



WHAT LEADS DRIVERS TO ILLICITLY NAP IN CONDITIONALLY AUTOMATED DRIVING?

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MOTIVATION

SLEEP AS A SIDE-EFFECT OF CONDITIONALLY AUTOMATED DRIVING?



- ▶ “semi-naturalistic” driving simulator study
 - ▶ Repeated usage of an automation driving system (ADS)
 - ▶ Between-factor of automation level: SAE L3 vs SAE L4

L3 function	L4 function
“[...] the driver may divert his attention from other traffic and control of the vehicle; he must, however, remain sufficiently alert that he can comply with the obligation [to take over control in response to a request to intervene]” (§1b, German Road Traffic Act)	[...] The driver is not responsible for the driving task. The driver is allowed to sleep.

- ▶ 14/30 participants actually slept during L3 (simulated) driving
- ▶ 15/30 participants stated that they would sleep during L3 driving in reality

What leads drivers to illicitly nap during conditionally automated driving?



THEORETICAL BACKGROUND

AUTOMATION: USE, MISUSE, DISUSE, ABUSE – AND DROWSINESS

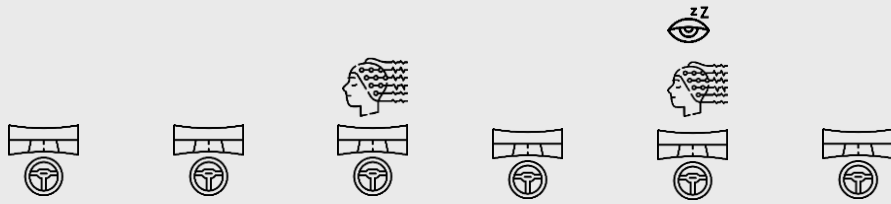
- ▶ **Misuse of automation** = overreliance on automation which results in wrong use of the system
 - ▶ Over-trust
 - ▶ High workload
 - ▶ Low (perceived) risk (Parasuraman & Riley, 1997)
- ▶ Wrong **mental model** of an automated driving system can lead to over-trust and automation misuse (Abraham et al., 2017; Seppelt & Victor, 2020)
- ▶ Automated driving contributes to the development of **drowsiness** (Neubauer, Matthews, & Saxby, 2014; Schömig et al., 2015; Vogelpohl et al., 2019)

Research questions

1. Are **over-trust**, **high workload** and **low perceived risk** associated with intention to sleep in L3 driving?
2. Is a **wrong mental model** associated with intention to sleep in L3 driving?
3. Is **automation-induced drowsiness** associated with intention to sleep in L3 driving?



METHOD



System usage (Silab®)

Eyetracking data (SmartEye®)

L3Pilot questionnaire (Metz et al., 2020)

+ additional items on mental model

Semi-structured interview on intention to sleep

DRIVING SIMULATOR STUDY

6 driving sessions with L3 ADS

2 with EEG measurement

1 after sleep deprivation

N = 30

POST-DRIVE QUESTIONNAIRE

After sixth drive

N = 30 (13 female, mean age = 37 years)

INTERVIEWS WITH SUBSAMPLE

After sixth drive

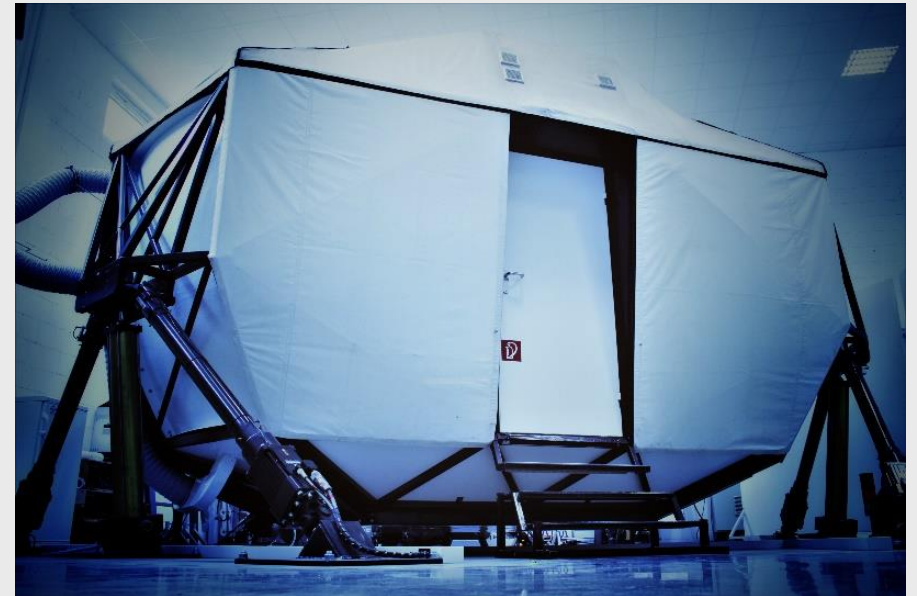
N = 22 (7 female, mean age = 41 years)



