

CROSSING THE STREET ACROSS THE GLOBE

A STUDY ON THE EFFECTS OF EHMI ON PEDESTRIANS IN THE US, GERMANY AND CHINA

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**BMW
GROUP**

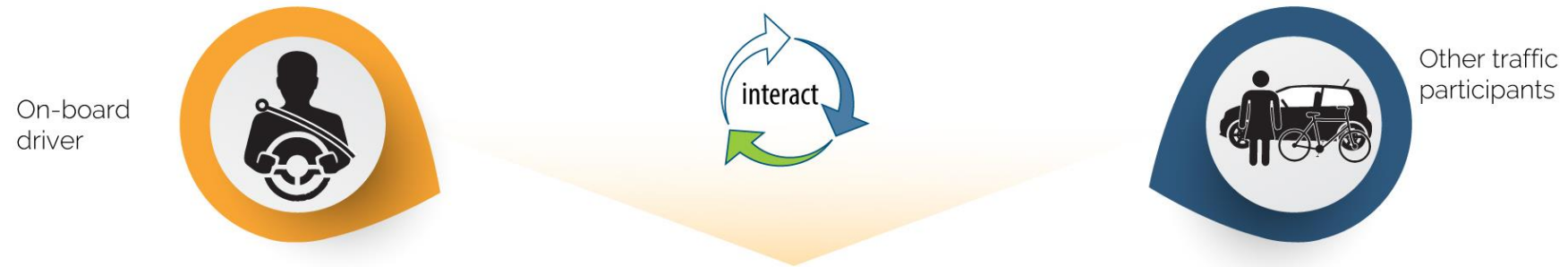
THE NEXT
100 YEARS



Rolls-Royce
Motor Cars Limited

THE CHALLENGE.

Situation Today



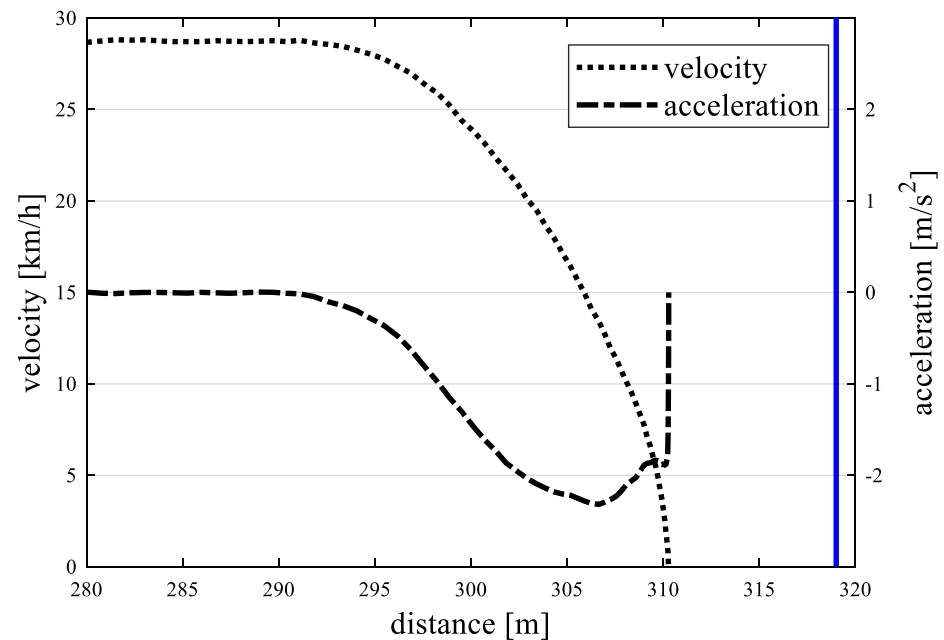
Future situation: Automated vehicles in mixed traffic environments



<https://www.interact-roadautomation.eu/about-interact/>

SHOWING VEHICLE INTENTIONS.

Driving behavior



(Fuest, Michalowksi, Träris, Bellem, Bengler, 2018)

Additional eHMI



CULTURAL DIFFERENCES AND THEIR IMPACT ON AVS AND EHMIS.

