WHO BENEFITS FROM NAPPING IN AUTOMATED DRIVING?

EFFECTS OF CHRONOTYPE ON SLEEP INERTIA.

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SAE Level 4
High driving automation

Drivers become
passengers

New use case:
sleeping

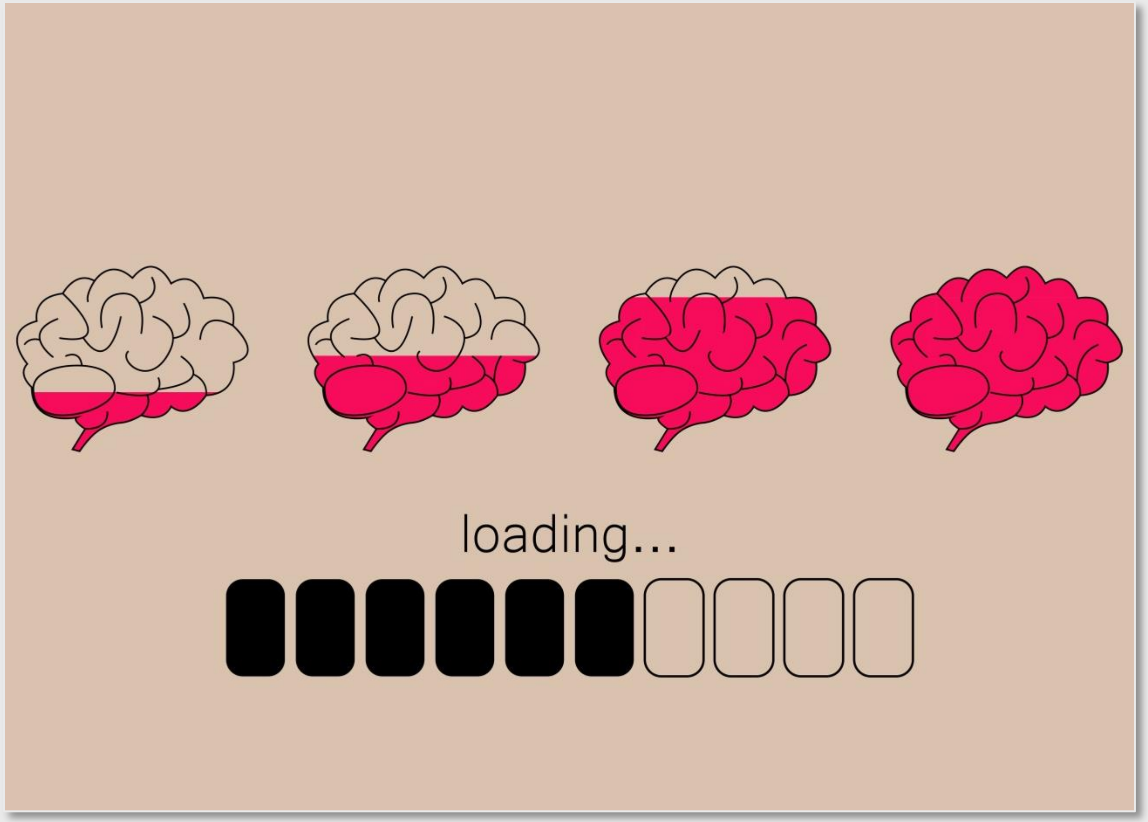
Mind off

Sleep Inertia

WHAT IS SLEEP INERTIA?

TRANSITION BETWEEN SLEEP AND WAKEFULNESS

- “Grogginess“
- Duration varies; normally max. 30 minutes
- Physiological correlates related to those for sleep (Trotti, 2017)
- Possible function: quick fall asleep after undesired wake-up (Hilditch & McHill, 2019)
- Impaired performance in different types of tasks (Tassi & Muzet, 2000)
- Impaired driving behavior and driving mistakes (Wörle, Metz & Baumann, 2021)



RESEARCH QUESTIONS

IMPACTS OF SLEEP INERTIA ON SUBJECTIVE WELLBEING AND DRIVING BEHAVIOR

- **Do we benefit** from sleeping during automated driving?
- **Who** benefits from napping in automated driving?
  - Effects of **chronotype** on Sleep Inertia
- **When** do we benefit from napping in automated driving?
  - Effects of **time of day** on Sleep Inertia
  - Effects of **time course** on Sleep Inertia

METHODS

Interior and mockup of the dynamic driving simulator at the WIVW.

