Ben-Gurion University of the Negev

HPEL HUMAN PERFORMANCE EVALUATION LAB

The effects of engagement with a Trivia game on driver's sleepiness, situation awareness, and adaptation in a PAV

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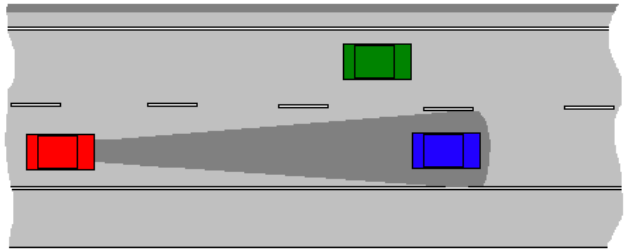
Mediator

Introduction

- PAD requires the driver's continuous supervision and full and immediate control in case of an automation failure.
- The driver is frequently found out-of-the-loop and only performs prolonged monotonous monitoring with little control.
- The driver might be in a cognitive underload that can induce sleepiness and passive fatigue (Desmond and Hancock, 2001), decrease vigilance, and impair the driver's capability to overtake the automation when needed.



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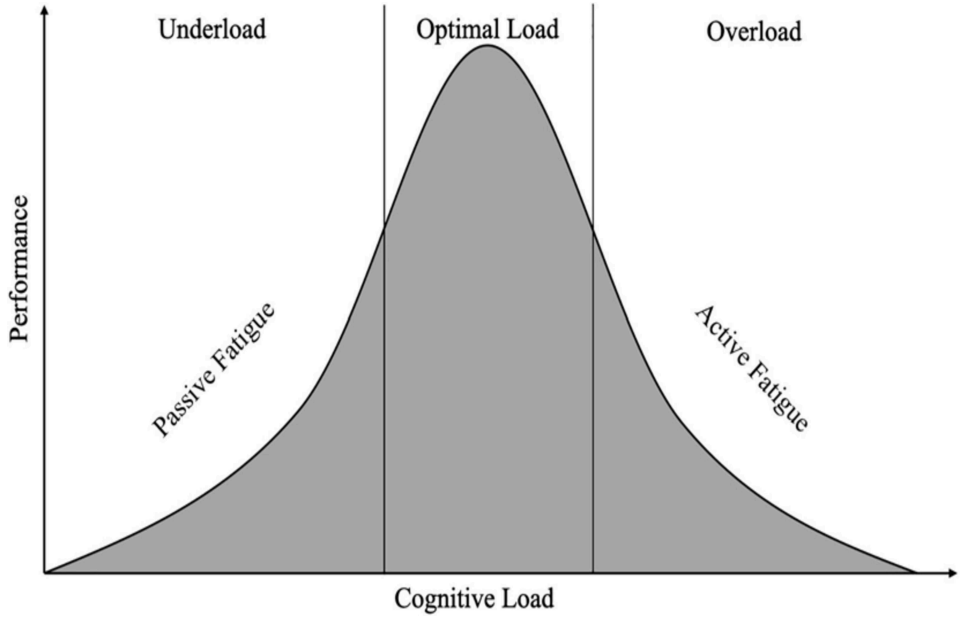


McWilliams, T., & Ward, N. (2021)

Introduction (cont.)

- Previous studies had shown the negative effects of underload, sleepiness, and vigilance decrease on driver's performance (McWilliams & Ward,2021).
  - failure to detect hazards
  - slower response to critical events
  - failure to overtake automation, etc.

- To prevent drivers from reaching this sleepy and degraded state, many countermeasures in the form of a Non-Driving Related Tasks (NDRT) have been proposed (Merat, Jamson, Lai & Carsten, 2012) .
  - Reading, watching movies, eating, playing games, texting, or talking on the phone, listening to music, and many more (Naujoks, Befelein, Wiedemann & Neukum, 2017).

Motivation and objectives

This study aims to:

- Examine whether an option to engage with an NDRT in the form of a Trivia game will stall drivers' fatigue progression under PAD, both in the short and the long term.

- Examine whether drivers will adapt to using PAV with the system and interface proposed.

Answering these questions will allow a better understanding of whether and how to mitigate the negative effects of passive fatigue in L2 driving.

Research hypotheses

- Engagement with an NDRT of a Trivia game will stall drivers’ fatigue progression under PAD.