Culture and Driving behavior

- Driving behavior differs between China and the western world
- Expectations towards the behavior of other cars / AVs might be different between cultures

Culture and HMIs

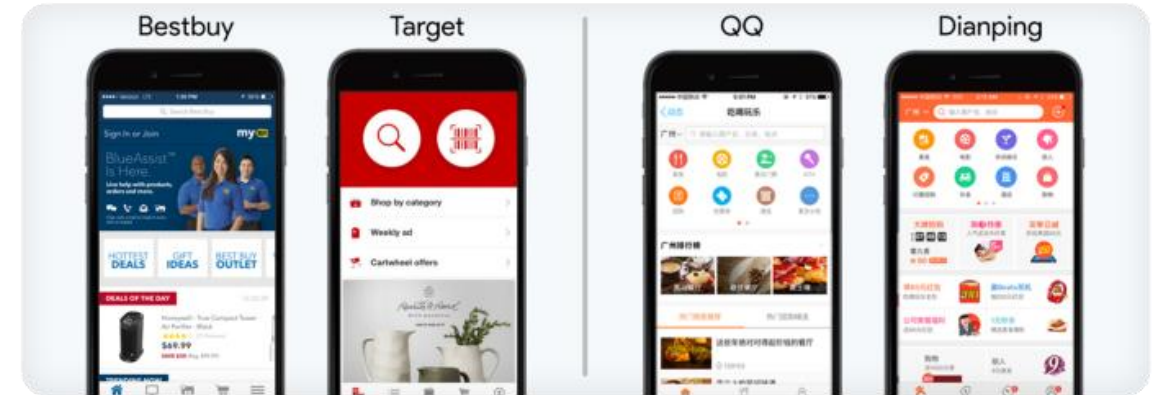
- HMIs differ depending on the cultural background
- Mental models and expectations of HMIs differ between cultures.

Attitude towards automated systems

- Differences have been found regarding attitude towards automation between Asians and Westerners

If eHMIs for AVs are introduced into different cultural contexts, there are two possible solutions:

- eHMIs are either not adapted by the manufacturer and must therefore work cross-culturally
- eHMIs are tailored to the specific markets into which the AV is introduced.



Different HMI patterns US vs. China

<https://medium.com/nyc-design/4-ux-trends-that-should-dominate-in-2019-d216ceec17f>

RESEARCH QUESTION.

// If the same eHMI concept was shown to people with different cultural backgrounds would they all understand it and benefit from it?



EXPERIMENTAL SETUP.