Exterior and motion platform of the driving simulator.

SETTING & SAMPLE

- Dynamic driving simulator at Wuerzburg Institute for Traffic Sciences (WIVW)
- Sample
  - N = 20
  - Prescreening and selecting according to individual chronotype (rMEQ; Randler, 2013)
    - n = 10 morningness types
    - n = 10 eveningness types

METHODS

STUDY DESIGN

2 experimental drives	1 reference drive
▶ Beginning of experimental session ▶ Early (6 a.m.) ▶ Late (9 p.m.) ▶ Max 4 hours of sleep in the night before session ▶ Duration ca. 2:45 h ▶ Arrival and departure by taxi	▶ Beginning of the sessions during daytime ▶ Normal sleep in the night before participation ▶ Duration ca. 1 h

- Partially randomized order of sessions

METHODS

PROCEDURE

EXPERIMENTAL DRIVES

- 20 – 45 Min. ▶ EEG + Instructions
- 10 Min. ▶ Familiarization
- 30 Min. ▶ Manual drive — *Sleepiness*
- 50 Min. ▶ Highly automated driving (L4) — *Sleep*
- 30 Min. ▶ Manual drive — *Sleep Inertia*
- 5 Min. ▶ Questionnaire

time ∑ 2:25 – 2:45 h

REFERENCE DRIVE

- 10 Min. ▶ Instructions
- 10 Min. ▶ Familiarization
- 30 Min. ▶ Manual drive
- 5 Min. ▶ Questionnaire

time ∑ 0:55 h

METHODS

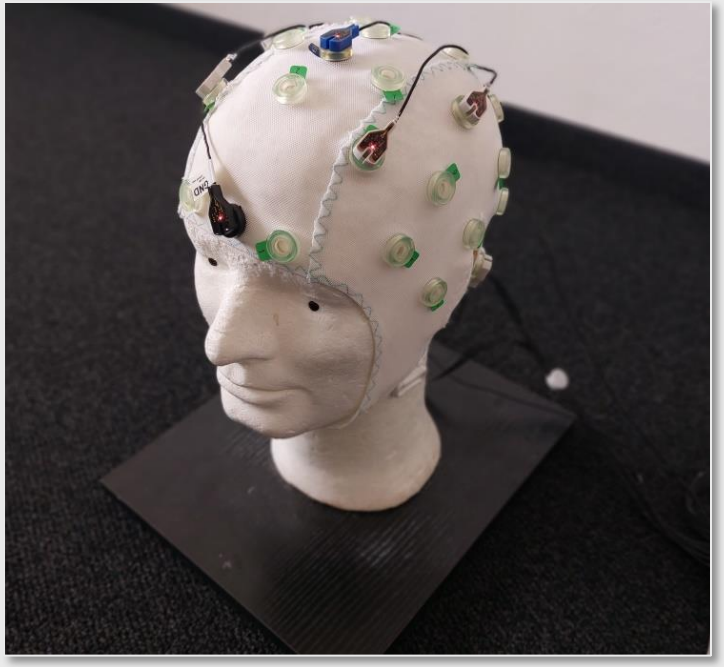
MANUAL DRIVES

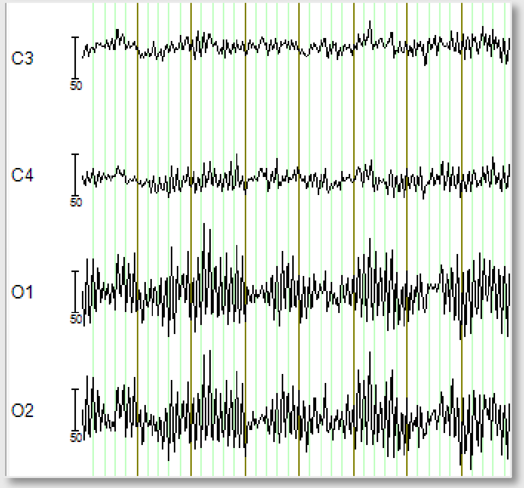
- Monotonous drive on freeway
- Every 5 min: self-rating of subjective state [scale: -4 to +4]
  - Arousal
  - Wellbeing
  - Motivation to continue manual driving
- Both manual drives are divided into 6 intervals (7 inquiries)
- Acoustic vigilance task

