

# How Automated Driving Systems can show their behavior: System Transparency for In-vehicle HMI of Highly Automated Vehicles to Improve User Experience

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BACKGROUND

- ADS face limitations in unfamiliar or complex traffic situations that their algorithms cannot resolve independently [1]. Remote Assistants (RA) can support the ADS in these situations [2].
  - The complexity of ADS leads to passenger confusion and psychological discomfort [3; 4]
  - Ecological Interface Design and Media Richness improve transparency by contextualizing information and transmitting social cues, enhancing understanding, trust, and user experience without overwhelming passengers [5; 6].
  - We compared ecological displays to enhance transparency and improve understanding, predictability, trust, and user experience.
- Research Question:** What are possible design guidelines to provide information about the system to passengers of ADS during different types of challenging situations without compromising the overall experience of passengers?

METHOD

**Lab-Study** (N = 37 [12 female];  $M_{age} = 34.19$ ;  $SD_{age} = 11.97$ )

**Task / Scenario**  
Participants experienced a VR simulation as passengers in a highly automated shuttle encountering different situations. Displays provided information with different levels of ecological design and social presence.

**Stimuli**  
Three HMI variants manipulating system transparency were tested, each presented with or without a social presence icon, across two situation types, resulting in four interface conditions:  
1. A **baseline HMI** without any additional information.  
2. A **text-based HMI** displaying information on the minimal risk maneuver (MRM) (see Fig. 1).  
3. An **ecological HMI** visualizing information on the MRM and the vehicles planning via color coding (see Fig. 2).  
4. A **combined HMI** integrating text and ecological visualization.

**Dependent variables measured after each interface variant:**

- Trust in Automation: Measured using the *Trust in Automation Questionnaire* (TiA; Körber, 2019; Körber & Gleissl, 2022)
- User Experience: Measured using the *User Experience Questionnaire* (UEQ; Schrepp et al., 2017)
- Additional Questions: interface specific aspects
- Preference Ranking of the three interfaces



Figure 1: Text-based HMI displaying information on the MRM.



Figure 2: Ecological HMI providing abstract information.

RESULTS

**Display Impact on Understanding, Predictability, and Trust**

- RM-ANOVA showed a significant effect on understanding and predictability ( $F(2.35, 84.58) = 58.43, p < .001, \omega^2 = 0.606$ ).
- RM-ANOVA showed a significant effect on trust ( $F(2.15, 77.71) = 51.824, p < .001, \omega^2 = 0.576$ ).

