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Misuse or abuse of automation? Exploring drivers' intentions to nap during automated driving

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ABSTRACT

In a driving simulator study on behavioural adaptation to a level 3 automated driving system (ADS), half of the participants slept during the study. Sleep was found to impair driver's take-over performance and lead to critical situations in previous studies. That is why in a follow-up interview study, we tried to understand if and why users would show this potentially dangerous behaviour when using a level 3 ADS in reality. The majority of participants who stated their willingness to sleep during automated driving in reality had a correct mental model of the level 3 ADS and understood that sleep was not allowed. Participants with willingness to sleep had higher trust levels and showed more trust-related behaviours. They slept more frequently during the study and experienced more take-over situations after sleep which they solved with less errors than participants without the willingness to sleep. Semi-structured interviews on the willingness to sleep with a subsample revealed that most of the participants with the willingness to sleep would sleep only under certain circumstances and when they had gained some experience with the ADS. The findings suggest that after some experience with the ADS, drivers are at risk of becoming complacent and they might sleep. Vehicle designers must consider automation complacency in the design of automation designing for appropriate trust levels or by using driver monitoring systems to detect sleep onset.

1. Introduction

The automation of driving changes the role of the driver fundamentally. Cars with level 3 automated driving systems (ADS; SAE, 2021) recently received permission to drive on open roads and mark the next step in the automation of driving (Honda, 2020; Mercedes-Benz, 2021). In level 3 automated driving (AD), the system executes large parts of the driving task and the driver can withdraw from the driving task and engage in non-driving related activities. However, drivers are still required to take back vehicle control when the system issues a request to intervene, for example at system boundaries or system failures. Sleep is a driver state that is clearly outside the intended use of a level 3 ADS since it does prevent the driver from taking control back safely at all times if required by the system. For the presented analyses, data from a driving simulator study on the effects of repeated usage of an ADS is used. In that study, unexpectedly about 50 % of the sample experienced sleep during (simulated) AD. This observation triggered a more detailed investigation of why drivers might sleep while driving with a level 3 AD.

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1.1. Non-intended use of automated driving systems

Level 3 ADS are not commonly used by regular drivers in their daily lives yet and therefore no real-life data are available on the usage of level 3 ADS. Level 2 ADS are available for a few years now and their usage can be investigated. One particular phenomenon repeatedly makes the headlines: Videos show drivers who sleep behind the wheel of their level 2 cars on real roads (Robinson, 2020; Smith, 2016; Solon, 2018). Even though the authenticity of these videos is often not verified, interview studies confirm that behaviours other than the intended use of automated driving are shown frequently: In one study, 50 drivers who used a level 2 ADS for 12 months were queried about their usage of their ADS (Kim, Song, & Doerzaph, 2020). The study found that in 57 % of safety–critical events during ADS usage, drivers had misused the ADS, for example, by engaging in secondary tasks, using the system on roads other than highways or taking the hands off the wheel. The study also found that misuse of automation was related to a more positive attitude towards the ADS. In another interview study with 103 users of a level 2 ADS, 21 users stated that they manipulated their vehicle (e.g. by weighting the steering wheel or placing their knees on the steering wheel) to be able to take their hands off the wheel (Nordhoff et al., 2023). 48 users used the system under conditions it is not designed for and 15 users stated that they had their mind off or were fatigued while driving with the ADS. These two interview studies show that users of ADS are using their level 2 ADS in ways unintended by the designers which are potentially safety–critical.

However, some driver behaviours which can be considered misuse or abuse of a level 2 ADS would be considered regular use of a level 3 ADS. In level 3 automated driving, drivers are allowed to take their hands off the steering wheel and to be inattentive to a certain degree. They do not need to monitor the driving environment. However, some behaviours are clearly not allowed in level 3 automated driving: Even though the exact role of the driver in level 3 driving is debated, experts agree that the driver must have "a reasonable level of alertness and attentiveness" (Huysamen, Collins, & Wardle, 2021, p.13) and that the driver must remain in the driver's seat. We therefore conclude that activities that permanently impair the driver's alertness and attentiveness, such as heavy fatigue, intoxication and sleep are adverse behaviours and potentially misuse or abuse of automation.

1.2. Incorrect mental model of automated driving

The above cited interview studies show that some users deliberately use their ADS in ways the system is not designed for (Kim et al., 2020; Nordhoff et al., 2023). One possible explanation for the wrong use of automation is that users simply do not understand the functionality and limitations of the system (Parasuraman & Riley, 1997). Studies consistently show that factors not related to the actual system capabilities such as the brand name suggest functionalities that the ADS might not have: Brand names that include the word "Pilot" are associated with higher capabilities than for example brand names including the word "Cruise" while all systems being level 2 ADS (Abraham, Seppelt, Mehler, & Reimer, 2017). Users of ADS must have a correct understanding of the system's functionality and especially its limitations. The building of a correct mental model also depends on the introduction or description of the system: Beggiato and Krems (2013) found that an incorrect or incomplete system description led to a wrong initial mental model of an ACC. After three trials of system usage, the mental model shifted towards a more correct understanding. However, even after experiencing the system, some participants who received an incorrect or incomplete system description still had a wrong understanding. A correct mental model is associated with better performance in edge-case events when ACC systems reach their functional boundaries (Gaspar, Carney, & Shull, 2020).

1.3. Use, misuse, disuse and abuse of automation

Parasuraman and Riley (1997) collected evidence on the relationship between human and automation in their influential paper. They describe *use* as the "voluntary activation or disengagement of automation" (p. 230). The willingness to use automation depends on the perceived reliability of the automated system; humans tend to use reliable systems. The authors further state a reduction in mental workload, low cognitive overhead meaning the benefits of the automation being obvious to the user, trust and low perceived risk of usage as factors that promote the use of automation. Further, low self-confidence in one's own manual skills increases the use of automation. *Misuse* of automation means the uncritical reliance on automation without recognizing its limitations. *Misuse* of automation is associated with users' or operators' inadequate monitoring behaviour and the failure to detect system malfunctions. It is associated with critical incidents and accidents, for example, in flight operations. Overreliance on the automation, decision biases and a wrong mental model lead to misuse of automation. When automated systems are poorly designed, for example when they have a high rate of false alarms, users might not use them even though they might be beneficial in some situations. Parasuraman and Riley (1997) refer to this underutilization as *disuse* of automation. When automation is designed without regard for the consequences for the user, Parasuraman and Riley (1997) refer to *abuse* of automation. An ill-designed automated system can promote misuse and disuse of automation.