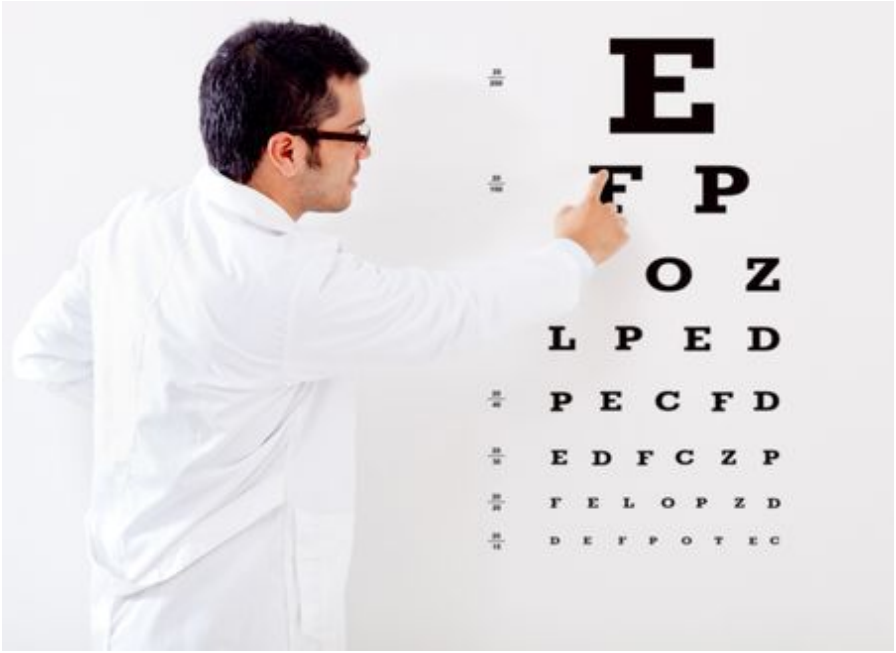
- The Mediators’ HMI will allow better adaptation to partially automated driving.

Method: participants

- Twenty-four participants, 12 females (Age: M=25.25, SD=2.83 years; Driving experience: M=7.25, SD=2.7 years) and 12 males (Age: M=27.3, SD=7.03 years; Driving experience: M=9.63, SD=7.26 years).

- Participants underwent visual acuity and contrast sensitivity tests to ensure they had a normal or corrected-to-normal vision (above 6/9).

- Participants declared they do not suffer from any cardiological problems, light sensitivity, or a tendency to headaches and nausea.



Method: apparatus

- **Driving simulator** - High fidelity RTI driving simulator consists of an engineless Cadillac-STS and a 7m diameter curved screen with three laser projectors displaying the virtual world on the curved screen.

Driving simulator

- **Eye tracker** - TOBII Pro Glasses 2 head-mounted Eye Tracking System.

TOBII Pro Glasses 2 Eye Tracking System

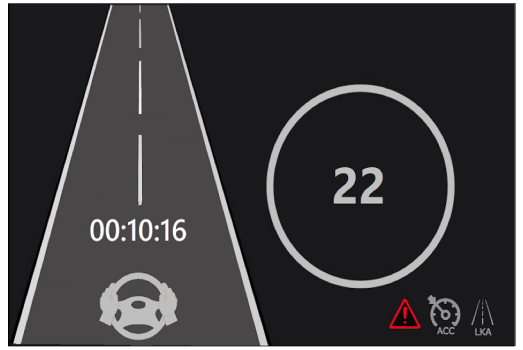
- **ECG** - BioPac ECG MP150 system consists of a matched wireless transmitter and receiver modules.

- **Questionnaires**
  - Demographics
  - Previous experience and familiarity with automation
  - Adoption and trust of automation
  - Workload – NASA TLX
  - Usability of the Mediator system
  - Knowledge verification regarding Mediator's HMI functionality

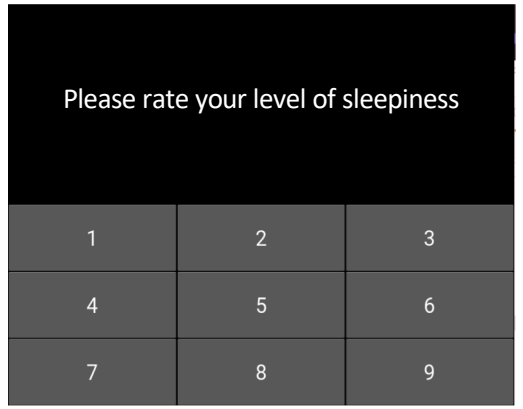
ECG BIOPAC system

Method: apparatus (cont.)

