

More Lives Saved



More Life Lived



Human-machine interface designs assisting drivers of automated vehicles during transitions: evaluation from end-user perspective

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Background

- This research was part of the Mediator project funded from the European Union's Horizon 2020 research programme under the grant agreement no. 814735.
- Automation levels (AD: Assisted driving and PD: Piloted driving) and its transitions needs to be communicated.
- Need for novel HMI interfaces.
- Multimodality improve recognition, understanding and promotes faster reactions (van Erp et al., 2015; Petermeijer et al., 2016, Manawadu et al., 2017).
- Light displays (LED strips) for communicating automation mode & transitions (Yang et al., 2018, Muthumani et al., 2020, Wilbrink et al., 2020, Dziennus et al., 2016).
- Positioning the light displays inside vehicle interiors.

Objective

- Compare additional displays on two locations (steering wheel vs bottom of windshield).
- Use case: communicating automation levels (AD-Assisted Driving, PD-Piloted driving) and transitions between the levels including manual driving.
- Three multimodal HMI (HMI-1, HMI-2 with additional light display and baseline without it).



HMI-1


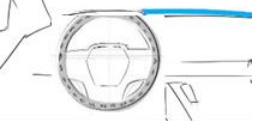






HMI-2



Baseline

HMI design & framework (HMI-1)

Interfaces	Manual	Assisted available	Assisted activating	Assisted driving	Piloted available	Piloted activating	Piloted driving	Planned transfer initiation	Unplanned transfer initiation	Manual
 LED on SW		✓	✓	✓	✓	✓	✓	✓	✓	
 LED on windshield										
 Instrument cluster		✓	✓	✓	✓	✓	✓	✓	✓	
 Voice messages		✓		✓	✓		✓	✓	✓	
 Seat belt pull									✓	
 Touch pads			✓			✓				

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HMI-1 (Assisted)



HMI-1 (Piloted)



HMI-2
(Assisted)



HMI-2
(Piloted)



HMI-1 (Planned TOR)



HMI-1 (Unplanned TOR)



HMI-2 (Planned TOR)



HMI-2 (Unplanned TOR)

Experimental design

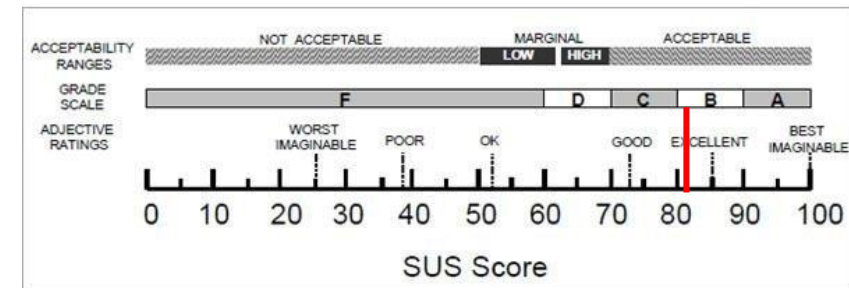
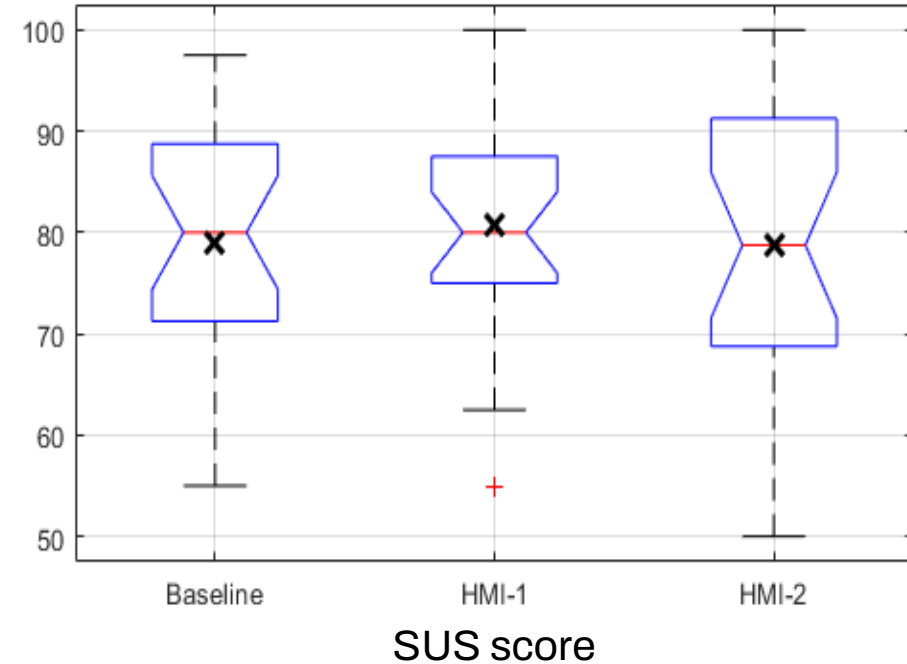
- Fixed base driving simulator.
- Three-lane motorway with no traffic.
- Assisted mode (AD): No feet on pedals, hands-on steering wheel and monitor.
- Piloted mode (PD) : No feet on pedals, no hands-on steering wheel, engage in secondary task (DOTS game).
- 24 volunteers, 4 groups , drove 3 laps (16 min per lap) with one HMI design.
- Data collection: System Usability Score (SUS) score, HMI desirable aspects, HMI design ranking.