Sleeping in conditionally automated driving is a clearly safety critical behaviour. According to the definitions discussed above, sleeping can constitute a misuse of automation. A level 3 ADS has certain limitations in its functional scope. *DrivePilot*, for instance, a level 3 ADS introduced by Mercedes-Benz, operates on defined motorway segments in Germany and it covers speeds up to 60 km/h (Edward, 2021; Mercedes-Benz, 2021). Whenever the operating conditions are not met, for example when the defined motorway segment ends, the driver needs to take over vehicle control. When drivers wake up to a request to intervene from a longer nap, their behaviour can be impaired by sleep inertia which can lead to critical situations (Wörle, Metz, Othersen, & Baumann, 2020; Wörle, Metz, Steinborn, Huestegge, & Baumann, 2021). Experts agree that sleep cannot be allowed in level 3 automated driving (Huysamen et al., 2021). Sleep in level 3 AD can be considered a misuse of automation if drivers over-rely on the ADS and do not recognize its limitations. However, evidence suggests that the automation of the driving task can promote sleepiness in drivers and therefore increase the risk of involuntarily falling asleep (Schömig, Hargutt, Neukum, Petermann-Stock, & Othersen, 2015; Vogelpohl, Kühn, Hummel, & Vollrath, 2019). Therefore, sleep could as well be considered an abuse of automation. In the following section, empirical evidence on sleep in automated driving as well as other forms of undesirable user behaviour related to automated driving will be discussed.

1.4. Sleep as a by-product of automation

One irony of automation is that easy tasks are easier to automate which often leaves the more complex tasks to the human operator (Bainbridge, 1983). In the case of automated driving, ADS are often able to execute the driving task under very controlled circumstances, for example, at low speeds on motorways with clear lane markings. When approaching more demanding environments such as urban traffic or adverse weather conditions, the human driver is required to take over. The driver's role shifts from driving to remaining available as a fall-back option as soon as the automation is activated. Evidence suggests that drivers become fatigued due to monotony and boredom in AD: Drivers become fatigued faster and reach higher levels of fatigue in automated driving compared to manual driving. These findings can be observed in simulated environments (Vogelpohl et al., 2019) as well as in real-world settings (Ahlström et al., 2021; Kundinger, Riener, Sofra, & Weigl, 2020). In an early study on driver behaviour when using an ADS, 8 out of 30 drivers fell asleep while using a level 3 ADS on a test track (Omae, Hashimoto, Sugamoto, & Shimizu, 2004). In level 3 automated driving, however, the option to engage in secondary tasks can counteract the development of drowsiness (Naujoks, Höfling, Purucker, & Zeeb, 2018; Schömig et al., 2015). Empirical evidence is mixed on whether drowsiness affects take-over performance at system boundaries: While some studies show a detrimental effect of fatigue (Kreuzmair, Gold, & Meyer, 2017) and sleepiness on take-over performance (Vogelpohl et al., 2019), other studies did not find any effect of fatigue on take-over performance (Feldhütter, Gold, Schneider, & Bengler, 2017). The same is true for the effects of sleep on take-over performance: Short naps did not have any effect on take-over performance or driving performance in one study (Hirsch, Diederichs, Widlroither, Graf, & Bischoff, 2020). Awakenings from stable sleep (N2 according to AASM, 2017) however, caused considerable performance impairments in take-over scenarios (Wörle, Metz, & Baumann, 2021; Wörle et al., 2020) and manual driving performance (Wörle, Metz, Steinborn, et al., 2021). It is generally agreed upon that sleep is not a safe driver state in level 3 AD while it might be allowed in level 4 AD (Ahlström, Wörle, Ljung Aust, & Diederichs, 2023; Huysamen et al., 2021; SAE, 2021).

1.5. Scope of the presented analyses

Taking together the evidence on misuse and abuse of level 2 ADS and the occurrence of fatigue and sleep in AD, several factors could serve as an explanation for the occurrence of sleep in the presented driving simulator study. Based on the literature, there are several explanations of why drivers might sleep while driving with a level 3 ADS:

- One explanation could be that drivers are not aware that sleep is not allowed while driving with the system active. In this case, drivers would have an incorrect mental model, assuming that sleeping while using the ADS is an intended way of system usage.
- One explanation could be that drivers fall asleep involuntarily when they are fatigued while driving with the ADS active.
- One explanation could be that drivers sleep deliberately although they know that it is not allowed.

In the presented analyses, questionnaire data, indicators of system handling and interview data are analysed with the aim to answer the research question: What factors are associated with drivers' willingness to sleep during level 3 automated driving and how does that change with repeated experience of AD?

2. Methods

2.1. Experimental procedure

A *driving simulator study* was conducted as part of the L3Pilot project (www.l3pilot.eu) with the primary aim to investigate behavioural adaptation to ADS with repeated usage of automation (for a detailed description of the general study setup, please refer to Wörle, Metz, Steinborn, et al., 2021; Metz, Wörle, Zerbe, et al., 2021). The used driving simulator consists of a production type BMW 520i. The motion system uses six degrees of freedom and can display linear acceleration up to 5 m/s^2. Three LCD projectors provide a 240° screen image. The simulator runs with the simulation software SILAB®.

It was hypothesized that drivers change their behaviour when they use an ADS repeatedly, for example, when they gain more trust in the system. All participants experienced six drives with the ADS that had a duration between 30 and 90 min. During the drives, 2–5 take-over situations were issued due to system boundaries (for example due to a construction site, heavy rain, the motorway exit). All participants completed a pre-drive questionnaire before the first test drive and an extensive post-drive questionnaire that covered issues such as willingness to use, acceptance and trust of AD after each of the test drives (for the full questionnaire, please refer to Metz et al., 2020).

The automation level was used as a between-subjects factor: Half of the sample used a level 3 ADS and the other half a level 4 ADS (SAE, 2021). The presented results are based on $N = 30$ participants using a level 3 ADS. All participants were instructed to use the ADS as they would use it in reality. During each drive, participants experienced system boundaries and requests to intervene with a takeover time budget of 15 s.

Participants who used the level 3 ADS were instructed that they could engage in other activities during the drive as long as they were always able to take back the driving task and that in case of a request to intervene, they were responsible for the safety of the driving task. Participants were instructed with the wording of §1b of the German Road Traffic Act, which specifies the responsibilities of the driver when using an ADS:

"[…] 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 retake control in response to a request to intervene]"

Two drives were specifically designed to provoke fatigue by being dull and monotonous (with, e.g., low traffic volume and restricted view due to fog) and in one of those two drives, participants were allowed a maximum of 4 h of sleep in the night before the drive and the test drive started at 6 a.m. to increase the sleep propensity. The order of those two drives was balanced over the sample. The aim was to investigate driver behaviour when using an ADS in the state of fatigue.

We expected that some participants who used the level 4 ADS might use their driving time to sleep, but we did not expect this behaviour in the level 3 ADS condition. However, after we observed participants falling asleep during level 3 AD, we designed an interview guideline on sleep during AD and conducted an *interview study* with a subsample. The full interview guideline is shown in the Annex.

2.2. Data collection and analysis

After each drive, participants completed a short version of the common questionnaire developed in the L3Pilot project (Metz et al., 2020), which included questions on trust and attitudes towards level 3 ADS, willingness to use and mobility-related questions. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). Questions on the mental model of level 3 ADS were added specifically for this study. The post-drive questionnaire was answered after every drive. In the following analysis, data from first contact (after 1st drive) and with experience (after 6th drive) are used. Six items are included in the presented analyses:

- **Willingness to use**: "I would use this system if it was in my car."
- **Perceived safety**: "I felt safe when driving with the system active."
- **Workload**: "Driving with this system was demanding."
- **Trust**: "I trust the system to drive."
- **Comfort**: "Driving with the system active was comfortable."
- **Increased drowsiness**: "Driving with the function on long journeys would make me tired."