- **Mediator's HMI** – Presented on two in-vehicle displays. A dashboard panel behind the steering wheel and an infotainment screen on the central console.
- **NDRT Trivia game** – Participants could engage with batches of 11 multiple-choice questions. The question and the possible answers were read out loud.
- **Drive and scenarios** - Each drive session lasted approximately 40 minutes, usually on a straight urban or highway road, and included four unmaterialized hazard scenarios. Each scenario presented a latent cue that could be spotted from a distance.

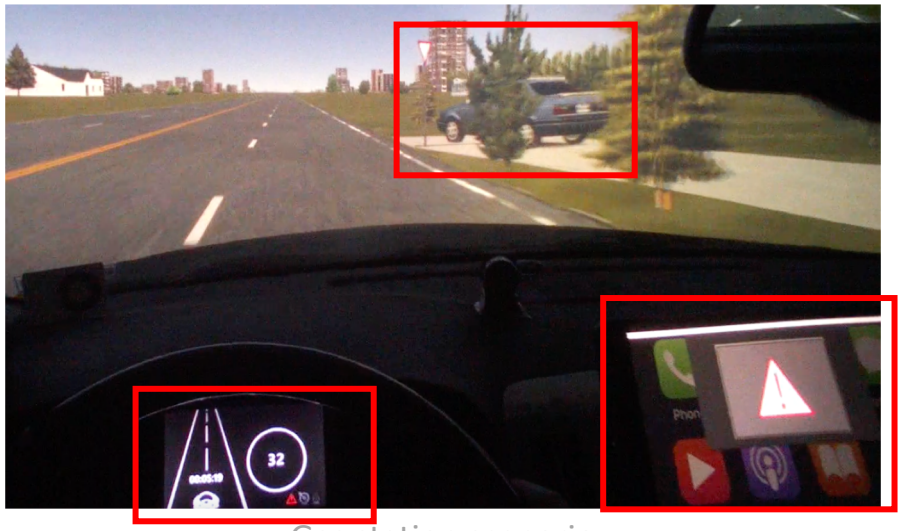


Dashboard



KSS questionnaire

Trivia game


Gas station scenario

Trivia suggestion

Method: experimental design

- Participants were randomly assigned to one of two experimental conditions (12 participants each): (1) with an NDRT or (2) without an NDRT (between-subjects independent variable).

- Participants drove two driving sessions of the same experimental condition one week apart (within-subject independent variable).

- Gender was balanced within each experimental condition, and scenarios were partially counterbalanced between participants.

- Dependent variables:
  - KSS questionnaire ranking.
  - HRV (RMSSD & SDNN).
  - Eye tracking – cue and hazard identification; scanning patterns.
  - Automation activation.
  - Questionnaires.

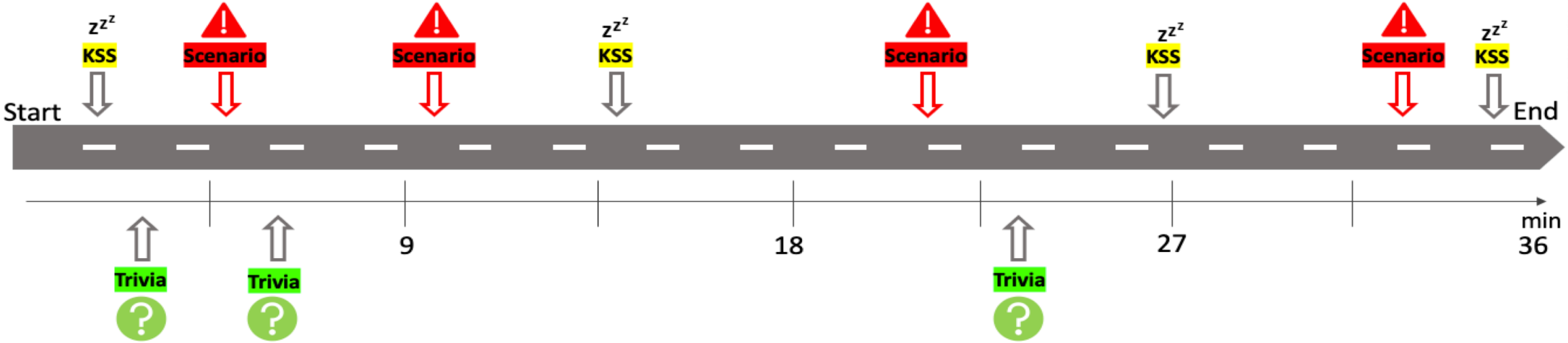
- All statistical analyses were performed using Linear Mixed Models (LMM).
  The participants were included as a random effect.

