In-Vehicle Interface Adaptation to Environment-Induced Cognitive Workload

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Abstract

Many car accidents are caused by human errors, including cognitive distractions. In-vehicle human-machine interfaces (HMIs) have evolved throughout the years to provide more functions. Interaction with the HMIs can, however, also lead to further distractions and therefore accidents. To tackle this problem, we propose using HMIs that adapt to the mental workload of the driver. In this work, we present the current status as well as preliminary results of a user study using naturalistic secondary tasks while driving (i.e., the primary task), that attempt to understand the effects of one such interface.

Theoretical Background

Mental Workload (MWL)

- Driving environment (visual complexity + vehicle control difficulty) affects MWL
- MWL = interaction of task demands, environmental and human factors [1]
- High MWL or overload → more driving mistakes and traffic accidents
- Physiological MWL measurements

In-Vehicle HMI

- Increasingly more advancing
- Impact on relationship between the driving task and MWL [2]
- Add comfort and help to the driving task → decrease of MWL
- Add distraction or additional task load → increase of MWL

Adaption of HMI

- Adaption to the current MWL or difficulty of the driving environment → Reduction of MWL or prevention of overload [3] → reduction of driving errors or accidents
- Possible adaption: presenting less information on the display with higher MWL
- Could also be distractive or irritating

Research Question and Hypotheses

- **RQ**: Does HMI adaption to driving environment difficulty reduce MWL compared to a static HMI with constant information?
- **H1**: The increase in MWL with environmental difficulty is lower for an adaptive system compared to a static system.
- **H2**: In the task conditions, there is a higher increase in MWL with environmental difficulty than in the no-task condition.
- **H3**: The increase in MWL with environmental difficulty is moderated by task difficulty. For more difficult tasks, the increase is larger.
- **H4**: The UX of an adaptive system is better compared to a static system.

Participants

N=35 (adaptive n=16); static group drove more kilometres per year (stat: 10639 km/year, adap: 2733 km/year)

Task

- Length: 30 minutes
- Complete tasks (i.e. type an address, reject a phone call) on the HMI while driving
- Everyday traffic rules, max 50 km/h

Driving Environment Design

- Two environments [4] (4 x 60 sec each), differing in
  - Visual complexity (i.e. number of buildings)
  - Vehicle control difficulty (i.e. sharpness of turns)

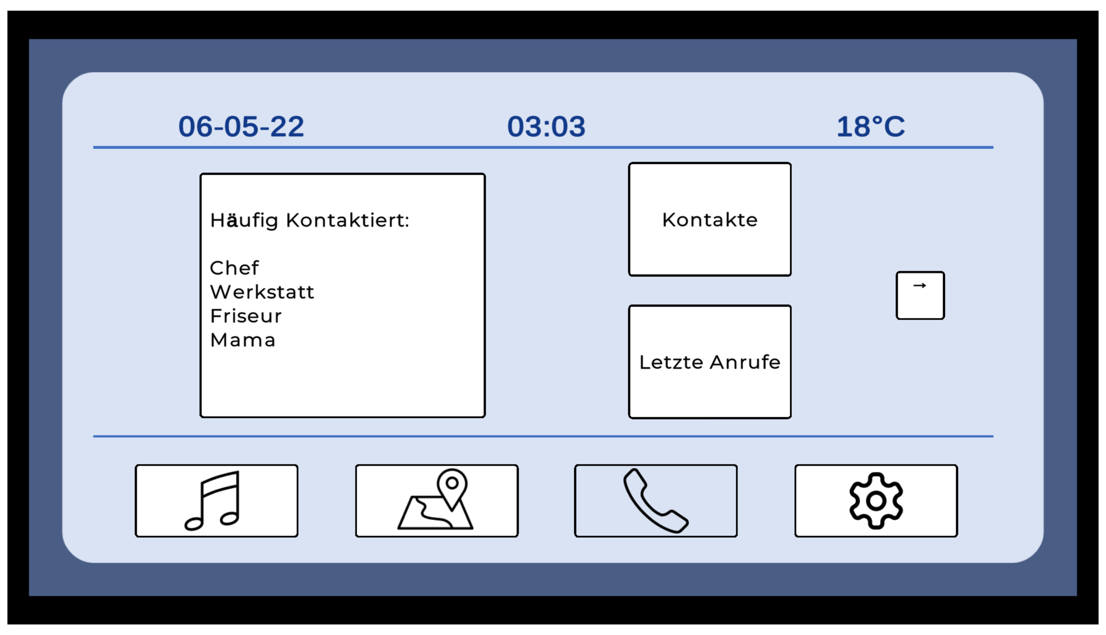
Measurements

- HR + HRV with ECG-based sensor
- Longitudinal + lateral driving measurements
- Interaction with the display + latency of task completion
- Demographic and UX questionnaire [5]

Interface Design

- Static: complex HMI → both environments
- Adaptive: complex HMI → countryside; simplified HMI → city