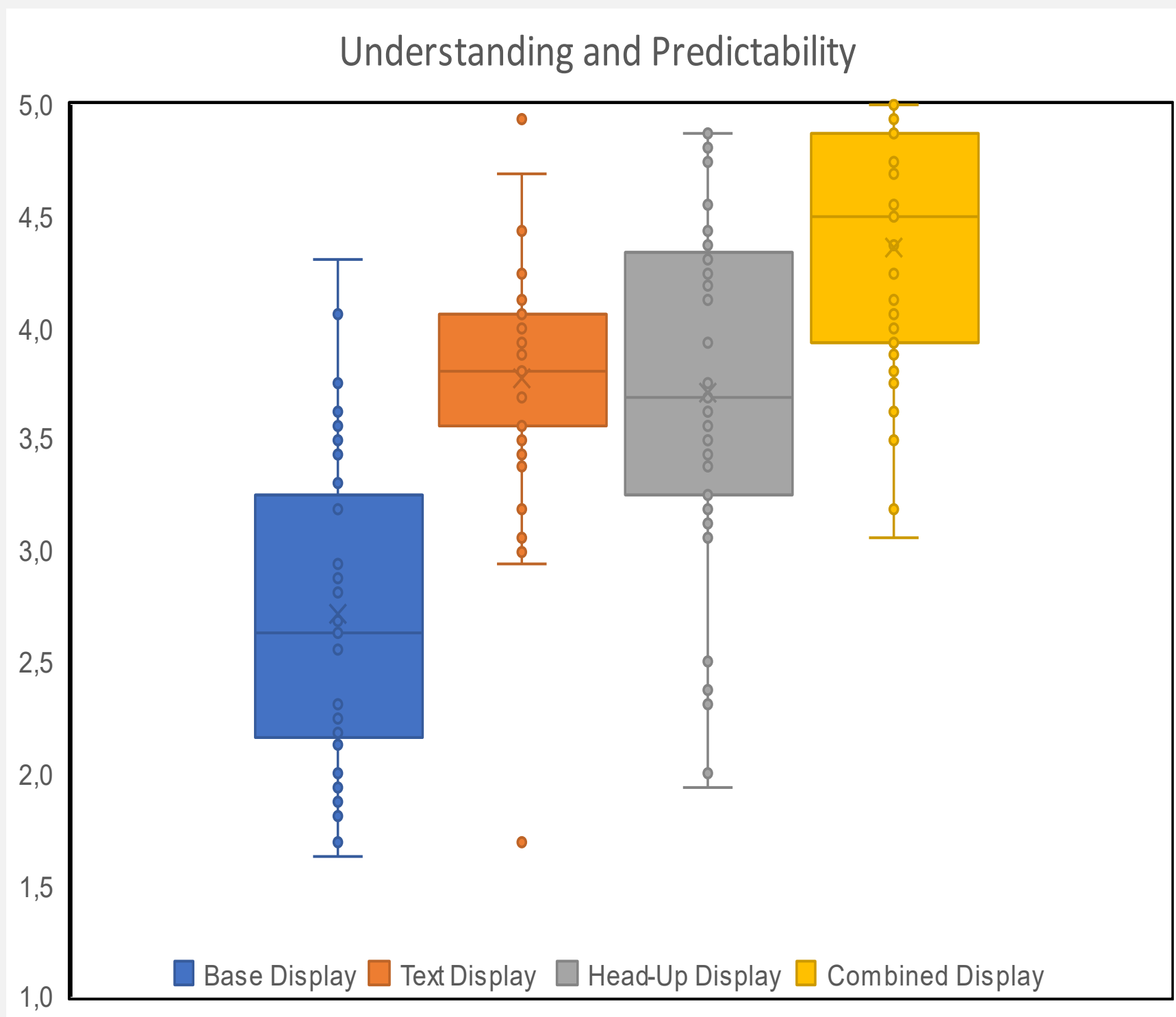


Figure 3: Understanding & predictability by different interfaces.

**Display Impact on User Experience**

- RM-ANOVA showed a significant effect on user experience ( $F(1.84, 66.23) = 50.129, p < .001, \omega^2 = 0.567$ ).

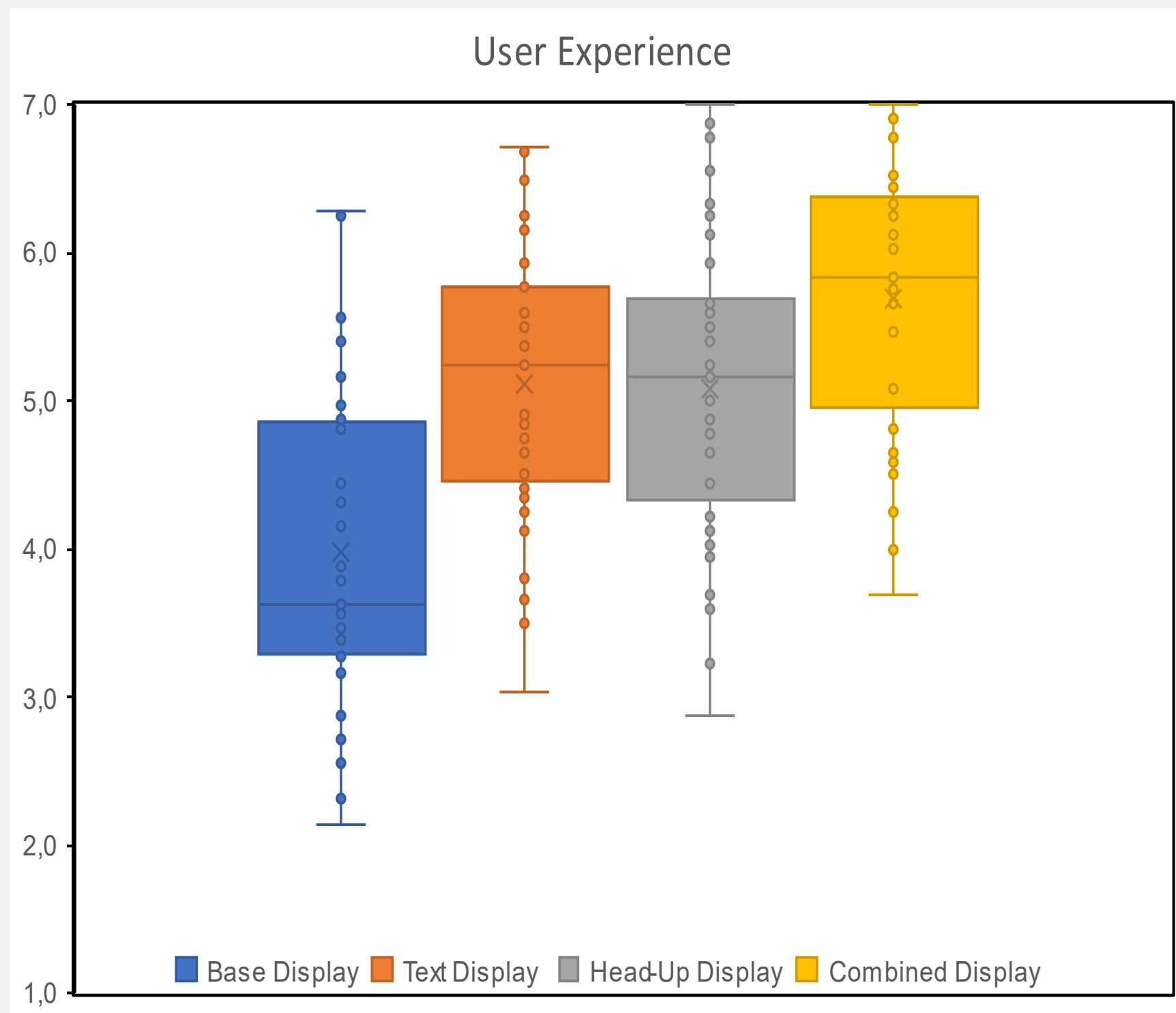


Figure 4: User experience by different interfaces.