Method: procedure

Participants were told:
- To drive as in real-world situations.
- The driving task is under their sole responsibility.
- They should keep driving under automation mode unless manual overtake was required.

vision tests → written instructions → ECG and eye tracker → 5 min training session → 40 min experiment drive → post-drive questionnaire

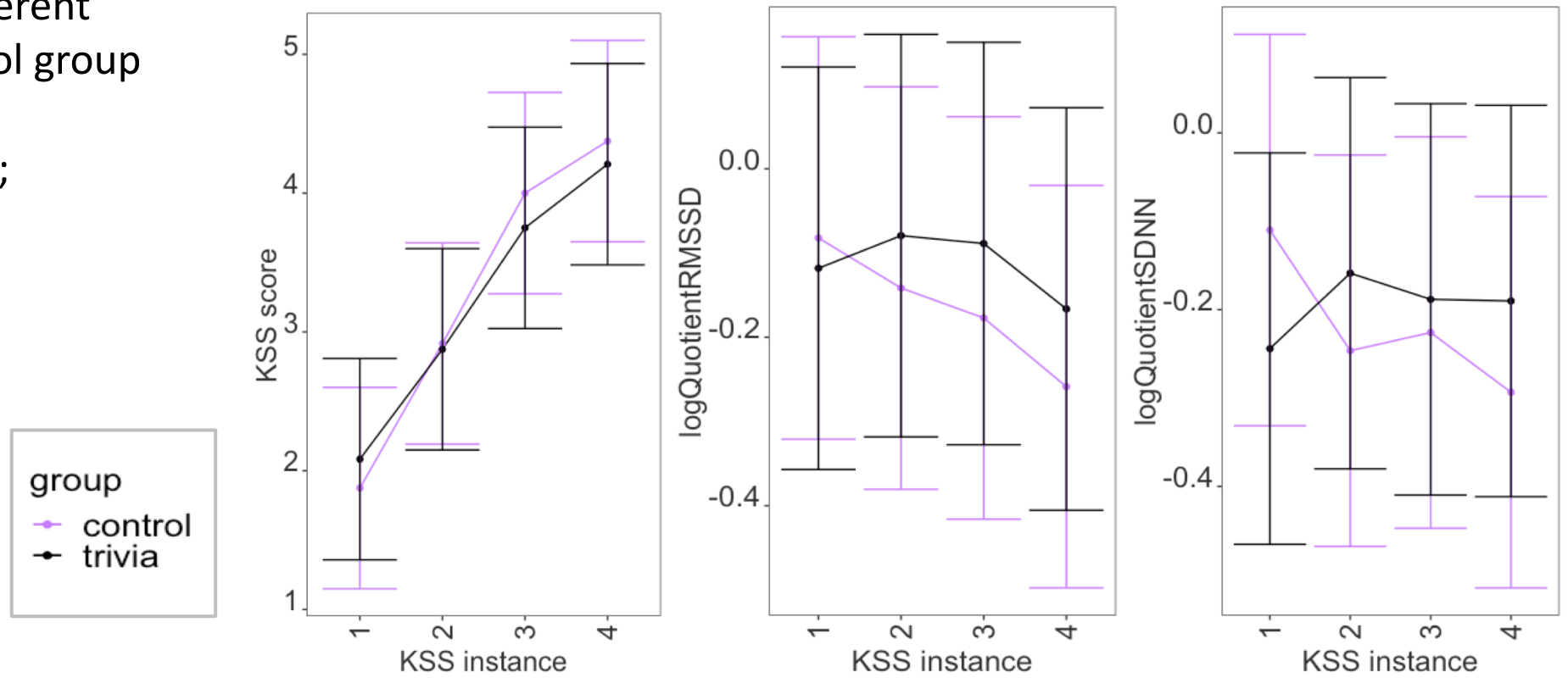
same procedure for the second session



Results: fatigue progression (KSS and HRV)

- The final KSS model yielded a significant main effect of KSS instance (X_3^2 =172.5, p<.01).
- The main effect of KSS instance was non-significant in the HRV models (RMSSD and SDNN); (X_3^2 =2.077, p=.55) & (X_3^2 =0.506, p=.92) respectively.
- KSS and HRV measures for sleepiness were not significantly different between Trivia and Control group (KSS: X_1^2 =0.02, p=.89; RMSSD: X_1^2 =0.156, p=.69; SDNN: X_1^2 =0.046, p=.83).