METHODS

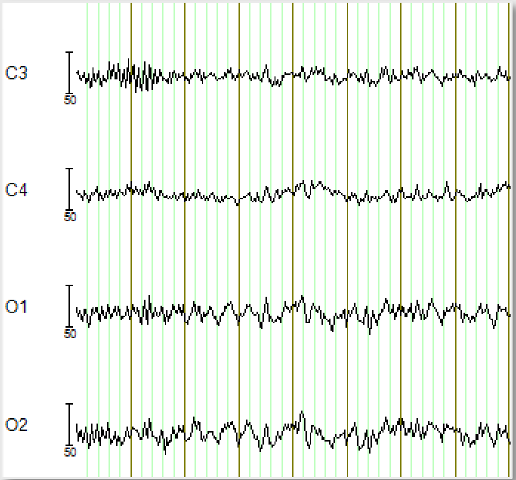
AUTOMATED DRIVING

- Reclined seat during automated driving
- Instruction: sleep
- EEG & Sleep scoring according to AASM (2017)

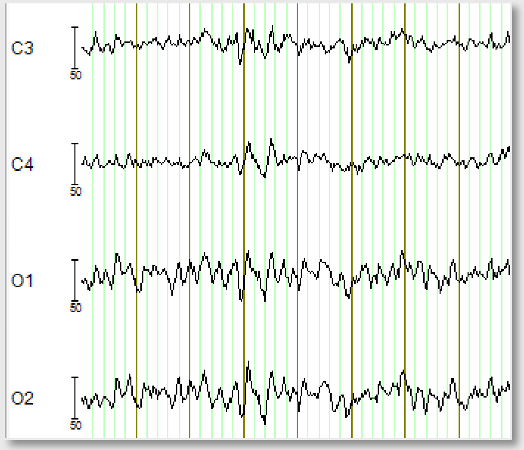




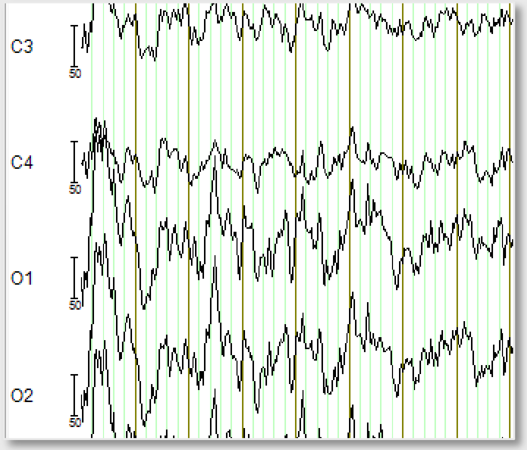
Wake (W)



Drifting off to sleep (N1)



Stable sleep (N2)



Deep sleep (N3)

METHODS

INDEPENDENT VARIABLES

Chronotype

- Morningness type
- Eveningness type

Drive/driver state

- Pre sleep (sleepiness)
- Post sleep (sleep inertia)

Time of day

- Morning (6 a.m.)
- Evening (9 p.m.)
- (Daytime)

Inquiry/Interval

- 7 inquiries
- 6 intervals

METHODS

DEPENDENT VARIABLES

Subjective state

- Arousal
- Wellbeing
- Motivation

Driving behavior

- Speed
- Standard Deviation of Lane Position (SDLP)

Sleep

- Sleep Stages (EEG)

RESULTS


Wie aktiviert fühlen Sie sich im Moment?
Wie gut fühlen Sie sich im Moment?
Wie gerne möchten Sie im Moment die manuelle Fahrt fortsetzen?
Am Ende der manuellen Fahrt (Frage von Versuchsleitung):