In the post-drive questionnaire, participants were asked how frequently they would perform certain non-driving related activities while using a level 3 ADS in reality. The scale ranged from 1 (never) to 6 (very frequently). One of these items was used to assess the willingness to sleep:

- **Willingness to sleep**: "Imagine your vehicle was equipped with the function you experienced today, how often would you engage in the following activities while the system is active? - Sleeping"

Based on the questionnaire after the 1st drive, participants were split into those who stated that they would "never sleep" while driving with AD (no willingness to sleep) and those who would do this at least "very infrequently" (willingness to sleep). For one participant, the data from this questionnaire was missing. This participant was assigned based on the expressed willingness to sleep from the questionnaire after the 6th drive. Those two groups were compared with regard to their behaviour while using the system and with regard to their evaluation of AD.

Additionally, the driver's understanding or mental model of the level 3 ADS was assessed in the post-drive questionnaire. Statements about the ADS were presented to the participants with the response options "correct", "incorrect" and "I don't know". One item was used to measure the mental model regarding sleep as a use case:

- **Mental model**: "During the automated journey, I am allowed to sleep".

Eye-tracking parameters were measured using a SmartEye® four-camera system throughout all drives. Two indicators were included in the analyses:

- **PRC**: Percentage Road Centre, percentage of time the participant's gaze was directed to the windscreen
- **PerCLOS**: Percentage of eyelid closure, an eye-tracking based measure of driver drowsiness (Dinges & Grace, 1998)

Driving and system parameters were recorded using SILAB®. Participants were free to activate and deactivate the system. System availability was indicated by an icon in the instrument cluster. One indicator was derived from the recorded system parameters:

- **System usage (%)**: percentage of driving time the system was activated

The engagement in non-driving related activities (NDRAs) was manually coded based on video recordings of all drives:

- **NDRA (%)**: percentage of driving time with ADS which was spend on non-driving related activities

To objectively assess sleep while driving, the EEG was measured during both monotonous drives. For those drives, sleep stages were coded according to the American Academy of Sleep Medicine standard (AASM, 2017) based on EEG. Sleep stages “wakefuleness” (W), “light sleep” (N1), “stable sleep” (N2), “deep sleep” (N3) and “REM sleep” (R) were coded.

- **Sleep** during the two monotonous drives: Sleep stages N1, N2, N3 and R were summarized as “sleep”

During the drive with sleep deprivation, up to three requests to intervene occurred: One due to roadworks (“Roadworks), on due to heavy rain that led to a section where AD was not available (“Rain”) and one prior to the exit at the end of the drive (“Exit”). For those takeover situations, the two groups were compared with regard to their driver state at the time the request to intervene was issued (awake vs. sleep), with regard to their immediate evaluation of the criticality of the experienced situation (Neukum & Krüger, 2003) and with regard to their take-over performance assessed with the video-based take-over controllability (TOC) rating (Naujoks, Wiedemann, Schömig, Jarosch, & Gold, 2018). Both, the subjectively experienced criticality as well as the observer rated take-over performance are grouped into five categories (as shown in Fig. 1).

For behavioural parameters and questionnaire data, non-parametric Mann-Whitney-U tests are performed to compare the two groups with and without willingness to sleep. This is done separately for the 1st and the 6th drive.

2.3. Sample

N = 31 participants (13 female, mean age = 37, SD = 12) took part in the *simulator study*. The data of one participant were excluded from the analyses due to data loss, resulting in a final sample of N = 30 participants. The *interview study* was conducted with a subsample of 22 participants (7 female, mean age = 41, SD = 12). All participants held a valid driving licence and had completed an extensive driving simulator training.

3. Results

3.1. Willingness to sleep and sleep during the study

17/30 participants stated after the 1st drive that they would sleep at least very infrequently if they had level 3 ADS in their car (Willingness to sleep). The willingness to sleep remained significantly stable over time ($\chi2(df = 1) = 11.0$, $p < 0.001$, see Table 1). After the 6th drive and after having experienced two fatigue-inducing drives, there were still 15/30 participants who stated in the post-drive questionnaire that they would sleep at least very infrequently with the ADS active.

Fig. 1. Subjective criticality rating scale (left) and rating sheet for the TOC-rating showing the detailed error categories (right).

Table 1
Number of participants expressing willingness to sleep after 1st contact and after 6th drive.

		Willingness to sleep – 1st drive		Sum
		No	Yes	
Willingness to sleep (6th drive)	No	11	4	15
	Yes	2	13	15
Sum		13	17	30

14/30 participants experienced EEG-verified sleep according to the AASM criteria at least once. Those who stated that they would sleep in reality, slept significantly more often at least once during the two monotonous drives ($\chi 2(df = 1) = 9.02$, $p < 0.01$, see Table 2).

Those willing to sleep did not only sleep more frequently; in the drive with sleep deprivation (fatigued) they also spent a higher proportion of driving time sleeping (Mann-Whitney-U: $Z_{corr} = -2.83$, $p_{corr} < 0.01$, see Fig. 2). Participants with willingness to sleep in real driving spent a median driving time of 20 % sleeping while participants with no willingness to sleep in real driving spent a median driving time of 5 % sleeping. During the monotonous drive without sleep deprivation (monoton), there was no difference between the two groups.

3.2. *Willingness to sleep and mental model*

One possible explanation for the willingness to sleep in level 3 AD could be that drivers are not aware that sleep is not a use case for level 3 AD. Therefor we compared the mental model with regard to sleep for drivers with willingness to sleep and drivers with no willingness to sleep. After the 1st drive the two groups did not differ significantly with regard to the their mental model regarding

Table 2
Number of participants expressing willingness to sleep in reality and participants who slept during the study.

	Willingness to sleep – 1st drive		Sum	
	No		Yes	
Sleep during study	No	11	5	16
	Yes	2	12	14
Sum	13	17	30	

Table 3
Relation between willingness to sleep and mental model with regard to sleep after the 1st and after the 6th drive.