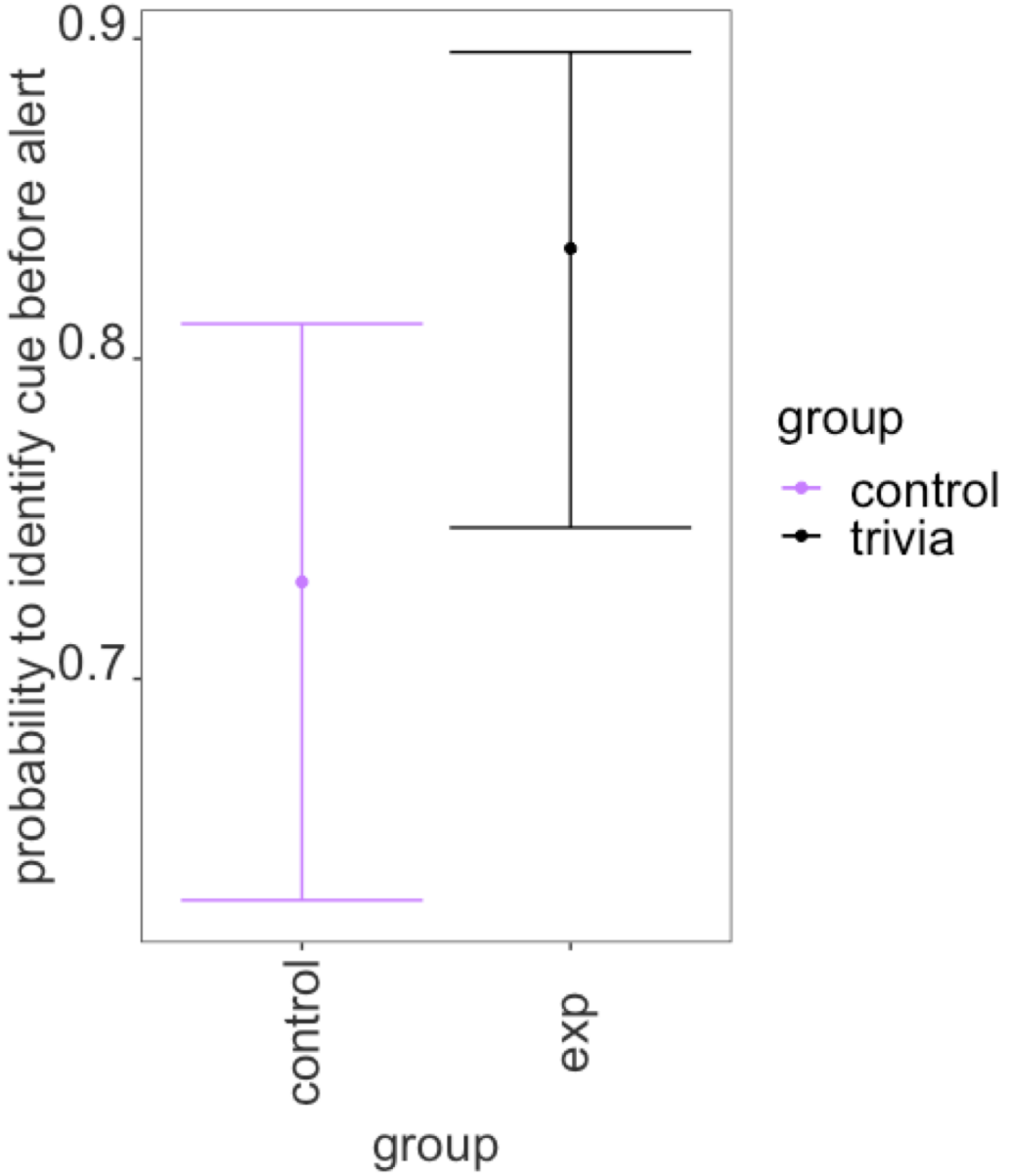
HRV was measured in time windows of 45 seconds preceding the KSS questionnaire's instance.



Results: SA and adaptation

- The probability of identifying the cue preceding a hazard and hazard alert notification was significantly (marginal) higher for the Trivia group than for the control group (X_1^2 =3.501, p=.06).

