

# Steady, flashing, sweeping – An exploratory evaluation of light signals as an eHMI in automated driving

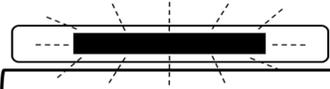
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## Introduction

**Communication** between **automated vehicles** (AVs), where the driver is potentially absent [1], and **vulnerable road users** (VRUs) requires a transformation to ensure road safety and comfort at different levels of vehicles' automation. External human-machine interfaces (**eHMIs**, e.g. light signals) could supplement implicit messages in ambiguous traffic situations [2]. Due to age-related impairments, the needs of **older traffic participants** should be considered in particular [3]. A total of  $N = 38$  participants (two age groups: <30 years vs. >65 years) evaluated three different light signals, presented by a light bar placed on a test vehicle's roof, in a field setting. Comprehensibility, trust [4], perceived usefulness and acceptance [5] of the signals were assessed. Results indicate that the displayed **signals are rather unintuitive** without prior information. Nevertheless, light signals as eHMIs were evaluated as **useful to communicate AVs' states and maneuvers to VRUs**. **Older participants** assessed the investigated signals consistently **more positive** compared to younger participants.

**Aim of the study: To test three different light signals as potential eHMIs in AVs with two different age groups.**

## Method

Between subjects	Within subjects	Field study
<p><b>Participants</b> (<math>N = 38</math>)</p> <p><i>Younger participants</i> (21–30 years)</p> <ul style="list-style-type: none"> <li><math>N = 19</math>; 9 women</li> <li><math>M = 27</math> years (<math>SD = 3.05</math>)</li> </ul> <p><i>Older participants</i> (66–82 years)</p> <ul style="list-style-type: none"> <li><math>N = 19</math>; 9 women</li> <li><math>M = 73</math> years (<math>SD = 4.08</math>)</li> </ul>  <p>Figure 1. The test vehicle with a light bar as an eHMI on top.</p>	<p><b>Light signals</b></p> <p><i>Automation mode</i>: steady light (vehicle in automated mode)</p>  <p><i>Starting mode</i>: flashing light (vehicle approaches)</p>  <p><i>Crossing mode</i>: sweeping light (VRU could cross in front of the vehicle)</p> 	<p><b>Apparatus</b></p> <p>Black Ford Tourneo Connect with light bar on top as eHMI</p> <p><b>Questionnaires</b></p> <p><i>7-point Likert-scale</i></p> <ul style="list-style-type: none"> <li>Comprehensibility,</li> <li>Trust [4],</li> <li>Usefulness of the <i>presented</i> light signals,</li> <li><i>General</i> usefulness of light signals as eHMIs in AVs;</li> </ul> <p><i>5-point rating-scale</i></p> <ul style="list-style-type: none"> <li>Acceptance [5]</li> </ul>

## Results

No sig. differences	For <b>Comprehensibility, Trust, Usefulness of the presented signals</b> and <b>General usefulness</b> there were:	$M_{<30 \text{ years}}$ ( $SD$ )	$M_{>65 \text{ years}}$ ( $SD$ )	
		Comprehensibility	4.70 (1.35)	5.42 (1.25)
		Trust [4]	5.08 (0.63)	5.46 (0.73)
		Usefulness ( <i>presented</i> )	5.47 (0.93)	5.95 (1.21)
		Usefulness ( <i>general</i> )	6.32 (0.81)	6.40 (1.00)

**Significant differences**

For **Acceptance** there were:

- Significant age differences for the scale *Usefulness* ( $F(1, 34) = , p = .006, \eta_p^2 = .20$ ; Figure 2); higher usefulness in older age group;
- Significant interaction between the age groups and the light signals regarding the scale *Satisfaction* ( $F(1.63, 57.09) = 4.35, p = .024, \eta_p^2 = .11$ ; Figure 3); higher satisfaction in older age group for automation mode and starting mode signals.

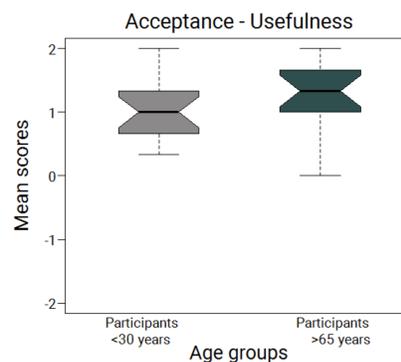


Figure 2. Acceptance – subscale usefulness.

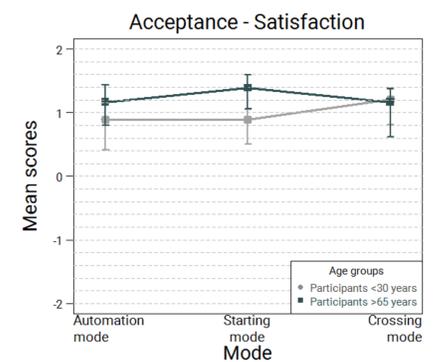


Figure 3. Acceptance – subscale satisfaction.

## Conclusion

### Findings

- Light signals were assessed more positive by *participants* >65 years, this might be to compensate for age-related impairments [3]
- Investigated* light signals were assessed as rather unintuitive without prior information, however light signals in *general* were considered as useful in AVs' context
- Differences between the age groups and signals' modes regarding the acceptance of the investigated light signals could be found

### Challenges

- Intuitive design** of light signals when used as eHMIs
- Adequate application of eHMIs if **implicit communication** should be supplemented [2]
- Considering particular requirements of **different user groups**

### Acknowledgements

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### References

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