RUMBA

Realisierung einer positiven User Experience mittels benutzerfreundlicher Ausgestaltung
des Innenraums für automatisierte Fahrfunktionen

Gefördert durch:

Bundesministerium
für Wirtschaft
und Klimaschutz

aufgrund eines Beschlusses
des Deutschen Bundestages

Neuroergonomic Insights on the Effects of Increasing Automation on Drivers’ Cognitive States and Processes

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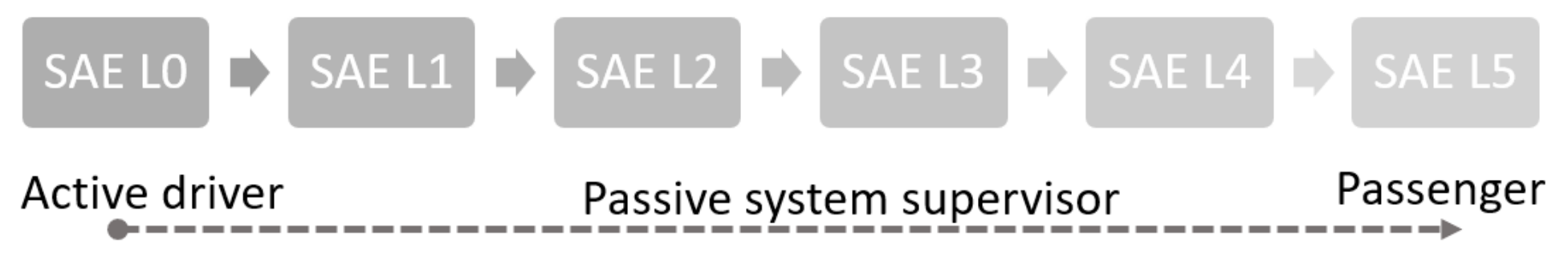
1 | Motivation

- Nineteen million new (semi)automated cars expected in 2024[1]
- **Humans remain involved** in operating (semi)automated cars
- Drivers must adapt to their **new role** behind steering wheel[2]



SAE L0 → SAE L1 → SAE L2 → SAE L3 → SAE L4 → SAE L5

Active driver — Passive system supervisor — Passenger

Figure 1 The changing role of the driver throughout the SAE levels of automation

- Comprehensive understanding how **automation affects cognitive states and processes** of the driver necessary for:
  - human-centred approach to HMI design[3];
  - advanced driver-monitoring systems.

2 | Cognitive States and Processes

Attentional Resource Allocation[4, 5, 6]

- **Limited pool of cognitive resources**
- Dynamically allocated during task performance
- Spare capacity for environmental monitoring

Mental Workload[7]

- **Degree of activation of the limited resource pool** during task performance

Passive Fatigue[8]

- Subjective experience **produced by cognitive underload** and monotony

- Often studied, but with major **limitations**:
  - Mostly simulator experiments, no real-world ERP studies reported
  - No direct comparison between automation levels

3 | Methods

- **Passive auditory oddball task**[9, 10] to evoke P300 ERP
  - Brain response to rare, unpredictable sounds
  - Index of cognitive processing – competition for resources
  - P300 amplitude and mental workload inversely correlated
- **Test track experiment** with 30 participants (age *M* = 42.6, *SD* = 14.0)
- **Independent variable**: automation level (manual, L2, L3; randomised)
- **Dependent variables**: P300 amplitude, NASA-TLX[11], Karolinska Sleepiness Scale[12]

Figure 2 The test track and the vehicle used in the experiment. The participant is wearing a 32-channel EEG cap and headphones for the auditory stimuli presentation.