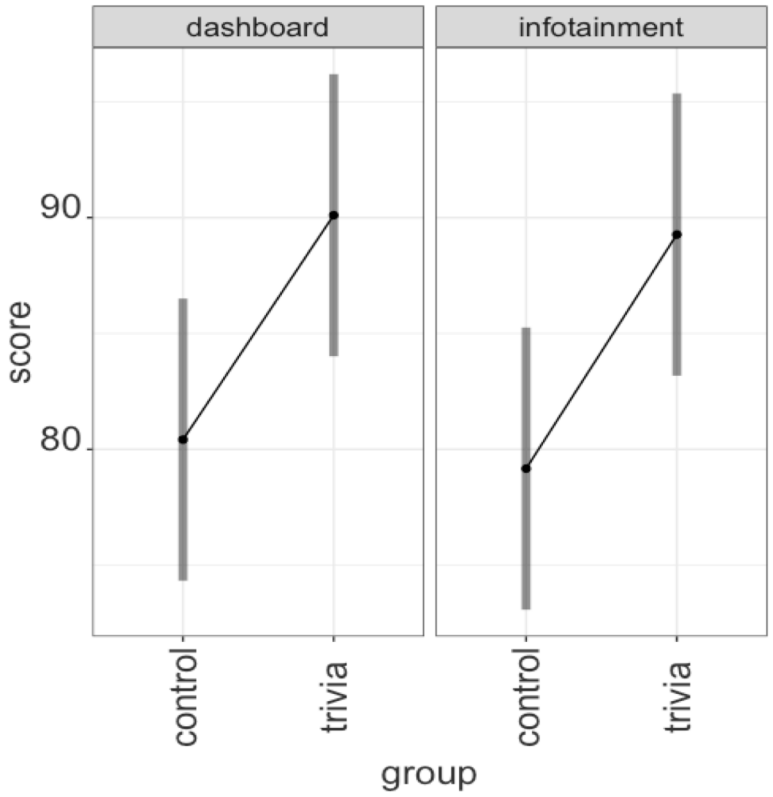
- After the alert appeared, the Trivia and control groups had similar probabilities of identifying a hazard (X_1^2 =0.638, p=.42) or deactivating the automation (X_1^2 =0.325, p=.57).