(a) Complex Interface



(b) Simplified Interface

References

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2. T. C. Lansdown, N. Brook-Carter, and T. Kersloot, "Distraction from multiple in-vehicle secondary tasks: vehicle performance and mental workload implications", Ergonomics **47**, 91–104 (2004).
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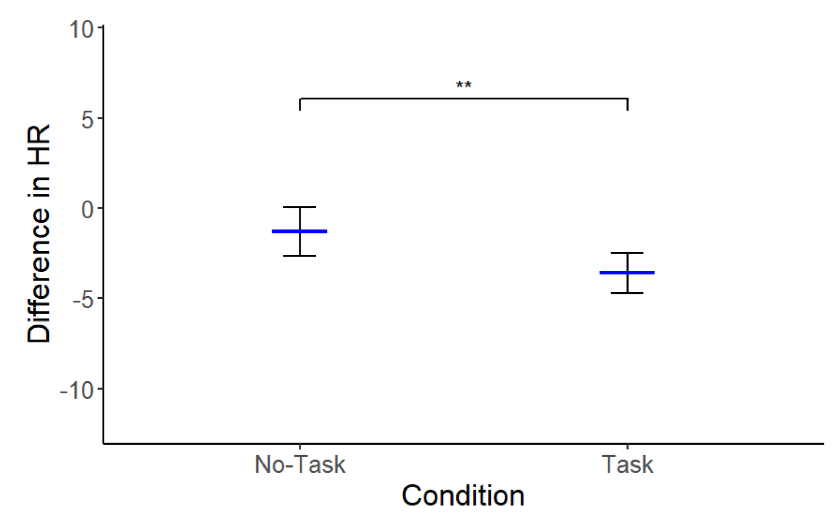
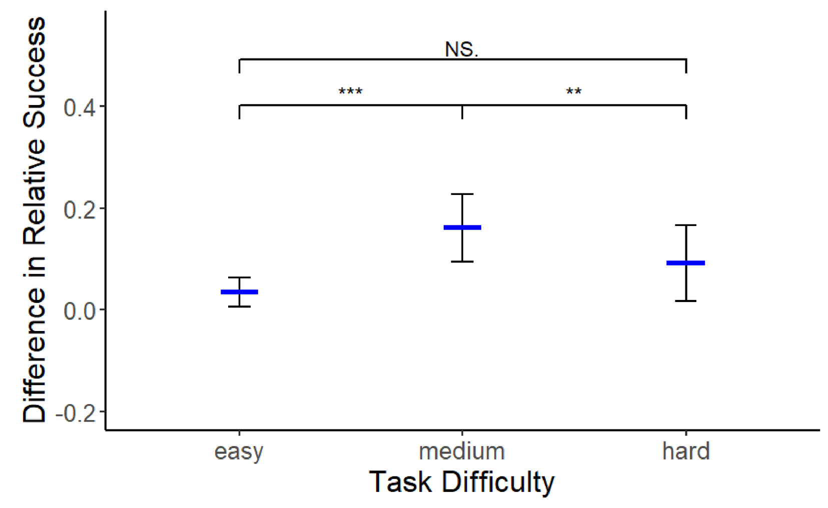
5. M. Schrepp and J. Thomaschewski, "Eine modulare erweiterung des user experience questionnaire", in Mensch und computer 2019 - usability professionals, edited by H. Fischer and S. Hess (2019).

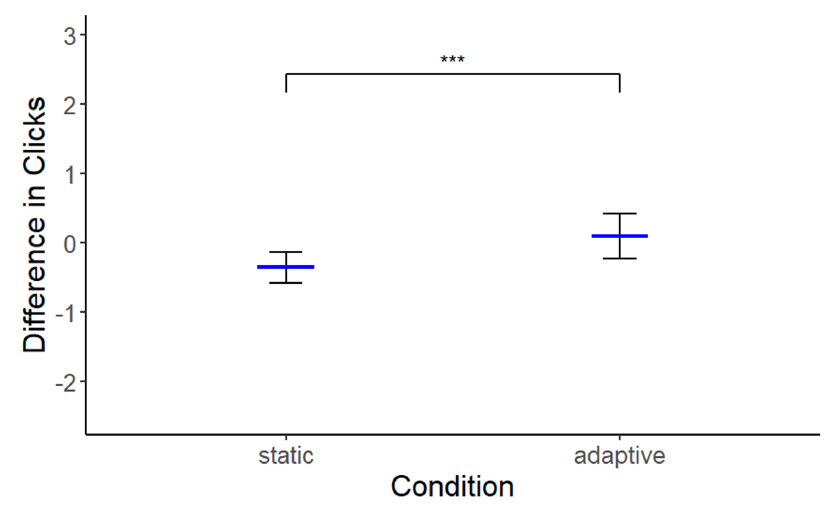
Preliminary Results



(a) higher difference in HR in the no-task-condition than in the task conditions



(b) for tasks of medium difficulty: greater difference in relative success



(c) static group showed better performance than the adaptive group

Discussion

H1, H2, H3: Trends of MWL opposed our hypotheses. Precisely, smaller sequence/training effect in the adaptive condition and no MWL differences measured by HR and HRV possibly due to compensatory behavior. **H4**: No differences in UX ratings. **Next Steps**: Investigate driving performance effect on MWL.