4 | Results

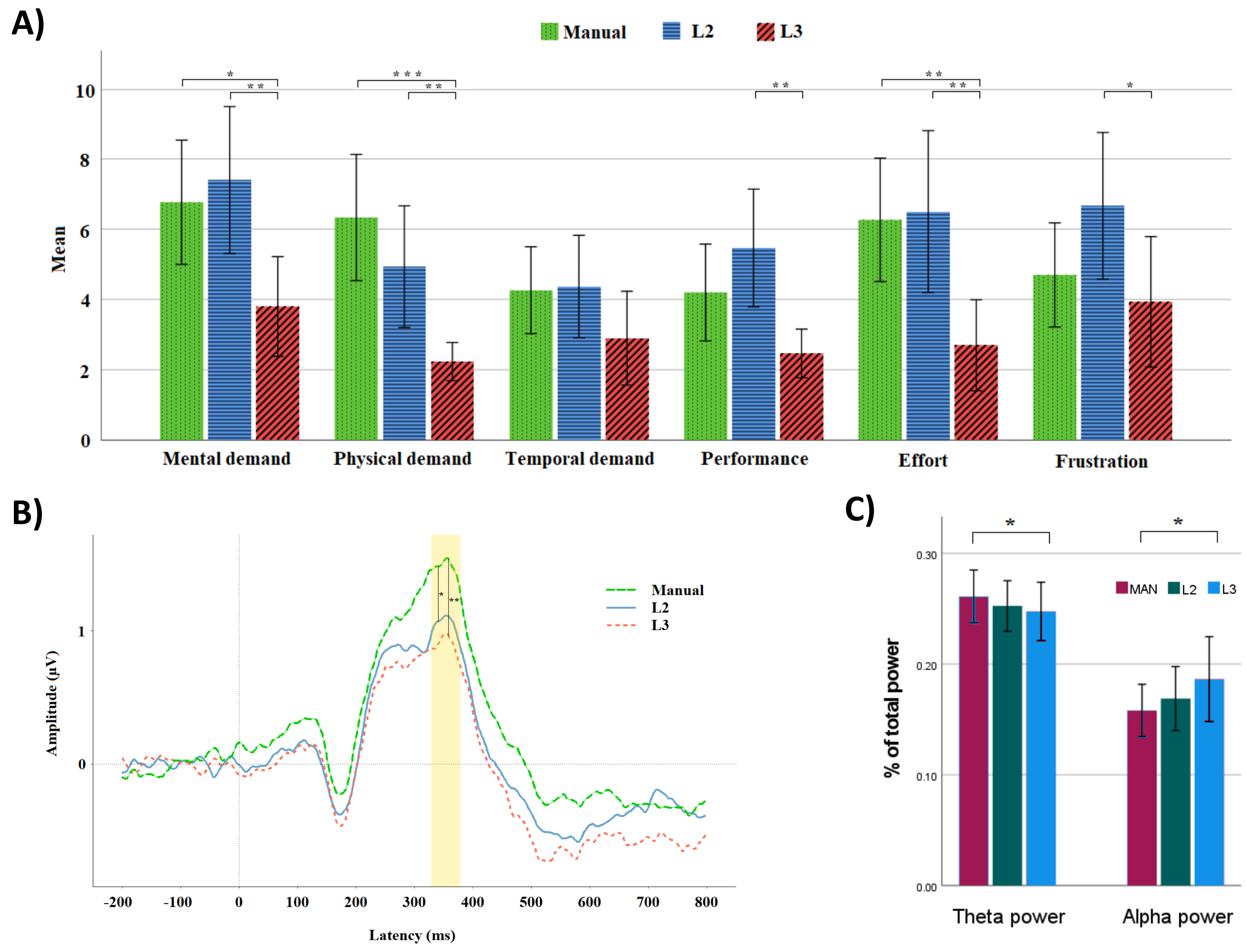


Figure 3 Significance is highlighted as * *p* < .05; ** *p* < .01, ***; *p* < .001; **3A** - Mean NASA-TLX scores (error bars – 95% CI); **3B** - ERPs evoked by the passive oddball task; **3C** - Alpha and Theta power spectral density.

- **Lowest mental workload perceived in L3**, no difference between manual and L2 driving
  - Overall NASA-TLX score differed ($F(1.68, 48.81) = 10.10$; $p < .001$; $\omega^2 = 0.11$)
- **Higher objective mental workload in manual driving**
  - Theta power differed ($F(2.00, 42.00) = 4.94$, $p = .012$, $\omega^2 = 0.01$)
- **More cognitive resources utilised for auditory stimuli processing in manual driving**
  - P300 amplitude differed ($\beta = 0.33$; $SE = 0.12$; $t = 2.76$; $p = .008$)
- **More fatigue and sleepiness in L3 driving**
  - Mean KSS score differed ($F(1.96, 43.15) = 3.39$, $p = .04$, $\omega^2 = 0.02$)
  - Alpha power differed ($F(2.00, 42.00) = 4.42$, $p = .02$, $\omega^2 = 0.02$)

5 | Discussion and Implications

- Automation leads to mental underload and passive fatigue
- **Critical difference between L2 and L3 driving** due to task shift
  - L3 drivers allowed to disengage!
- Interface design should account for **distracted, sleepy drivers**
- **Advanced driver monitoring systems**
  - Automation should dynamically adapt to drivers’ current needs
  - Optimisation of task load and engagement

6 | Links & Acknowledgements

Literature

Personal website (NF)

SHAPE-IT

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 860410

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