	Willingness to sleep	Mental Model – Sleep allowed			Sum
		Don't know	No	Yes	
1st drive	No	1	11	0	12
	Yes	3	11	3	17
	Sum	4	22	3	29
6th drive	No	0	13	0	13
	Yes	3	11	2	16
	Sum	3	24	2	29

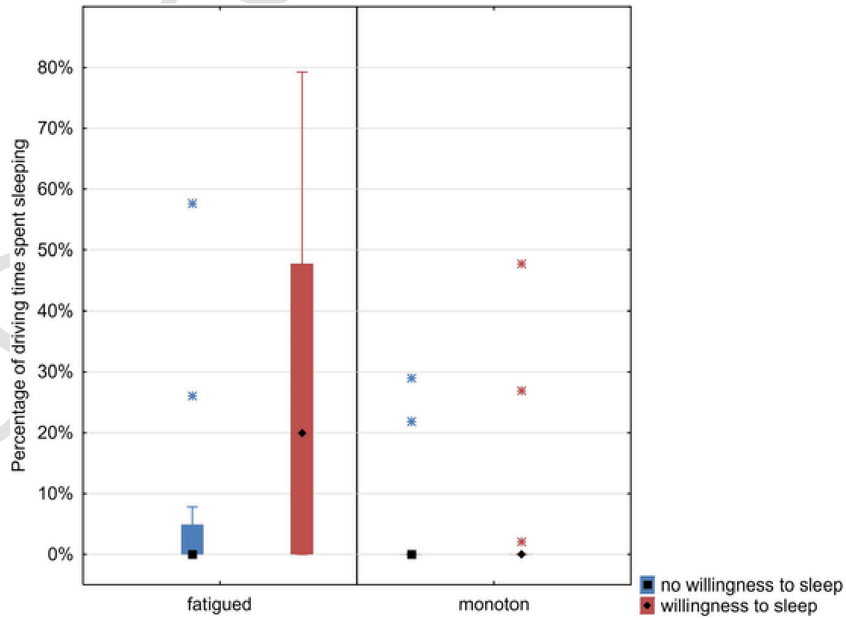

Fig. 2. Proportion of driving time spent sleeping during the monotonous drive (monoton) and during the monotonous drive under sleep deprivation (fatigued). The figure shows the median, 25%-75% interval, the area without outliers and the outliers.

sleep in level 3 AD, but descriptively it seems that participants with willingness to sleep agreed more to the statement that sleep is allowed. After the 6th drive, there is a tendency that participants who expressed their willingness to sleep stated more frequently that sleep during AD is allowed or were not sure about the correct answer ($\chi2(df = 2) = 4.91$, $p = 0.086$, Table 3).

3.3. Willingness to sleep and system handling and evaluation

Drivers who are willing to sleep while driving with ADS showed a higher acceptance for the system (see Fig. 3). After the 1st drive, they agreed more with the statement that the system worked as it should, expressed less the need to monitor the system during driving and stated a higher perceived safety. This resulted in a tendency for higher trust in the ADS. After the 6th drive, they still agreed more with the statement that the system worked as it should, expressed less the need to monitor the system during driving and showed higher trust compared to those who wouldn't sleep. The two groups did not differ in their agreement with the statement that driving with a level 3 ADS leads to fatigue.

The differences in evaluation of the ADS were reflected in the actual handling of the ADS during the drives. Participants who are willing to sleep used the ADS during a higher proportion of time it was available. During the 1st drive, this group spent more time on non-driving related activities and monitored the driving environment less. The difference in the distribution of attention can still be found during the 6th drive. The difference between the two groups in the proportion of time spent on non-driving related activities was reduced in the 6th drive because then, also the group without willingness to sleep spent more time on non-driving related activities, reaching a similar level as the other group already had during the 1st drive (see Table 4). The two groups did not differ in PerCLOS which is a direct behavioural measure of fatigue.

3.4. Willingness to sleep and takeovers

For the analyses on the relationship between willingness to sleep and take-over performance and subjective experience, only the fatigued drive was considered since the frequency of sleep events was the highest in this drive. Participants who expressed their willingness to sleep, received significantly more requests to intervene while being asleep ($\chi2(df = 7) = 21.3$, $p < 0.01$). This is not surprising because participants with the willingness to sleep in reality also spent more time sleeping during the experimental drives (see Fig. 2). As can be seen in Table 5, this is due to more requests to intervene while being asleep in the Rain scenario and prior to the Exit scenario.

For the Exit scenario, the frequencies of categories for self-reported criticality and for observer-rated take-over performance were not significantly impacted by willingness to sleep or by the driver state at the time of the request to intervene. However, in the Rain scenario, there was a significant impact of willingness to sleep and driver state on subjective criticality ($\chi2(df = 4) = 12.86$, $p < 0.05$; Table 6) and on take-over performance ($\chi2(df = 4) = 12.04$, $p < 0.05$; Table 7). In the group with willingness to sleep, the take-over situation was rated more frequently as harmless although the driver was asleep at the time of the request to intervene. For the take-over performance, the effect is due to the fact that in the group with willingness to sleep, the performance was rated more

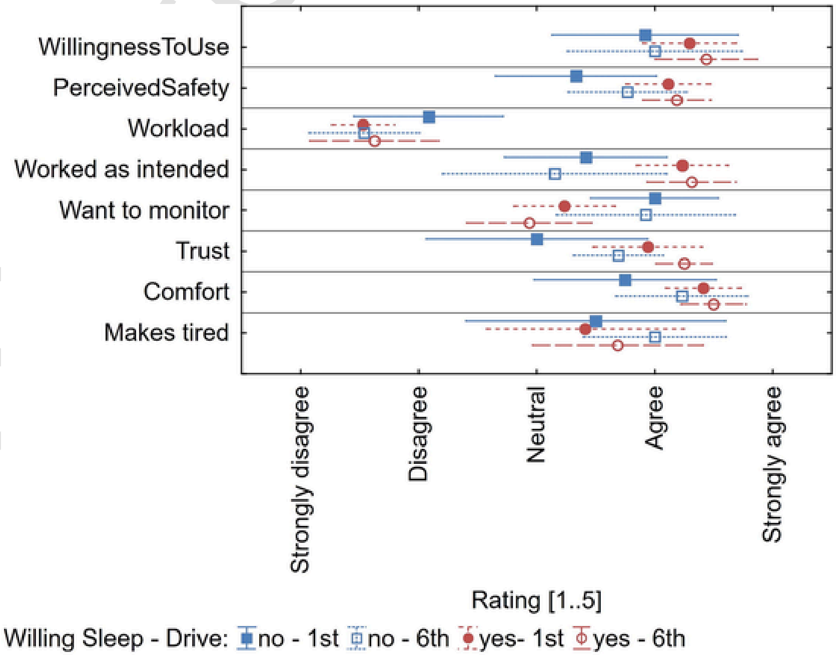

Fig. 3. Impact of willingness to sleep and repeated usage (1st vs. 6th drive) on evaluation of the ADS.

Table 4
Results of Mann-Whitney-U tests on the effect of willingness to sleep on parameters reflecting the usage of ADS and on the evaluation of the ADS, separately for 1st and 6th drive.

Behavioural indicator	1st drive				6th drive			
	md (no will)	md (will)	Z_{corr}	p_{corr}	md (no will)	md (will)	Z_{corr}	p_{corr}
Willingness to use	4.00	4.00	−0.51		4.00	5.00	−0.82	
Perceived Safety	3.50	4.00	**−2.07**	**0.038**	4.00	4.00	−1.44	
Workload	2.00	2.00	1.56		1.00	1.00	0.03	
Works as intended	3.50	4.00	**−2.14**	**0.032**	3.00	4.00	**−2.42**	**0.016**
Want to monitor	4.00	3.00	**2.04**	**0.042**	4.00	3.00	**2.39**	**0.017**
Trust	4.00	4.00	−1.90	0.057	4.00	4.50	**−2.55**	**0.011**
Comfort	4.00	4.00	−1.54		4.00	4.00	−0.56	
Makes tired	4.00	4.00	0.21		4.00	5.00	0.46	
Usage (%)	90	93	**−2.22**	< **0.05**	91	93	−1.76	0.079
NDRA (%)	62	89	**−2.24**	< **0.05**	87	93	−1.63	
PerCLOS (%)	6	12	−1.00		14	8	0.75	
PRC (%)	34	19	**2.55**	< **0.05**	20	11	**2.39**	< **0.05**

Abbreviations: md = median, no will = no willingness to sleep, will = willingness to sleep, NDRA = Non-driving related activities, PRC = percentage road centre.