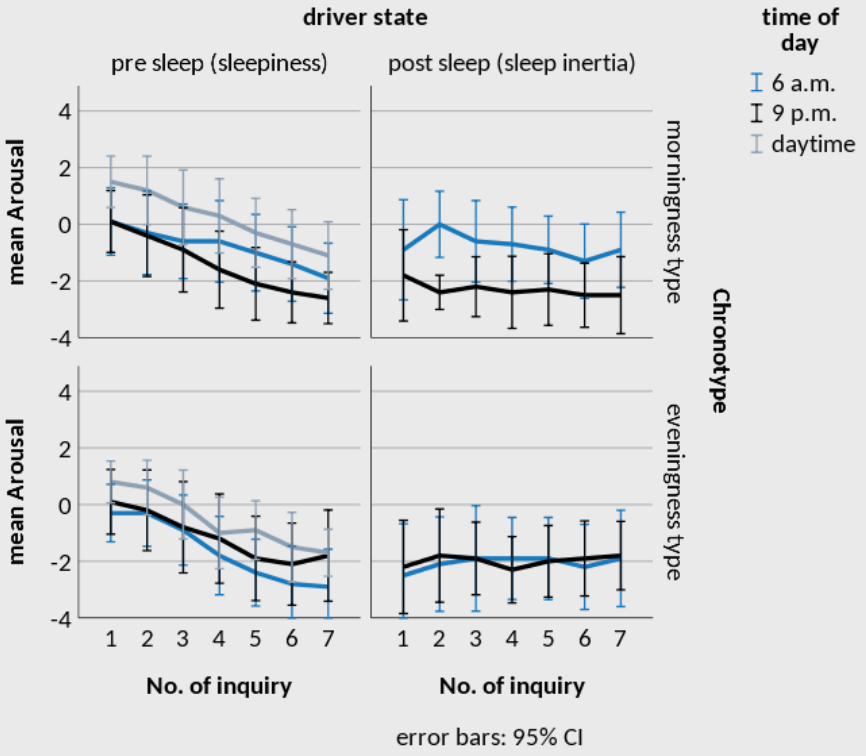
RESULTS

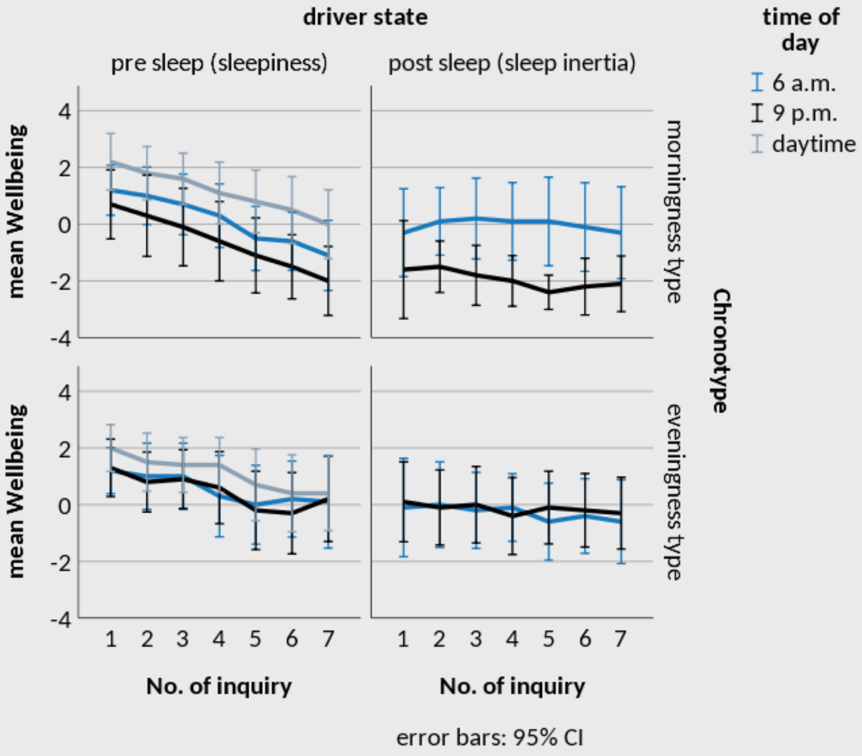
MANIPULATION CHECK: SLEEP

- EEG-verified sleep in 37 of 40 driving sessions
- Deep sleep (N3) in 13 driving sessions, mainly in the evening
- Deeper sleep when chronotype did not fit the time of day