Groups	Lap1	Lap2	Lap3
G1	Bas (P)→ (U) → (P)→ (U)	HMI-1 (U)→ (P) → (P)→ (U)	HMI-2 ((P)→ (U) → (P)→ (U)
G2	HMI-2 (P)→ (U) → (P)→ (U)	HMI-1 (U)→ (P) → (P)→ (U)	Bas (P)→ (U) → (P)→ (U)
G3	Bas (P)→ (U) → (P)→ (U)	HMI-2 (U)→ (P) → (P)→ (U)	HMI-1 (P)→ (U) → (P)→ (U)
G4	HMI-1 (P)→ (U) → (P)→ (U)	HMI-2 (U)→ (P) → (P)→ (U)	Bas (P)→ (U) → (P)→ (U)

Baseline = No LED, HMI-1= Steering wheel LED, HMI-2 = Windshield LED, P= Planned TOR, U = Unplanned TOR

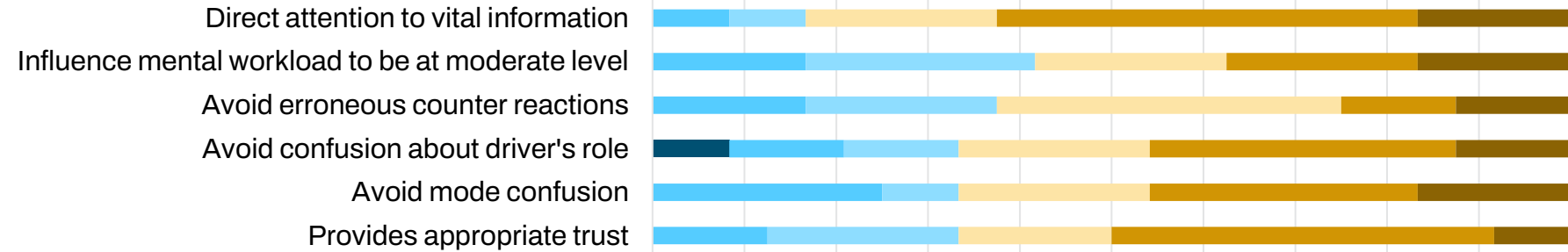
Results: SUS score

- Measure of people's subjective perception of usability of the system.
- Baseline : 79
- HMI-1 : 81
- HMI-2 : 79
- No statistical significance (repeated-measure ANOVA between the HMI designs ($F(2,69)=0.19, p = 0.834$)).

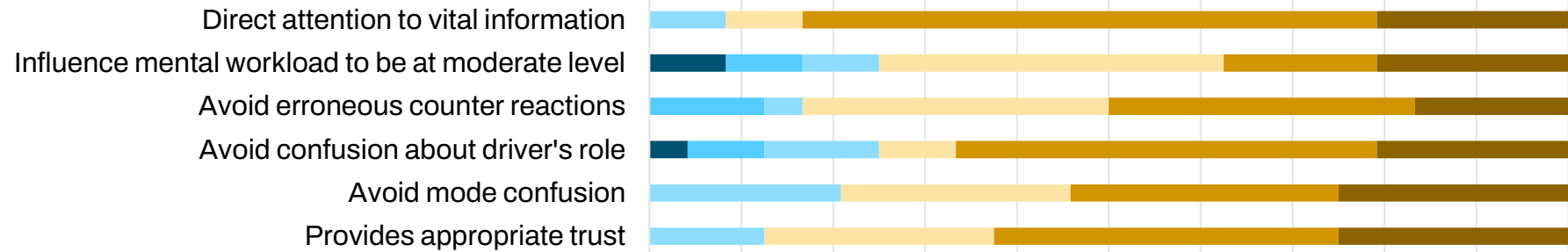


Grade rankings of SUS scores from “Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale,” by A. Bangor, P.T. Kortum, and J.T. Miller, 2009, Journal of Usability Studies, 4(3), 114-123.