Table 5
Relation between willingness to sleep and state at the time of the request to intervene separate for the three take-over situations in the drive with sleep deprivation. The number of requests to intervene per category is shown.

Take-over situation	Willingness to sleep	Driver state at request to intervene		Sum
		awake	sleep	
Roadworks	No	12	1	13
	Yes	11	6	17
	Sum	23	7	30
Rain	No	10	2	12
	Yes	5	11	16
	Sum	15	13	28
Exit	No	12	0	12
	Yes	11	5	16
	Sum	23	5	28

Table 6
Relation between willingness to sleep, state at the time of the request to intervene and experienced criticality of the take-over situation separate for the take-over situations Rain and Exit. The number of requests to intervene per category is shown.

Willingness to sleep	State	Rain			Exit		
		harmless	unpleas.	dangerous	harmless	unpleas.	dangerous
No	Awake	9	1	0	5	6	1
	Sleep	0	2	0	0	0	0
Yes	Awake	5	0	0	10	1	0
	Sleep	10	1	0	3	2	0

Table 7
Relation between willingness to sleep, state at the time of the request to intervene and take-over performance separate for the take-over situations Rain and Exit. The number of requests to intervene per category is shown.

Willingness to sleep	State	Rain		Exit	
		imperfections	errors	imperfections	errors
No	Awake	3	7	2	10
	Sleep	1	1	0	0
Yes	Awake	1	4	0	11
	Sleep	7	4	0	4

frequently as being with minor imperfections although the driver was asleep. In contrast, in the group with no willingness to sleep the TOC-rating yielded “errors” more frequently even when the driver was awake.

3.5. Interview data

After the 6th driving session, a subsample of 22 participants took part in a semi-structured interview on their willingness to sleep in level 3 ADS. In contrast to the written questionnaire, in the interviews, only 7 participants stated that they would sleep in reality in AD. When asked for their motivation, they gave the following reasons:

- *“It is my personal free time in the car. At home, there are the children and, in the car, I can take my time to sleep.”*
- *“Time goes by faster and I can catch up on some sleep.”*
- *“I would only sleep if there is not so much traffic.”*
- *“If I had 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.”*
- *“I would become drowsy faster. […] If I had enough trust in the system, I would definitively sleep because after that, I have more time for other things. Especially when I am alone in the car, I would do it.”*
- *“Maybe not in the beginning, but later on.”*
- *“I think if it was really safe, I could imagine to sleep. I think it is strange in the beginning when you are allowed to sleep. And I believe it takes a while until I would feel comfortable enough to sleep.”*

Three participants were unsure about whether they would sleep:

- *“I would do it rather unintentionally.”*
- *“I would only doze.”*
- *“In reality, you never know how the environment reacts, other drivers and so on. I would relax and close my eyes maybe, but ultimately fight against sleep. […] Maybe after half a year or a year and when there is a passenger present on the co-driver seat who can alert me. Then I might do it.”*

When asked if it is possible to respond appropriately to requests to intervene after sleep, only one participant stated a clear “yes”. Three participants believe that it depends on how deep the driver is asleep and the other participants state that it is not possible.

Of those participants who stated that they would not sleep, some participants stated their missing trust in the AD as reason:

- *“I am not in control and I cannot intervene. Sometimes, the warnings were too late.”*
- *“It is a machine or a computer and something could happen anytime.”*
- *“I don’t trust the whole thing enough and the drives have shown that other cars come really close and I want to avoid this.”*
- *“It does not feel safe, it is still a machine and not a human.”*
- *“I don’t trust the autopilot enough. […] it is too risky to completely hand over the control to something.”*

The occurrence of dangerous situations is stated by most participants as reason not to sleep in automated driving:

- *“I would not drive after sleep deprivation because it is too dangerous.”*
- *“As a passenger in a car, I often fall asleep. As a driver, I don’t feel so drowsy that I would fall asleep. Sleep would be a too extreme side task for me. I can imagine doing some side task, but being completely “gone” – that would be too unsafe for me.”*
- *“Sleep would be too dangerous.”*
- *“If I had a fully autonomous vehicle, I could imagine to sleep. But with only an assistance system where I have to intervene – no!”*
- *“I would be afraid to miss the take-over request.”*
- *“Personally, I cannot imagine to sleep. I am responsible also for others.”*
- *“When I am driving, I am still responsible for what the car is doing and I am the one liable when something happens. For me, sleeping would be too dangerous.”*

4. Discussion

In a driving simulator study on behaviour and acceptance of level 3 AD, an unexpectedly large proportion of the sample expressed their willingness to use the driving time with AD to sleep. This attitude remained relatively stable after repeated use of the simulated ADS. Sleep in level 3 AD, where the driver is the fall-back option in case of system boundaries, can be considered a misuse or abuse of automation (Parasuraman & Riley, 1997). The reason for this is that drivers need to be able to respond to requests to intervene at system boundaries and be able to take over the driving task anytime. One of the hypothesized explanations for the willingness to sleep was that drivers had an incorrect mental model of the AD and that they believed sleep was an accepted use case for level 3 AD. However, the results from the post-drive questionnaires show clearly that the participants understand that sleep is not allowed. Even though drivers who expressed their willingness to sleep during AD had marginally more often an incorrect mental model of AD, the majority of drivers in that group was aware that sleep is not allowed. A wrong understanding is therefore not the explanation for the willingness to sleep during AD. A detailed analysis of participants' attitudes towards AD and their behaviour when using a simulated ADS during the study hinted in a different direction: Participants who expressed their willingness to sleep during AD stated higher trust and perceived safety and less the need to monitor the road. These attitudes were also reflected in their behaviour during the study: They engaged the ADS more and they monitored the road less. Participants who expressed their willingness to sleep showed this behaviour also during the study: They slept more frequently during the simulated drives than participants who would not sleep during AD in reality and therefore also received request to intervene while being asleep more frequently. Participants who are willing to sleep during AD experienced the take-over scenarios after sleep more often as harmless. This subjective experience is also reflected in the objective assessment of the take-over scenarios: Participants who expressed their willingness to sleep during AD committed less errors in the take-over scenarios, even when they were asleep before the request to intervene.

When they were asked by an interviewer at the end of the study, a smaller proportion of participants stated their willingness to sleep in AD. Some participants stated that they would sleep only under certain circumstances, for example on familiar routes, when the traffic volume is low or after they had gained some experience with and trust in the ADS. Participants who stated no willingness to sleep in the interviews named safety issues and low trust in the ADS as reasons.