RESULTS

SUBJECTIVE WELLBEING

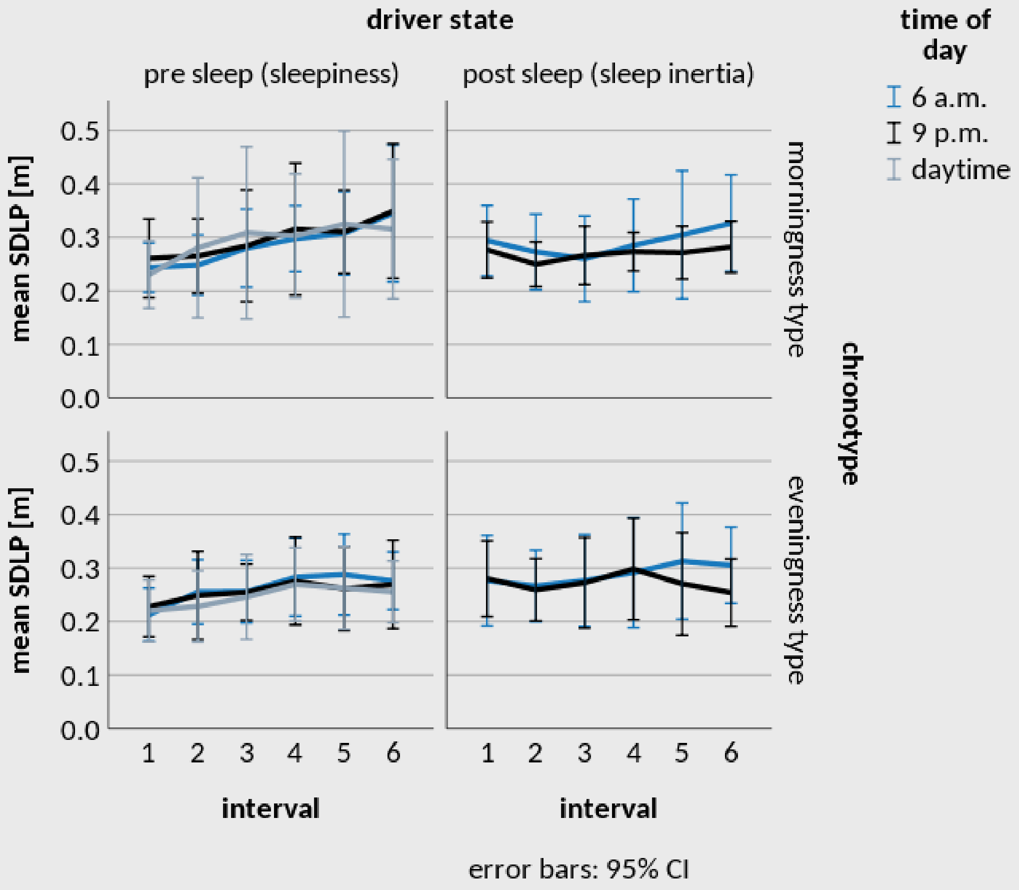




- Pre sleep: constant decrease in arousal and wellbeing
- Post sleep: stabilization on low level
- Interaction effect chronotype * time of day: Morningness types differ significantly between the times of day and subjectively benefit from a nap in the morning
  Arousal: $F(1, 18) = 8.14$, $p = .011$, $\eta_p^2 = .311$ | Wellbeing: $F(1, 18) = 5.08$, $p = .037$, $\eta_p^2 = .220$

