
Eyes on road	4.12	1.67	4.31	1.67
Left hand	4.57	1.81	4.76	1.53
Right hand	7.81	8.23	7.71	7.82

*button press to confirm take over



- There is a tendency for the **takeover time** to be slightly slower with car sickness than without car sickness [$t(32) = -1.847$, $p = .074$, $d = 0.32$].
- **Target braking:** The distance to the target line did not differ between conditions [$z = 229.50$, $p = .362$].
- **Slaloms:** The number of hit cones did not differ between the conditions, neither at the freely chosen speed [$z = 88.50$, $p = .536$] nor at the target speed of 25 km/h [$z = 63.50$, $p = .112$].

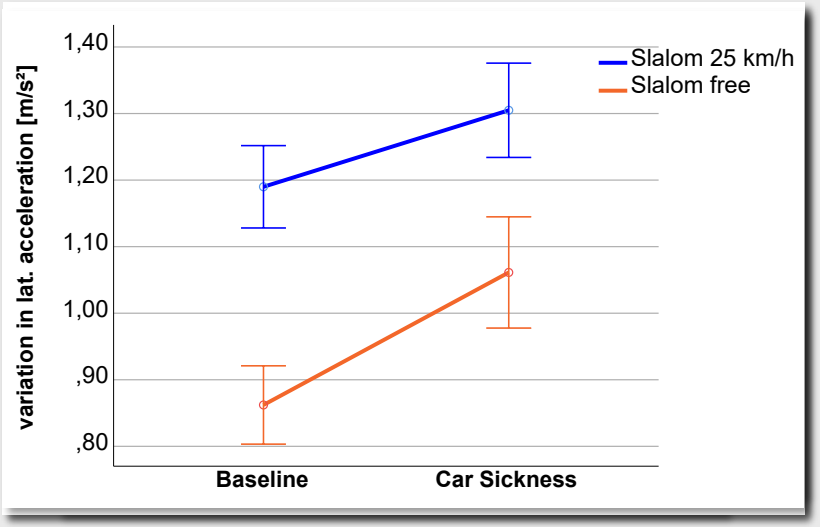


OBJECTIVE MEASURES

DRVING DATA

Braking tasks

Measure	Baseline M	Baseline SD	Car Sickness M	Car Sickness SD	N	t (df)	p
Emergency braking							
Reaction time (ms)	655	184	674	231	30	-1.047 (29)	.304
Max braking pressure	120.09	35.09	108.26	40.02	30	2.264 (29)	**.031**
Target braking							
Deviation to target speed	1.97	1.25	2.57	1.79	30	-1.576 (29)	.126
Max speed	31.76	1.54	32.35	2.09	30	-1.425 (29)	.165
Max braking pressure	28.77	19.73	26.01	13.57	29	0.651 (28)	.521



Slaloms

Measure	Condition F	Condition df	Condition p	Slalom F	Slalom df	Slalom p	Condition*Slalom F	Condition*Slalom df	Condition*Slalom p
Mean speed	3.838	(1,26)	.061	57.912	(1,26)	**<.001**	6.931	(1,26)	**.014**
Variation in speed (*SD*)	5.577	(1,26)	**.026**	22.487	(1,26)	**<.001**	0.044	(1,26)	.835
Max lat. Acceleration (*M*)	2.825	(1,28)	.104	42.361	(1,28)	**<.001**	7.857	(1,28)	**.009**
Variation lat. Acceleration (*SD*)	9.471	(1,28)	**.005**	20.590	(1,28)	**<.001**	0.962	(1,28)	.335

SUMMARY & DISCUSSION

SUMMARY & DISCUSSION

Subjectively, there is a **lower fitness to drive** and a **higher criticality**, **mental workload** and **difficulty** of takeover and driving with car sickness

- The majority of participants **felt impaired while** driving, e.g. **distracted** by symptoms or **reduced attention** and **concentration**, due to car sickness

- However, **objectively** there were **no safety critical performance impairments** of takeover and driving under the influence of car sickness, only a more dynamic driving style and slightly longer takeover times

→ partly contradictory to self-perception

objectively car sickness is not a critical driver state, but subjectively it is

- future studies to replicate results, e.g. with more realistic driving scenarios or sustained driving performance over longer period of time

THANK YOU

Contact:

Myriam Metzulat metzulat@wivw.de

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Hi-Drive
Designing Automation

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