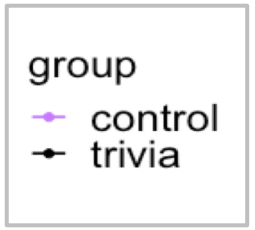


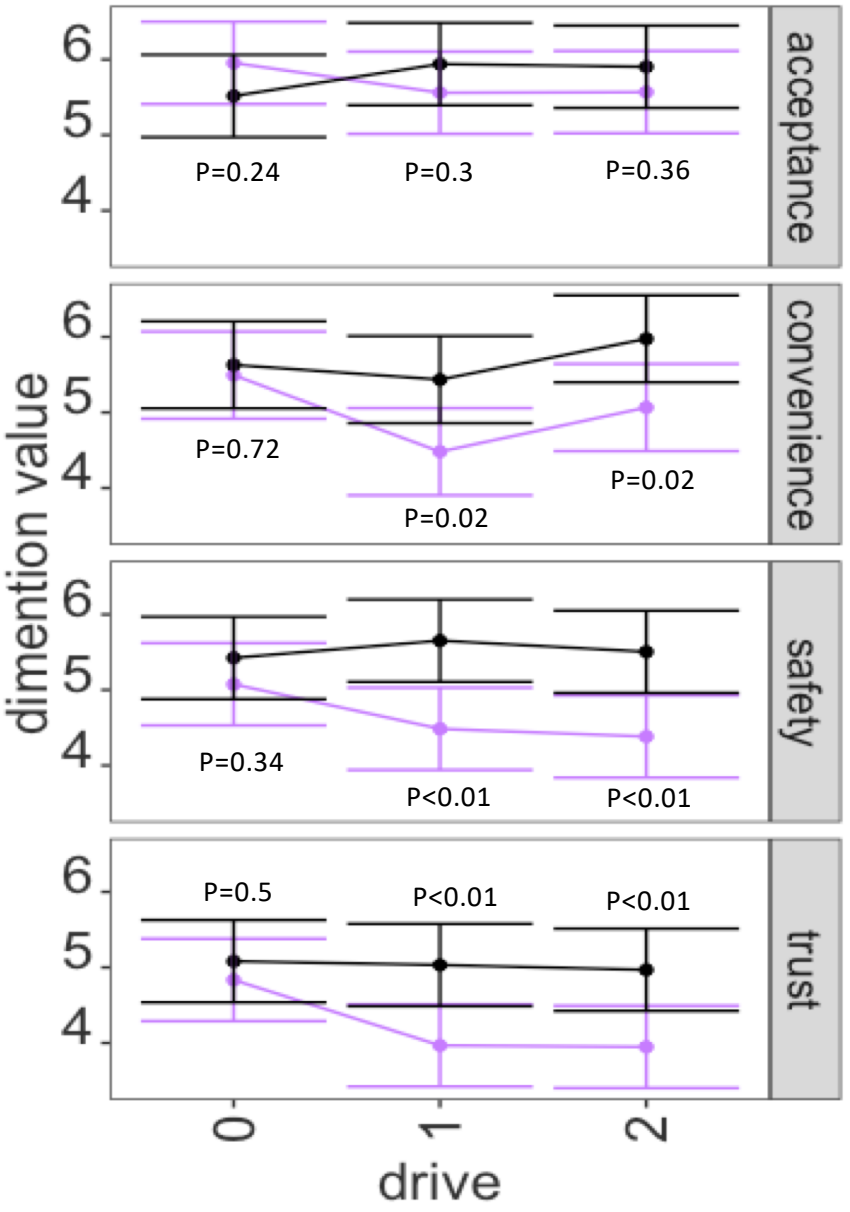
Results: adaptation

- Convenience, trust, and safety perception of automated vehicles were rated higher by the Trivia group after both drives.

- Usability of both dashboard and infotainment systems was rated higher by the Trivia group.



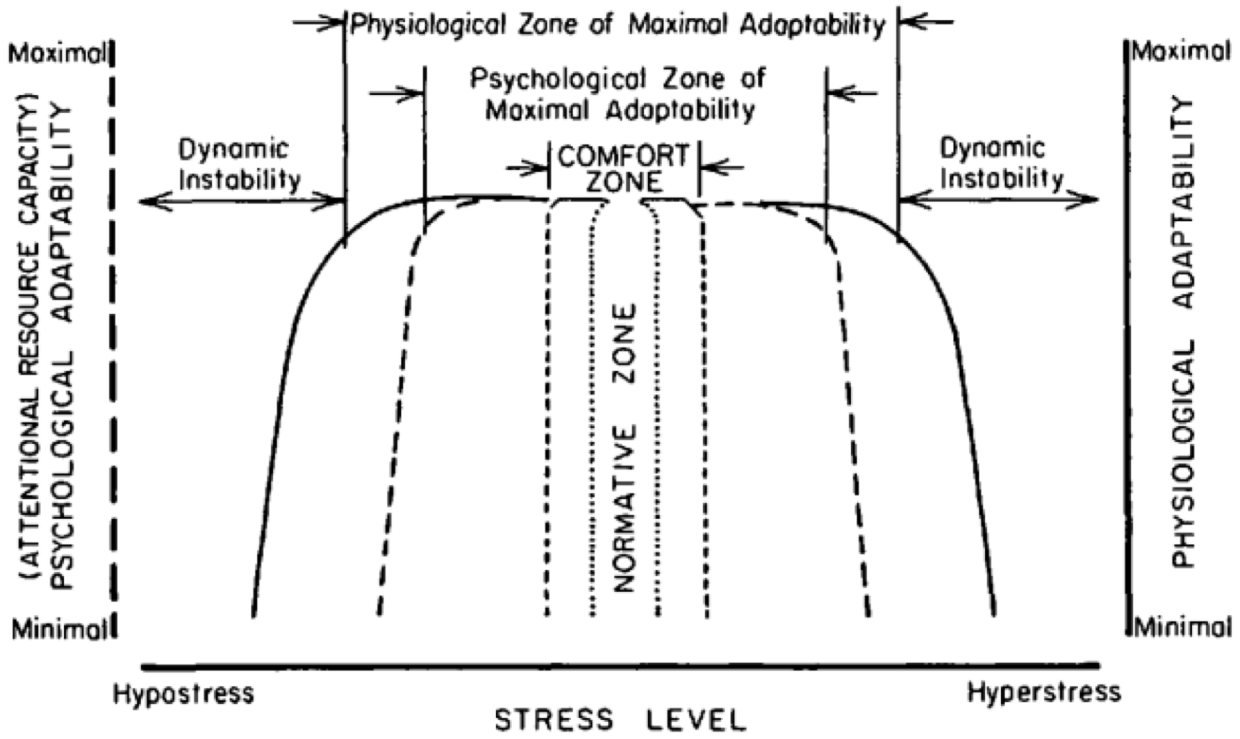




Discussion: task load stress and adaptability response

- Task demand is the primary source of stress and can vary between extreme values of underload and overload.