**Operator Icon (Social Presence) Impact on Trust and User Experience**

- A paired-samples t-test showed a significant effect on user experience ( $T(36) = 2.48, p = .018$ ).
- A paired-samples t-test showed a significant effect on trust ( $T(36) = 2.25, p = .030$ ).

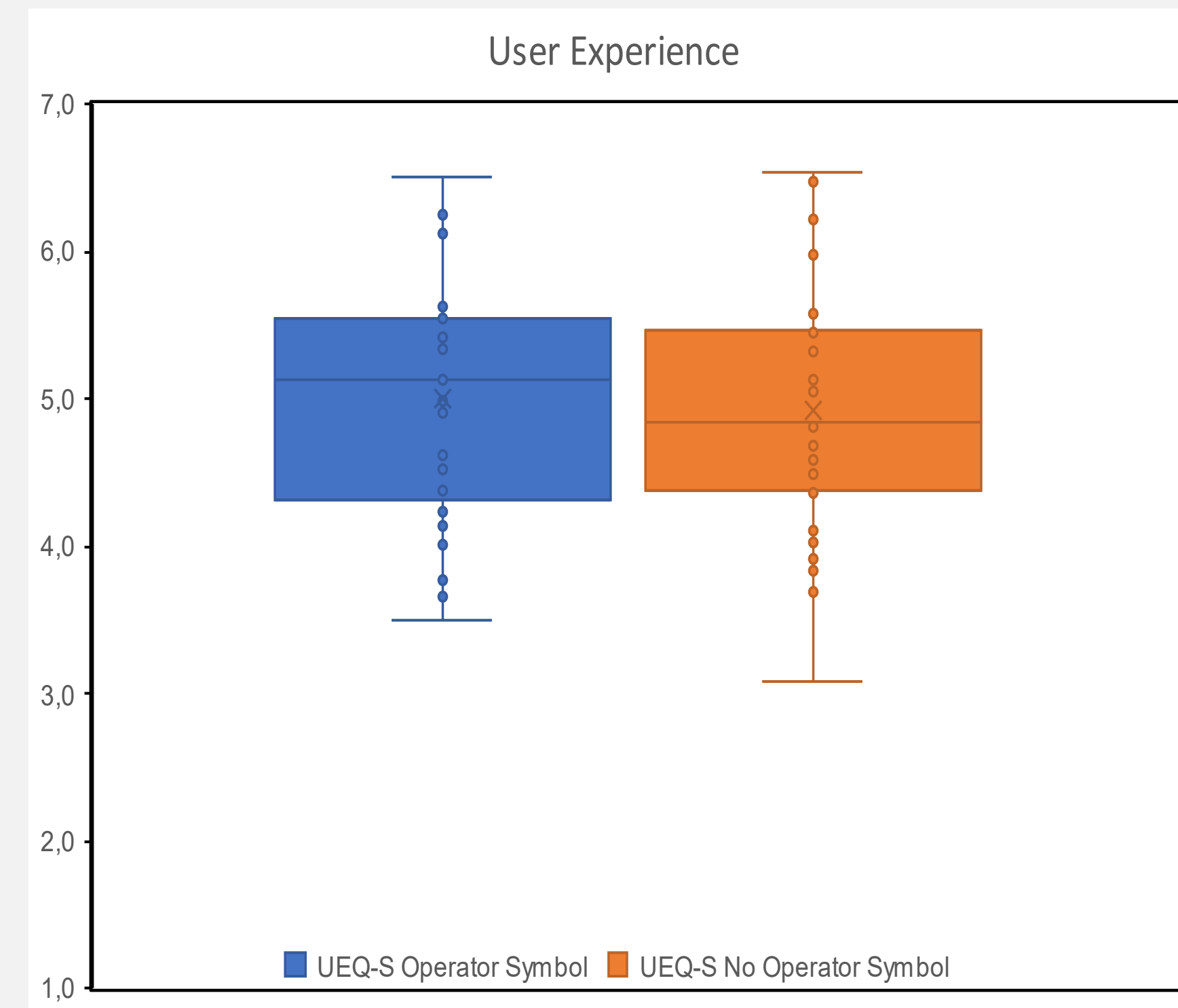


Figure 5: User experience by operator symbol.

CONCLUSION

- Ecological HMIs significantly improved understanding, predictability, trust, and user experience compared to the baseline [7; 8].
  - The combined design achieved the highest ratings, indicating ecological displays enhance transparency information [7].
  - Despite increased information density, user experience remained high, suggesting that an ecological interface supports users effectively without causing cognitive overload [7].
- Social presence significantly improved user experience and trust.
  - Results indicate that user experience may improve with social presence [9].

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