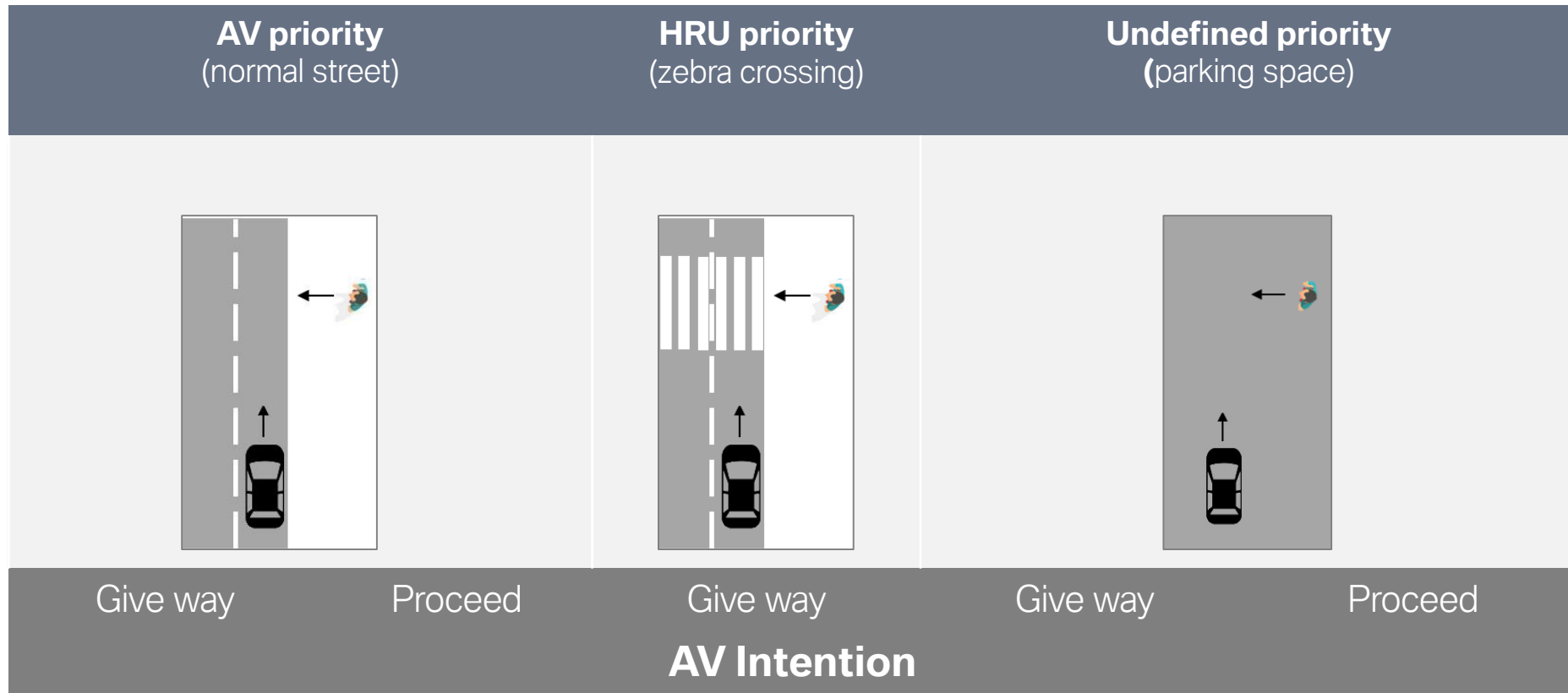


Study overview

- Virtual Reality study in urban environment with participants as pedestrians
- An automated vehicle is approaching from the left → Participants have to decide whether the car allows them to cross the street/ parking space or not. At the moment the participant has recognized the intention of the AV a button is pressed and the simulation is stopped







EXPERIMENTAL SETUP.

// Traffic scenes & priority












EXPERIMENTAL SETUP.

// eHMI Variants

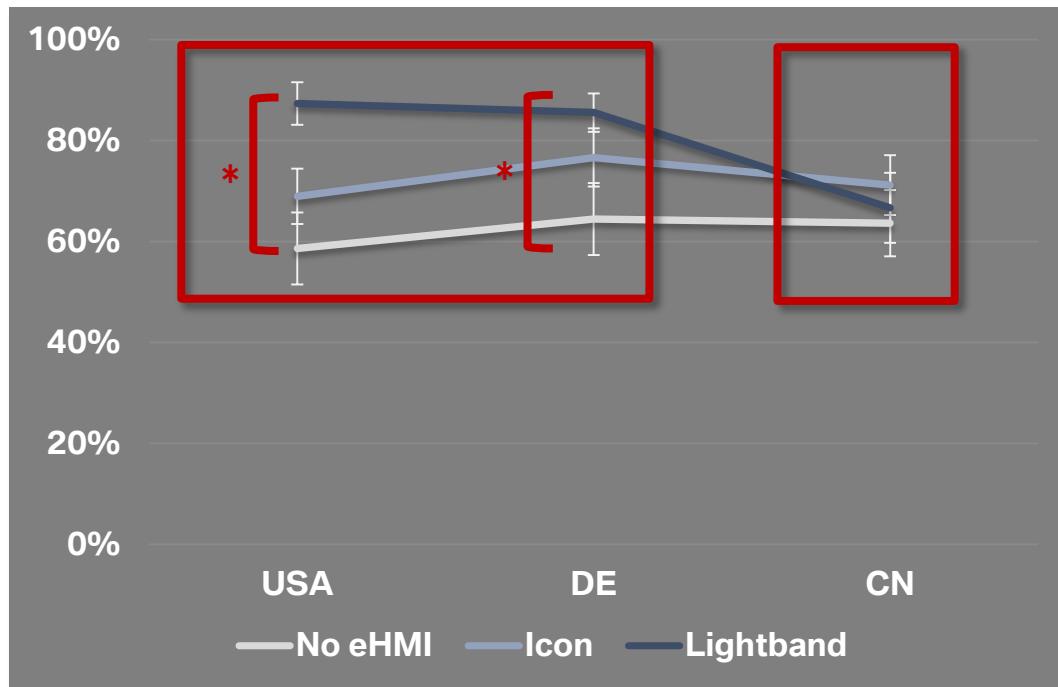
	No Signal (baseline)	Icon	Lightband
Give way			
Proceed			

DEMOGRAPHICS AND SAMPLE.