RESULTS

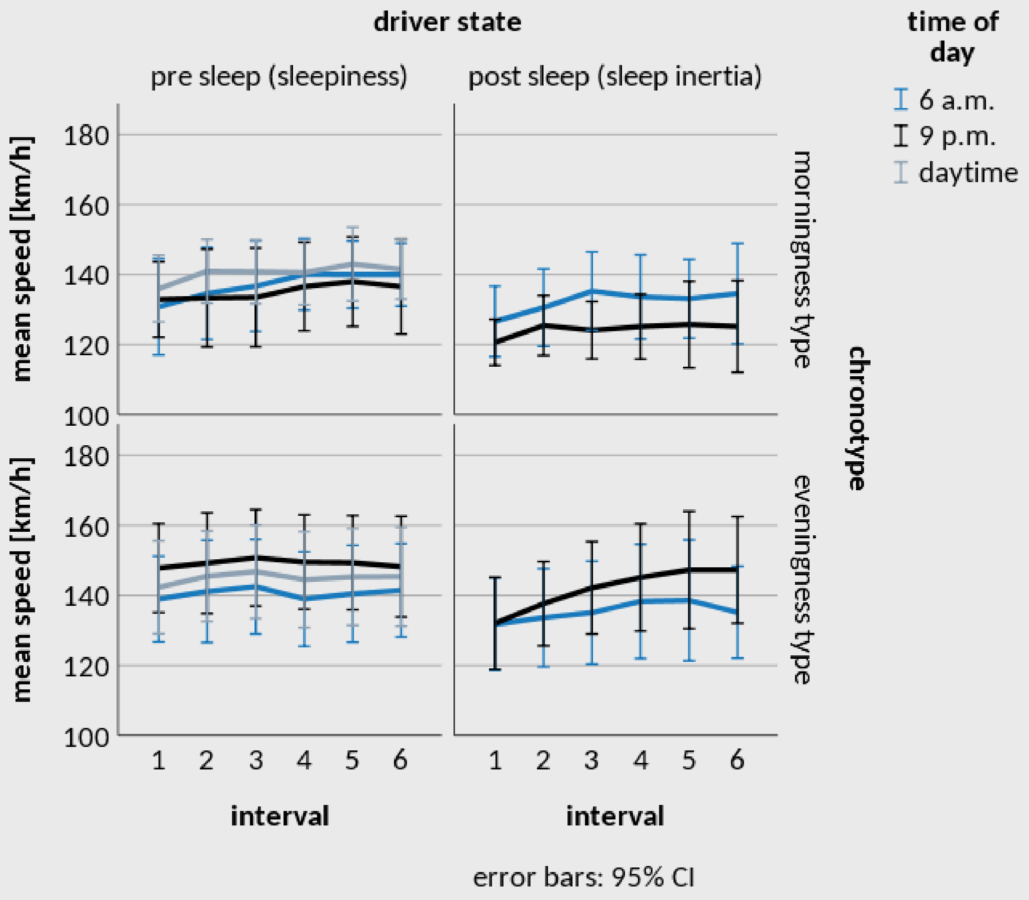
DRIVING BEHAVIOR: LANE KEEPING



- Pre sleep: constant impairment in lane keeping (SDLP)
- Post sleep: stabilization on a poor level
- No significant main and interaction effects between chronotypes and times of day

RESULTS

DRIVING BEHAVIOR: SPEED



- Participants drove significantly faster when the time of day fitted their individual chronotype
  $F(1, 18) = 17.78$, $p = .001$, $\eta_p^2 = .497$
- Mean speed significantly lower post sleep compared to pre sleep
  $F(1, 18) = 13.65$, $p = .002$, $\eta_p^2 = .431$
- Post sleep: under sleep inertia, speed and wellbeing are significantly correlated[a]:
  - Pre sleep: $r(219) = -.018$, $p = .794$
  - Post sleep: $r(219) = .266$, $p < .001$
- Compensation for lower fitness?

Note:
a) Correlation coefficient for repeated measures analyses

SUMMARY & DISCUSSION

SUMMARY & DISCUSSION

- **Do we benefit** from sleeping during automated driving?
  - **Yes and no:** sleep averted a further decrease of subjective arousal and wellbeing
  - Small benefit for **morningness** types sleeping in the morning
  - **Trade-off** between recovery and sleep inertia
  - Closer **link between subjective state and driver behavior** under sleep inertia compared to sleepiness

- **Limitations**
  - Partial sleep deprivation
  - Small sample
  - Simple driving scenario

- **Future research**
  - Effects of sleep quality on sleep inertia
  - Effects of sleep inertia on complex driving tasks

THANK YOU FOR YOUR ATTENTION!

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REFERENCES

- AASM. (2017). *The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications*. American Academy of Sleep Medicine.
- Hilditch, C. J., & McHill, A. W. (2019). Sleep inertia: current insights. *Nature and science of sleep*, *11*, 155.
- SAE. (2021). *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (Vol. J3016)*. SAE International.
- 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.
- Wörle, J., Metz, B., & Baumann, M. (2021). Sleep inertia in automated driving: Post-sleep take-over and driving performance. *Accident Analysis & Prevention*, *150*, 105918.