How should a minimal risk maneuver of a highly automated shuttle be communicated to its users via its internal human-machine interface? Applying the media richness theory to user-centered interface design.

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BACKGROUND

- New traffic situations are challenging for highly automated vehicles (HAVs) if they exceed the systems' capabilities [1,2]. If a situation is identified as unsolvable, the HAV applies a Minimal Risk Maneuver (MRM) and stops.
- As a result of MRMs, passengers may experience negative emotions such as insecurities, since they have no driver to communicate with directly [3].
- Increased media-richness, integrated into an internal human-machine interface (iHMI), may surrogate for the missing driver and increase user experience and trust in the system [4,5,6]. Different levels of media-richness may be achieved by using different designs of the vehicles iHMI [7].

Research Question: Can media-rich iHMIs in HAVs improve passengers' user experience and trust in HAVs during MRMs?

METHOD

Simulator-study (N = 29 [8 female]; M_{age} = 44.55; SD_{age} = 19.92)

Task / Scenario
- Participants experienced a virtual-reality drive through a city as a passenger in an HAV. They encountered three different problematic situations, resulting in the HAV executing an MRM.

Stimuli
- Three interfaces were used to manipulate media-richness and were randomly presented with the situations in a block design.

1. A **visual iHMI** showed the route of participants with additional information on the MRM (see fig. 1).
2. A **visual + voice iHMI** provided the passenger with additional information compared to the visual interface.
3. Lastly, a **visual + voice + avatar iHMI**, powered by MetaHumans in UE5, was shown for most media-richness, temporarily interrupting the visual interface (see fig. 2).

Dependent variables measured after each interface variant:
- Trust in Automation: German version of the Trust in Automation Questionnaire (TiA; [5]) with 19 items on a Likert scale from 1 = *Strongly disagree* to 5 = *Strongly agree* (e.g., "The system works reliably.").
- User Experience Questionnaire : German version of the User Experience Questionnaire (UEQ-S; [6]) with eight items on a Likert scale from 1 to 7, e.g. *Inefficient* (1) – *Efficient* (7).

Figure 1: The interface showing the visual iHMI with MRM information.

Figure 2: The interface showing the avatar iHMI during an MRM.

RESULTS

Trust in Automation

- Significant differences in trust towards the HAV were found via RM-ANOVA, Greenhouse-Geisser $F(1.93, 0.15) = 4.13$, $p = .023$. (see fig. 3)
- Bonferroni-adjusted post-hoc analysis revealed significantly higher values for the visual + voice interface compared to the visual only interface (MDiff = -0.17, 95%-CI[-0.26, -0.01])

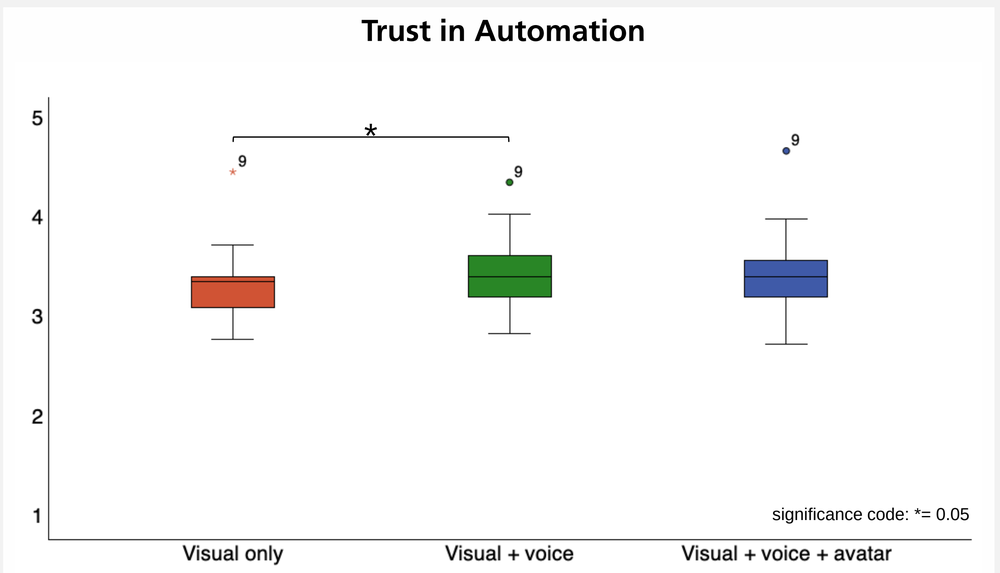

Figure 3: Reported trust in automation for each interface condition.

User Experience

- Significant differences in user experience were shown via a RM-ANOVA, Greenhouse-Geisser $F(1.88, 2.97) = 6.22$, $p < .004$ (fig. 4).
- Bonferroni-adjusted post-hoc analysis revealed significantly higher values for the visual + voice interface (MDiff = -0.5, 95%-CI[-0.92, -0.08]) and the visual + voice + avatar interface (MDiff = -0.6, 95%-CI[-1.07, -0.07]) compared to the visual

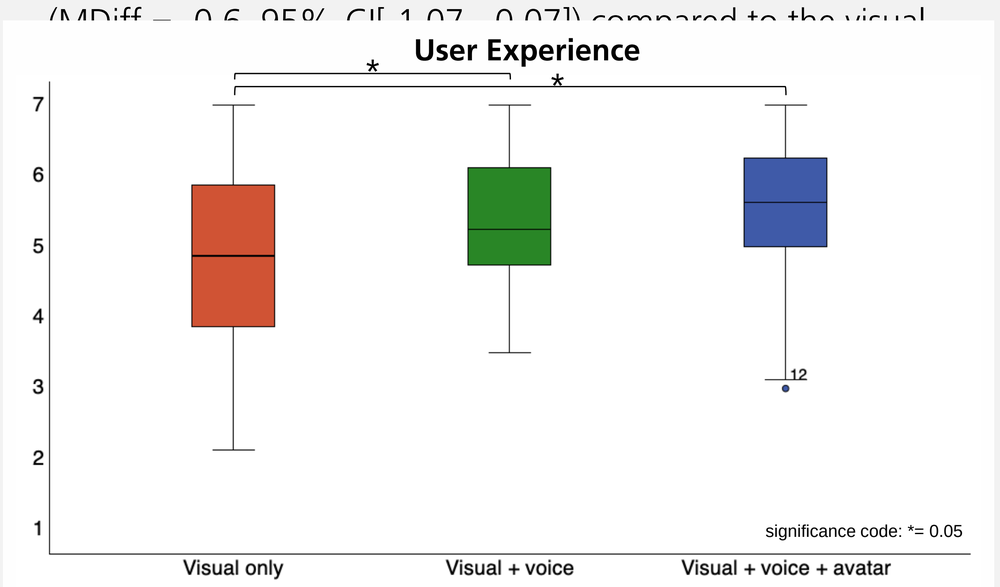

Figure 4: Reported user experience for each interface condition.

CONCLUSION

- Higher levels of media-richness can increase trust in the HAV during MRMs.
  → However, this effect could only be shown for the visual + voice condition.
- Both conditions with more media-richness provided a significantly better user experience than the visual interface only condition.
  → Higher levels of media richness can improve user experience in HAVs.
- As there were no significant improvements for trust in the avatar condition, more situations of increasing criticality may provide further insights.
- Also, the effect on user experience might be affected by the avatar design and personal user preference.

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