- The range between those two extremes gradually affects the nested levels within the extended-U function: the comfort zone, physiological, and psychological levels.

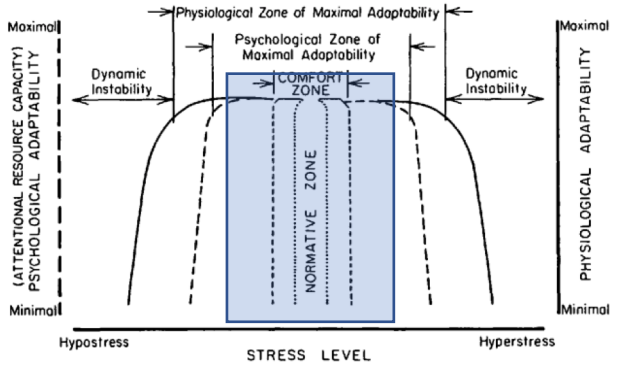


The stress-adaptation model of Hancock and Warm (1989)

Discussion (cont.)

- Fatigue progression during the drive was observed only at the psychological level (KSS).
- The engagement with an NDRT of Trivia was ineffective in stalling fatigue progression (KSS and HRV) but did help in maintaining situation awareness and vigilance in hazardous scenarios (cue identification).

We thus argue that drivers in this study demonstrated psychological adaptation but not physiological adaptation.



- The Mediator's HMI concept of scenario alert successfully mitigated NDRT's effects on vigilance deterioration (hazard identification and automation deactivation).
- The Trivia group showed better cognitive adaptation for using PAD (convenience, trust, and safety questionnaires) and the Mediator's HMI (usability questionnaires).

Discussion and conclusions

future analyses of this study

- Long-term effects on behavioral adaptation, reliance on automation, fatigue and workload.
- Performance, trust, and fatigue analysis between different groups within the study.

study limitations and future work

- Longer drive duration.
- Different partitions or difficulty of the Trivia game.
- Other variations of physiological measures.

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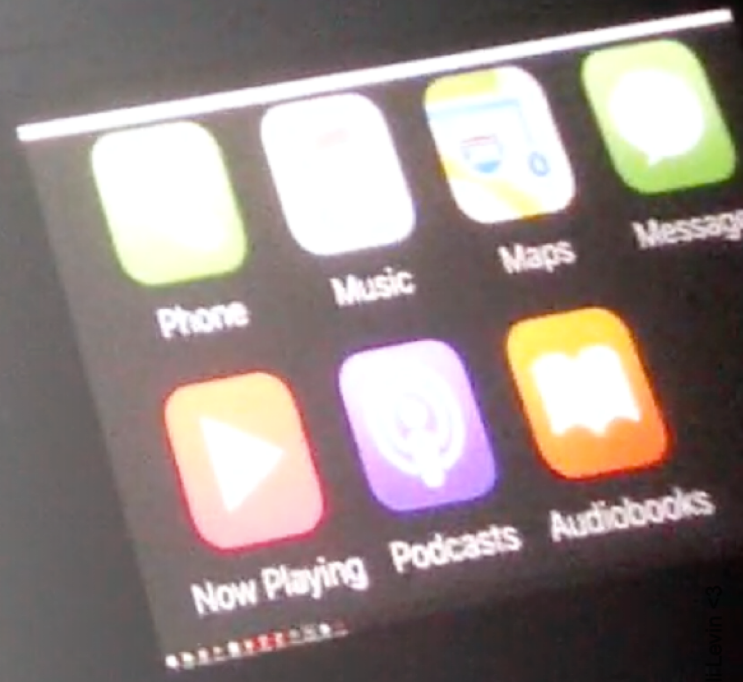

Mediator

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more about the Mediator project:
https://mediatorproject.eu/

Appendix: statistical analysis

- Initial full model (LMM)

$$y = \beta_0 + \beta_1 group + \beta_2 drive + \beta_3 gender + \beta_4 kssInstance + \beta_5 group * drive + \beta_6 group * gender + \beta_7 group * kssInstance + \beta_8 drive * gender + \beta_9 drive * kssInstance + \beta_{10} gender * kssInstance + v_0 participant + \epsilon$$

- Model ANOVA: Wald chi-square test
- Post-hoc analysis: contrast pairwise comparisons (Tukey's HDS)
- Significance level: α = .05

Appendix: references

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