METHOD

BEHAVIOURAL MEASURES

- ▶ **System usage (%)**: proportion of time the system was activated
- ▶ **NDRA (%)**: proportion of driving with L3 ADS which was spend on non-driving related activities
- ▶ **PRC**: Percentage Road Center, proportion of time the participant's gaze was directed to the windshield (SmartEye®)
- ▶ **PerCLOS**: Percentage of eyelid closure, an eye-tracking based measure of driver drowsiness (Dinges & Grace, 1998; SmarteEye®)



High fidelity driving simulator



METHOD

QUESTIONNAIRE

- ▶ **Willingness to use:** “I would use this system if it was in my car.” (5 point)
- ▶ **Perceived safety:** “I felt safe when driving with the system active.” (5 point)
- ▶ **Workload:** “Driving with this system was demanding.” (5 point)
- ▶ **Trust:** “I trust the system to drive.” (5 point)
- ▶ **Comfort:** “Driving with the system active was comfortable.” (5 point)
- ▶ **Increased drowsiness:** “Driving with the function on long journeys would make me tired.” (5 point)
- ▶ **Safety during takeover:** “During the takeover I always felt safe.” (5 point)
- ▶ **Behavioural intention:** How frequently would you sleep if you had the system available in your car?
- ▶ **Mental Model:** “When I use the system, I am allowed to sleep.” (Correct – Not correct – I don’t know)

INTERVIEW

- ▶ Did you sleep during the study when the automated driving system was active? Did you want to sleep?
- ▶ If you could use such a system in real life, would you sleep while driving with the system?
- ▶ Is it possible to respond appropriately to a request to intervene when you are asleep?



RESULTS

OBSERVED BEHAVIOR, BEHAVIORAL INTENTION & MENTAL MODEL

- ▶ 78% of participants who slept during the study would sleep in reality
- ▶ 25% of participants who did not sleep during the study would sleep in reality

Behavioral intention	Mental model “When I use the system, I am allowed to sleep.”		
	Correct	Incorrect	I don’t know
Yes	2	10	3
No	0	15	0



RESULTS

INTENTION TO SLEEP

► Point-biserial correlations with variable “intention to sleep”

	r	T(27)	P-value
System usage	0.369	2.066	.049
NDRA engagement	0.432	2.492	.019
PRC	-0.363	-2.024	.053
PerCLOS	-0.140	-0.737	.467
Willingness to use	0.421	2.410	.023
Perceived safety	0.306	1.673	.106
Workload	-0.213	-1.130	.268
Trust	-0.129	-0.674	.506
Comfort	0.437	2.524	.018
Increased drowsiness	-0.031	-0.161	.873
Safety during takeover	0.492	2.934	.007



RESULTS

INTERVIEWS

- ▶ 7/22 participants would sleep during L3 ADS
- ▶ Some participants believe that sleep during an automated drive would make travelling easier and more comfortable
- ▶ Some participants would only sleep under certain conditions
 - ▶ Only on familiar routes
 - ▶ Only in low traffic scenarios
- ▶ Some participants want to observe the system at first and if it works as expected, they would feel comfortable to sleep
- ▶ All participants believe that it is not possible to respond appropriately to a request to intervene after sleep

"I would only [sleep] if there is not so much traffic."

"It's my personal free time in the car. At home, there are the children and in the car I could sleep."

"Time goes by faster and I can catch up on some sleep."

"If I gained some experience with the system and with the route. If I had driven the route X times and the system never asked me to take over."



DISCUSSION

- ▶ Half of the participants are willing to sleep during AD after experiencing simulated L3 ADS
 - Misuse of L3 (conditional) automation

- ▶ Intention to sleep due to....
 - ▶ Wrong mental model? → No. Most participants understand that sleeping is not allowed in L3 ADS

 - ▶ Over-trust? → No. Generally high trust levels. No relation with intention to sleep

 - ▶ High mental workload? → No. No relation between intention to sleep and workload during L3 ADS

 - ▶ Low perceived risk? → Yes. Perceived safety during takeover is a predictor for intention to sleep

 - ▶ Automation-induced drowsiness? → No. No relation between intention to sleep and subjective or objective drowsiness during L3 ADS



DISCUSSION

- ▶ High **usage** of the system, **engagement in NDRAs**, **willingness to use**, **comfort** and **subjective safety during takeover** associated with intention to sleep
- ▶ Interviews: Sleep on familiar routes and after reliable system functioning
- ▶ Automation complacency?
 - ▶ “psychological state characterized by a low index of suspicion” (Wiener, 1981)
 - ▶ Assumption that “all is well” (Parasuraman & Manzey, 2010)
- ▶ Three common features (Parasuraman & Manzey, 2010)
 1. Human operator monitoring of an automated system is involved
 2. Frequency of monitoring lower than optimal level
 3. Directly observable effects on system performance
- 1. Monitoring not required in L3 AD, but sufficient level of alertness
- 2. Sleep is not a sufficient level of alertness
- 3. Driver performance after sleep is impaired (Wörle, Metz, & Baumann, 2021)

Broader definition of automation complacency for conditionally automated systems necessary?



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THANK YOU!