It has to be considered however, that the willingness to sleep does not mean that these study participants would actually sleep during AD. The perceived risk during AD in a driving simulator is lower than during AD in reality. The participants had experienced a simulated ADS that was safe and worked without any flaws. In reality, drivers might experience unexpected behaviours of the ADS or more frequent and possibly more critical take-over scenarios. Nevertheless, the finding that participants who experienced take-over scenarios repeatedly state they would sleep if they could use such a system in reality is remarkable and requires deeper investigation and discussion.

4.1. Trust and trust-related behaviour

Participants who expressed their willingness to sleep during AD had higher trust levels and showed trust-related behaviours more frequently. Misuse of automation is generally related to on overreliance or over-trust in the automation and therefore the failure to monitor the system appropriately (Parasuraman & Riley, 1997). Therefore, the findings from our study are in line with the definition of automation misuse. It has to be considered, however, that also the group without willingness to sleep stated high trust levels and that there is no defined level of trust that could be considered over-trust or overreliance. The trust levels remained stable on a high level with repeated experience of the ADS for both groups. Trust-related behaviours increased over time. Both, participants with the willingness to sleep and without the willingness to sleep, engaged more in non-driving related activities in the last drive compared to the first drive and consequently glanced at the road less. These observed behavioural changes over time need to be considered in the light of the results from the interviews: One pattern in the interview statements from drivers who stated their willingness to sleep during AD was that they would not do it in the beginning, but only if they evaluated the ADS as safe after a certain time of usage and under certain conditions. This could be a hint at the development of automation complacency (Parasuraman & Manzey, 2010). Automation complacency refers to the assumption that "all is well" when in fact, a dangerous situation could arise. Automation complacency is more frequent when the system is highly reliable. This is reflected in participants' statements that they would sleep when they experienced the ADS's reliability for a number of times. In the study, participants evaluated the system as safe, they reported high trust and showed increasing trust-related behaviours with repeated usage. It needs to be considered, however, that the ADS participants experienced in the study worked without flaws and there were no critical situations implemented. The participants experienced system boundaries and requests to intervene in each of the six drives, but the take-over scenarios were designed to be non-critical. Therefore, the participants' willingness to sleep during AD remained stable with repeated usage. It is unclear how the willingness to sleep would have changed if the participants had experienced critical situations such as system failures or complex take-over scenarios during the study.

4.2. Experience of take-over scenarios after sleep

As discussed in the previous section, the majority of participants reported high trust in the ADS and experienced AD as safe. Situations that are likely to be experienced as less safe are take-over scenarios where the driver has to engage in the driving task due to system boundaries. During the study, the participants had to solve different take-over scenarios such as manoeuvring through a construction site or driving in heavy rain with restricted visibility. After each take-over scenario, the participants were asked to rate their subjective criticality of the situation. Those participants who stated their willingness to sleep experienced the take-over scenarios as less critical and they generally rated a higher subjective safety of the take-over scenarios, at least in the beginning. It is very plausible that participants who generally experience take-over scenarios as less critical might be more confident in their ability to solve a take-over scenario even after sleep. After each take-over scenario, the participants' take-over performance was assessed with the TOC-rating (Naujoks, Wiedemann, et al., 2018). Interestingly, the take-over performance of those participants who stated their willingness to sleep was in fact better in one scenario (i.e., the "Exit" scenario). Participants who stated their willingness to sleep slept more frequently during the study and they experienced more take-over scenarios after sleep. It is known from previous research that after sleep performance is restricted by sleep inertia which is reflected in impaired take-over performance (Wörle, Metz, & Baumann, 2021; Wörle et al., 2020). However, the take-over performance of participants who expressed willingness to sleep in our study was better than the performance of participants with no willingness to sleep, even when they were asleep before the request to intervene. Therefore, one conclusion could be that individuals who are willing to sleep during AD not only have a higher confidence in the system capabilities as well as in their own capabilities, but that this confidence might be justified. This finding – again – is also in line with the participants' interview statements that they would sleep after they had gained some (positive) experience with the ADS. One explanation might be that individuals generally experience awakenings from sleep differently and that there are inter-individual differences in the proneness to sleep inertia and therefore to restricted performance after awakening (Trotti, 2017). Some individuals might also have more experience with performing difficult tasks after sleep and therefore be more confident in their capabilities. One participant, for example, stated in the interview that he works as a paramedic and he has a lot of experience with on-call duties where he regularly takes naps and has to respond quickly when he is called to duty. Therefore, it might be concluded that not only trust in the automation, but also trust in one's own capabilities explain the willingness to sleep during AD.

4.3. Complacency

The finding that drivers who have higher confidence in the system and in their own capabilities also perform better in take-over situations should not lead to the assumption that it might be appropriate for some individuals to sleep during level 3 AD. The driver is still the fall-back option and critical situations such as sudden system boundaries or even system failures can occur. The effects of sleep on driver performance also depend on many factors such as the duration or depth of sleep, prior sleep deprivation or the time of the day (Hilditch & McHill, 2019; Tassi & Muzet, 2000). Therefore, even for those participants who performed safe take-over scenarios after sleep in our study, it does not mean that they will always be able to do so. Even highly trained professionals, for example pilots, were so impacted by sleep inertia that their deteriorated performance led to aviation accidents and incidents (see, for example, TSB, 2011). The increase of trust-related behaviours with repeated usage as well as participants' interview statements that they would sleep (while being aware that sleep is not allowed) after they had observed the system behaviour for a while suggests that drivers become complacent over time. Automation complacency refers to the overreliance, insufficient monitoring behaviour and the assumption that "all is well" even though critical situations might occur (Parasuraman & Manzey, 2010). Automation complacency was found as an explanation for misuse of level 2 AD (Nordhoff et al., 2023) and the results of our study suggest that it is an important issue also in higher AD.