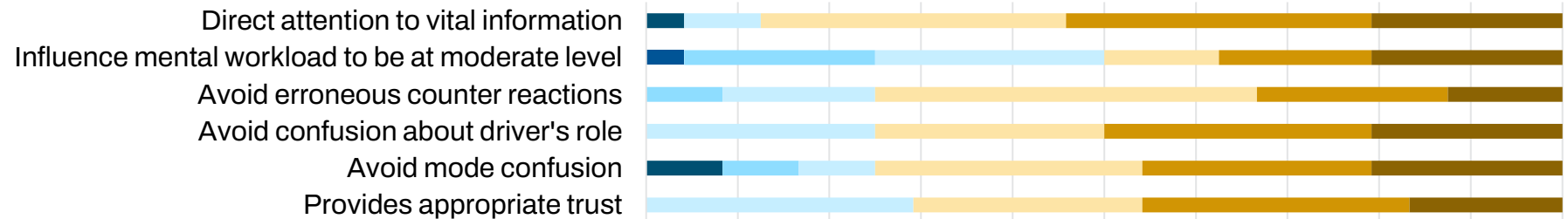
HMI desirable aspects



Baseline



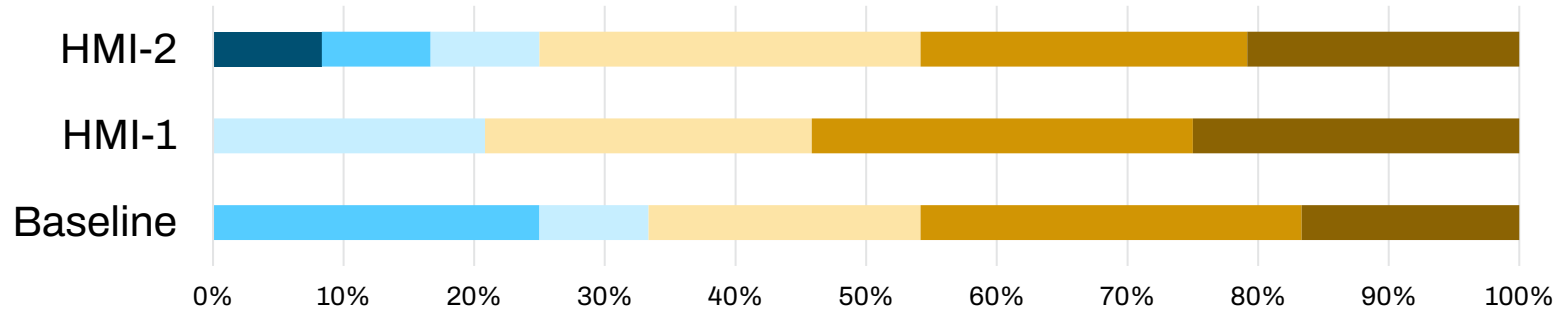
HMI-1



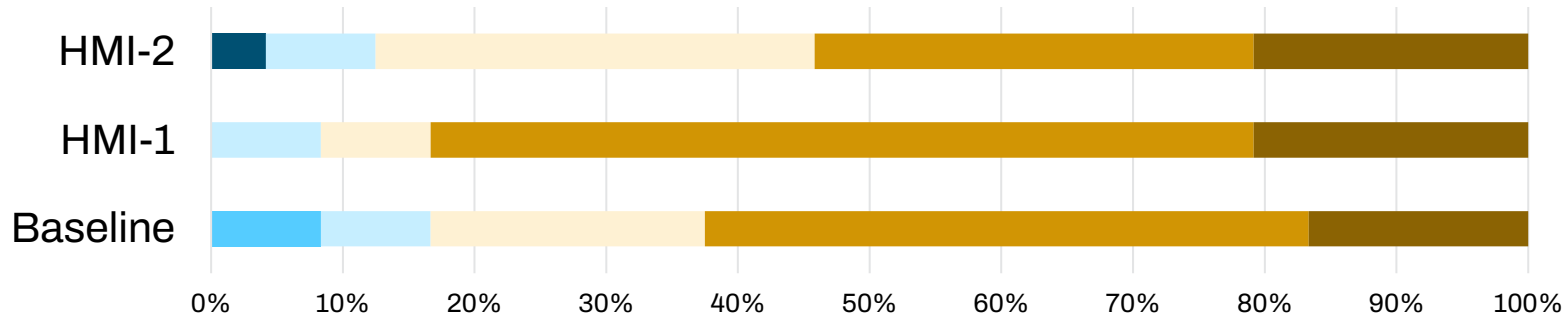
HMI-2
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0.0% 10.0% 20.0% 30.0% 40.0% 50.0% 60.0% 70.0% 80.0% 90.0% 100.0%
 ■ Strongly disagree ■ Disagree ■ Somewhat disagree ■ Neutral ■ Somewhat agree ■ Agree ■ Strongly agree