4.4. Sleep: Misuse or abuse of automation?

Sleep is not a planned use case of a level 3 ADS (Huysamen et al., 2021) and studies have shown that driving behaviour is heavily impaired due to sleep inertia (Wörle, Metz, & Baumann, 2021; Wörle, Metz, Steinborn, et al., 2021) and could thus pose a serious safety risk. The present study revealed that high trust and complacency can result in drivers sleeping during level 3 AD. It is not clear how to interpret this finding. On the one hand, participants stated in the interview study that they would deliberately sleep even though they understood that sleep is not a use case for level 3 AD and that it is legally not allowed. Participants with the willingness to sleep did not agree more with the statement that AD made them drowsy. These findings suggest that sleeping is a deliberate choice rather than the inability to remain awake and therefore misuse of automation. Misuse of automation is defined as *"overreliance on automation (*e.g. *using it when it should not be used, failing to monitor it effectively)"* (Parasuraman & Riley, 1997). Therefore, sleep can be considered misuse of automation. On the other hand, a number of studies has shown that AD increases the risk of drowsiness (Kundinger, Wintersberger, & Riener, 2019; Schömig et al., 2015; Vogelpohl et al., 2019). Furthermore, over-trust and automation complacency can be the result of poor design and therefore abuse of automation (Parasuraman & Riley, 1997). It could be argued that any system that theoretically enables the driver to sleep – a use case that is highly desired by many (Becker et al., 2018; Kyriakidis, Happee, & de Winter, 2015) – while this behaviour is not allowed, is per se bad design or abuse of automation. A technologically mature ADS that functions without flaws most of the time can inevitably lead to automation complacency. An AD user will not remain vigilant enough to detect (rare) system failures. Paradoxically – the better the ADS, the higher the risk for automation complacency. It can therefore be argued that an automated system that on the one hand suggests that the user can relax and does not need to monitor, but then requires user intervention in critical situations, as it is the case in level 3 AD, should not be allowed in public traffic. Vehicle manufacturer Volvo, for example, has recognized this issue and considered not releasing any level 3 ADS (Volvo Cars, 2017), however changed their strategy later and announced the release of level 3 "Ride Pilot" (Volvo Cars, 2022). In any case, sleep during level 3 AD must be avoided to prevent dangerous situations. One solution to keep the driver in the loop and prevent them from sleeping could be to occasionally engage them in the driving task (Dillmann et al., 2021). Another solution could be driver monitoring systems that have the capacity to detect the onset of sleep or long eyelid closures.

4.5. Limitations

When interpreting the results of the study, some limitations have to be considered: The fact that sleep was observed in a simulator study does not allow to make assumptions about real world behaviour. A simulated environment cannot infer the same perception of risk as a real driving situation. That is why we focused on the participants willingness to sleep in real life rather than the behaviour observed during the simulated drives. It is also striking that in the interview study, a lower proportion of participants stated that they would sleep during AD than in the questionnaire. In the interviews, the participant's statements might have been biased by social desirability. As illustrated by the mainly correct statements that sleep is not allowed in level 3 AD, participants were aware that this is an illicit behaviour. Therefore, they might have answered in a more conformist way. These limitations have to be kept in mind when interpreting the results of the study.

4.6. Conclusion

About half of the participants of our study who experienced level 3 automated driving stated that they would sleep during automated driving in real world driving even though they are aware that sleep is not allowed. Sleep is a dangerous behaviour when using automated driving systems that require the driver to act as a fall-back option and therefore drivers have to be prevented from sleeping. The majority of participants who indicated their willingness to sleep was aware that sleep is not allowed. The findings suggest that after some experience with the system, users are at risk of becoming complacent and neglect the requirement to remain alert. Illicit driver behaviours that are observed in today's traffic such as distracted manual driving or napping in level 2 automated driving could even increase with higher automation levels. Therefore, user education and even legal definition of the driver state (as defined, for example, in the German Road Traffic Act) might not be sufficient to prevent drivers from sleeping during automated driving. Technical solutions are needed that detect sleep onset and prevent drivers from falling asleep. Current driver monitoring systems are optimized to detect distraction or drowsiness, but they should be able to detect sleep onset as well. Other solutions could be cooperative driving systems that engage the driver in a way that prevents automation complacency. The findings of the study also raise the question of what other dangerous behaviours might occur in conditionally automated driving. We found indications for sleep as one form of automation misuse, but other behaviours such as leaving the driver seat or drunk driving might arise due to automation complacency as well. These issues need to be addressed before level 3 automated driving systems are introduced to the public on a large scale.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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Annex.

Interview guideline.

1. Did you sleep during the study when the automated driving system was active?
2. Did you sleep deliberately? Why yes? / Why no?
3. Did you use any specific strategy to keep awake?
4. If you could use such a system in real life, would you sleep when it is active?
5. Why yes? / Why no?
6. Do you think, you are more prone to sleep during automated driving than during manual driving?
7. Why yes? / Why no?
8. Is it possible to respond appropriately to a request to intervene when you are asleep?
9. Why yes? / Why no?
10. Is it possible to respond appropriately to a request to intervene when you are not asleep but very sleepy?
11. Should sleep during automated driving be prohibited by law?
12. Why yes? / Why no?

References

Abraham, H., Seppelt, B., Mehler, B., & Reimer, B. (2017). What's in a name: Vehicle technology branding & consumer expectations for automation. *Proceedings of the 9th international conference on automotive user interfaces and interactive vehicular applications* (pp. 226–234).

Ahlström, C., Wörle, J., Ljung Aust, M., & Diederichs, F. (2023). Road Vehicle Automation and Its Effects on Fatigue, Sleep, Rest, and Recuperation. In C., Rudin-Brown, & A., Filtness (Eds.), *The Handbook of Fatigue Management in Transportation* (pp. 523–524). CRC Press.

Ahlström, C., Zemblys, R., Jansson, H., Forsberg, C., Karlsson, J., & Anund, A. (2021). *Effects of partially automated driving on the development of driver sleepiness. Accident Analysis & Prevention, 153*, 106058.

Bainbridge, L. (1983). *Ironies of automation - analysis, design and evaluation of man-machine systems. Automatica, 19*(6), 775–779.

Becker, T., Herrmann, F., Duwe, D., Stegmüller, S., Röckle, F., & Niko, U. (2018). *Enabling the Value of Time. Retrieved from.* http://publica.fraunhofer.de/documents/N-497231.html.

Dillmann, J., den Hartigh, R.J.R., Kurpiers, C.M., Pelzer, J., Raisch, F.K., Cox, R.F.A., & De Waard, D. (2021). *Keeping the driver in the loop through semi-automated or*

manual lane-changes in conditionally automated driving. Accident Analysis and Prevention, 162, 106397.
Dinges, D. F., & Grace, R. (1998). *PERCLOS: A valid psychophysiological measure of alertness as assessed by psychomotor vigilance*. Retrieved from https://rosap.ntl.bts.gov/view/dot/113.
Edward, K. (2021). Mercedes-Benz introduces world's first internationally valid system for conditionally automated driving. Forbes. Retrieved from https://www.forbes.com/sites/kyleedward/2021/12/29/mercedes-benz-introduces-worlds-first-internationally-valid-system-for-conditionally-automated-driving/.
Feldhütter, A., Gold, C., Schneider, S., & Bengler, K. (2017). How the duration of automated driving influences take-over performance and gaze behavior. In C.M., Schlick, S., Duckwitz, F., Flemisch, M., Frenz, S., Kuz, A., Mertens, & S., Mütze-Niewöhner (Eds.), *Advances in Ergonomic Design of Systems, Products and Processes* (pp. 309–318). Springer.
Hilditch, C.J., & McHill, A.W. (2019). *Sleep inertia: Current insights. Nature and Science of Sleep, 11*, 155–165.
Hirsch, M., Diederichs, F., Widlroither, H., Graf, R., & Bischoff, S. (2020). *Sleep and take-over in automated driving. International journal of transportation science and technology, 9*(1), 42–51.
Honda (Producer). (2020, 10.11.2022). *Honda receives type designation for level 3 automated driving in Japan*. Retrieved from https://global.honda/newsroom/news/2020/4201111eng.html.
Huysamen, K., Collins, M., & Wardle, A. (2021). General safety regulation - Technical study to assess and develop performance requirements and test protocol for variou measures implementing the new General Safety Regulation, for accident avoidance and vehicle occupant, pedestrian and cyclist protection in case of collisions. Driver Availability Monitoring Systems (DAMS). Final Report to the European Commission.
Kim, H., Song, M., & Doerzaph, Z. (2020). *Real-World Use of Partially Automated Driving Systems and Driver Impressions. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 64*(1).
Kreuzmair, C., Gold, C., & Meyer, M.-L. (2017). *The influence of driver fatigue on take-over performance in highly automated vehicles*. Paper presented at the 25th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Detroit, Michigan.
Kundinger, T., Riener, A., Sofra, N., & Weigl, K. (2020). Driver drowsiness in automated and manual driving: Insights from a test track study. *Proceedings of the 25th International Conference on Intelligent User Interfaces* (pp. 369–379).
Kundinger, T., Wintersberger, P., & Riener, A. (2019). (Over) Trust in Automated Driving: The Sleeping Pill of Tomorrow? *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–6).
Kyriakidis, M., Happee, R., & de Winter, J.C. (2015). *Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. Transportation research part F: Traffic psychology and behaviour, 32*, 127–140.
Mercedes-Benz (Producer). (2021, 24.06.2022). First internationally valid system approval for conditionally automated driving. Retrieved from https://group.mercedes-benz.com/innovation/product-innovation/autonomous-driving/system-approval-for-conditionally-automated-driving.html.
Metz, B., Rösener, C., Louw, T., Aittoniemi, E., Bjorvatn, A., Wörle, J., . . . Streubel, T. (2020). *L3 Pilot Deliverable D3.3. Evaluation methods.* Retrieved from ww.l3pilot.eu.
Metz, B., Wörle, J., Hanig, M., Schmitt, M., Lutz, A., & Neukum, A. (2021). *Repeated usage of a motorway automated driving function: Automation level and behavioural adaptation. Transportation research part F: Traffic psychology and behaviour, 81*, 82–100.
Metz, B., Wörle, J., Zerbe, A., Schindhelm, R., Frey, A., Bonarens, F., . . . Tivesten, E. (2021). *L3Pilot Deliverable 7.2: L3/L4 long-term study about user experiences*. Retrieved from www.l3pilot.eu.
Naujoks, F., Höfling, S., Purucker, C., & Zeeb, K. (2018). *From partial and high automation to manual driving: Relationship between non-driving related tasks, drowsiness and take-over performance. Accident Analysis & Prevention, 121*, 28–42.
Naujoks, F., Wiedemann, K., Schömig, N., Jarosch, O., & Gold, C. (2018). *Expert-based controllability assessment of control transitions from automated to manual driving. MethodsX, 5*, 579–592.
Neukum, A., & Krüger, H.-P. (2003). *Fahrerreaktionen bei Lenksystemstörungen-Untersuchungsmethodik und Bewertungskriterien. VDI-Berichte, 1791*, 297–318.
Nordhoff, S., Lee, J.D., Calvert, S.C., Berge, S., Hagenzieker, M., & Happee, R. (2023). *(Mis-) use of standard Autopilot and Full Self-Driving (FSD) Beta: Results from interviews with users of Tesla's FSD Beta. Frontiers in Psychology, 14*, 1101520.
Omae, M., Hashimoto, N., Sugamoto, T., & Shimizu, H. (2004). *Evaluation of driver's reaction time to failure of lateral controller at automatic driving. Proceedings of International Symposium on Advanced Vehicle Control, 2004*, 157–162.
Parasuraman, R., & Manzey, D.H. (2010). *Complacency and bias in human use of automation: An attentional integration. Human Factors, 52*(3), 381–410.
Parasuraman, R., & Riley, V. (1997). *Humans and automation: Use, misuse, disuse, abuse. Human Factors, 39*(2), 230–253.
Robinson, K. (2020, December 24. 2020). *'A legal first': B.C. man accused of dangerous driving for sleeping in self-driving, speeding Tesla.* Global News. Retrieved from https://globalnews.ca/news/7534323/a-legal-first-b-c-man-accused-of-dangerous-driving-for-sleeping-in-self-driving-speeding-tesla/.
SAE. (2021). J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. SAE J3016. Retrieved from www.sae.org.
Schömig, N., Hargutt, V., Neukum, A., Petermann-Stock, I., & Othersen, I. (2015). *The interaction between highly automated driving and the development of drowsiness.* Paper presented at the 6th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences, AHFE 2015, Las Vegas, USA.
Smith, D. (2016, 24.05.2018). *A Tesla driver was caught sleeping on the highway with his car on Autopilot.* Business Insider. Retrieved from https://www.businessinsider.com/tesla-autopilot-driver-caught-sleeping-2016-5?IR=T.
Solon, O. (2018, 24.01.2018). *Who's driving? Autonomous cars may be entering the most dangerous phase.* The Guardian. Retrieved from https://www.theguardian.com/technology/2018/jan/24/self-driving-cars-dangerous-period-false-security.
Tassi, P., & Muzet, A. (2000). *Sleep inertia. Sleep medicine reviews, 4*(4), 341–353.
Trotti, L.M. (2017). *Waking up is the hardest thing I do all day: Sleep inertia and sleep drunkenness. Sleep medicine reviews, 35*, 76–84.
TSB. (2011). *Aviaton Investigation Report. Pitch Excursion Air Canada Boeing 767-333, North Atlantic Ocean, 14 January 2011.* Transportation Safety Board of Canada. Retrieved from https://www.tsb.gc.ca/eng/rapports-reports/aviation/2011/a11f0012/a11f0012.html.
Vogelpohl, T., Kühn, M., Hummel, T., & Vollrath, M. (2019). *Asleep at the automated wheel—Sleepiness and fatigue during highly automated driving. Accident Analysis & Prevention* (126), 70–84.
Volvo Cars (2017). Volvo Cars CEO urges governments and car industry to share safety-related traffic data. Retrieved from https://www.media.volvocars.com/global/en-gb/media/pressreleases/207164/volvo-cars-ceo-urges-governments-and-car-industry-to-share-safety-related-traffic-data.
Volvo Cars (2022). Volvo Cars' unsupervised autonomous driving feature Ride Pilot to debut in California. Retrieved from https://www.media.volvocars.com/global/en-gb/media/pressreleases/292917/volvo-cars-unsupervised-autonomous-driving-feature-ride-pilot-to-debut-in-california.
Wörle, J., Metz, B., & Baumann, M. (2021). *Sleep inertia in automated driving: Post-sleep take-over and driving performance. Accident Analysis & Prevention, 150*, 105918.
Wörle, J., Metz, B., Othersen, I., & Baumann, M. (2020). *Sleep in highly automated driving: Take-over performance after waking Up. Accident Analysis & Prevention, 144*, 105617.
Wörle, J., Metz, B., Steinborn, M.B., Huestegge, L., & Baumann, M. (2021). *Differential effects of driver sleepiness and sleep inertia on driving behavior. Transportation research part F: traffic psychology and behaviour, 82*, 111–120.