HMI desirable aspects



Avoids mode confusion



Direct attention to vital information

■ Strongly disagree
 ■ Disagree
 ■ Somewhat disagree
 ■ Neutral
 ■ Somewhat agree
 ■ Agree
 ■ Strongly agree



Baseline

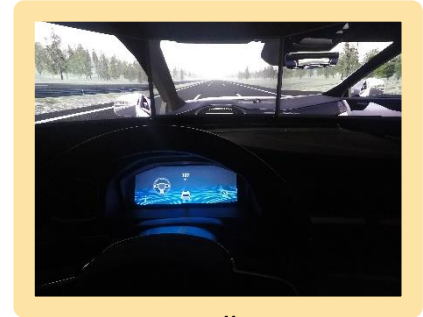
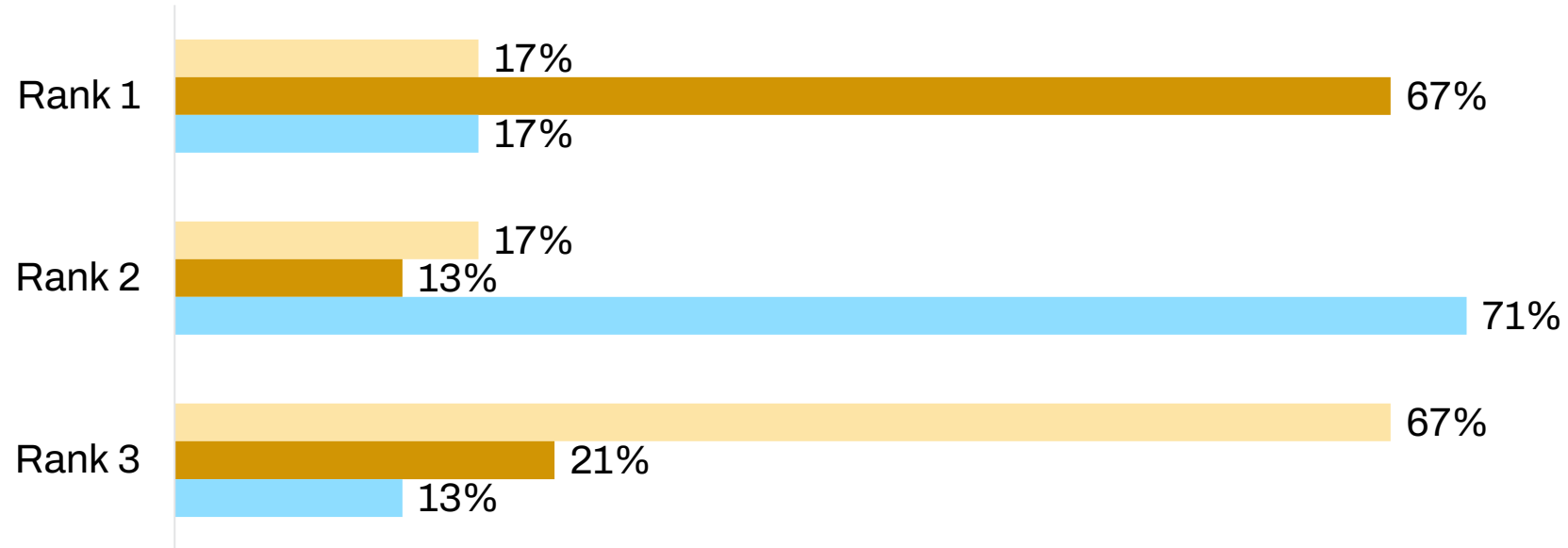


HMI-1



HMI-2
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HMI design ranking



Baseline



HMI-1



HMI-2



Interview responses

- Activation routine is longer, could be simpler, now I must listen to voice, see light bar, see cluster to get one information, it could be improved, just one push button and I'm there (1).
- I do like the LEDs showing activated mode, I do like the LED showing progress towards taking control (count down).
- Not sure if I liked the LEDs indicating that the two modes were ready for activation. Think I would rather leave that function behind (1); animations could be avoided (1).

Summary

- HMI-1 received a higher mean SUS rating (81) than HMI-2 (79) and baseline (79).
- Desirability of HMI designs : HMI-1 received the high rating.
- HMI design ranking : 67% of participants preferred HMI-1 as rank 1.

Limitations

- No hazard or threat situation in the simulated environment.
- LED illumination patterns.
- Sample size.

Conclusion

- HMI-1 with visual cues on steering wheel for communicating automation levels and transitions, improve
 - perceived usability,
 - desirability and
 - user preference.
- Personalization of HMI elements can further improve the attractiveness of HMI design.



Thank you

Reach out
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