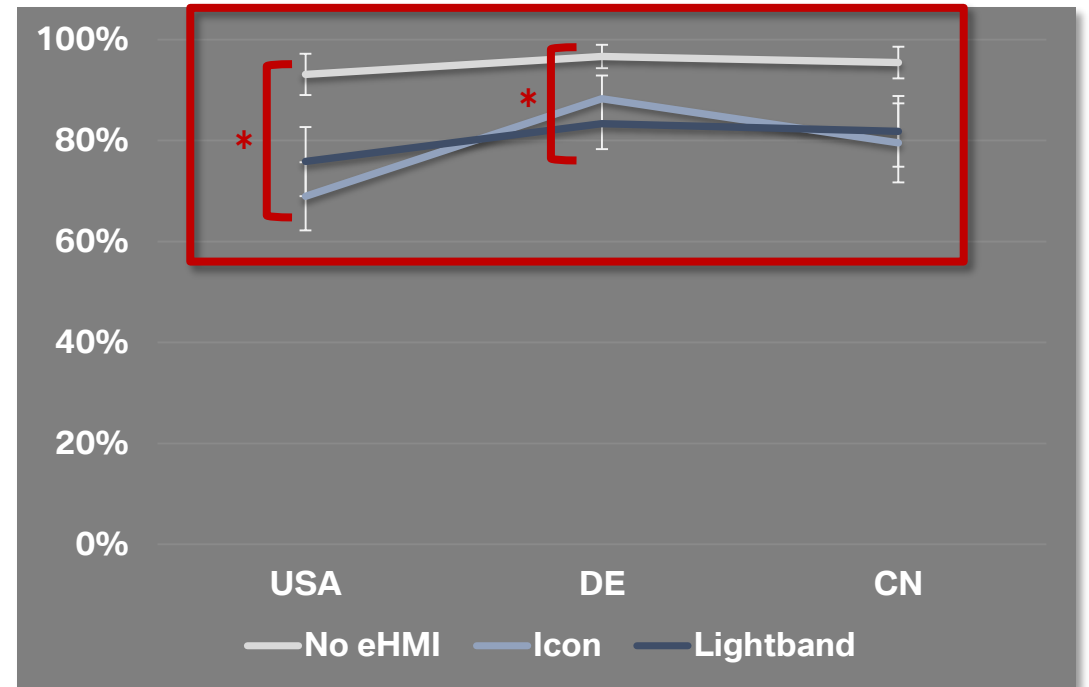
		
n = 29	n = 30	n = 23
M = 36 years (SD = 16 years)	M = 43 years (SD = 13 years)	M = 42 years (SD = 13 years)
 n = 13	 n = 16	 n = 12
 n = 16	 n = 14	 n = 11

CORRECT INTERPETATION OF AV INTENTION.

// AV gives way



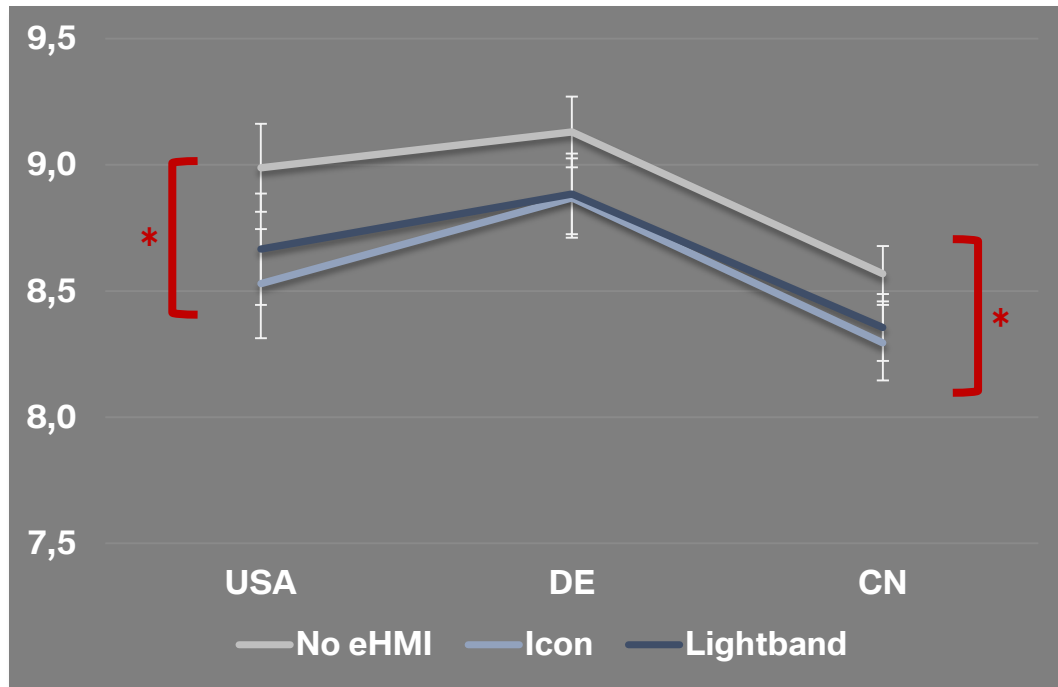
// Proceed



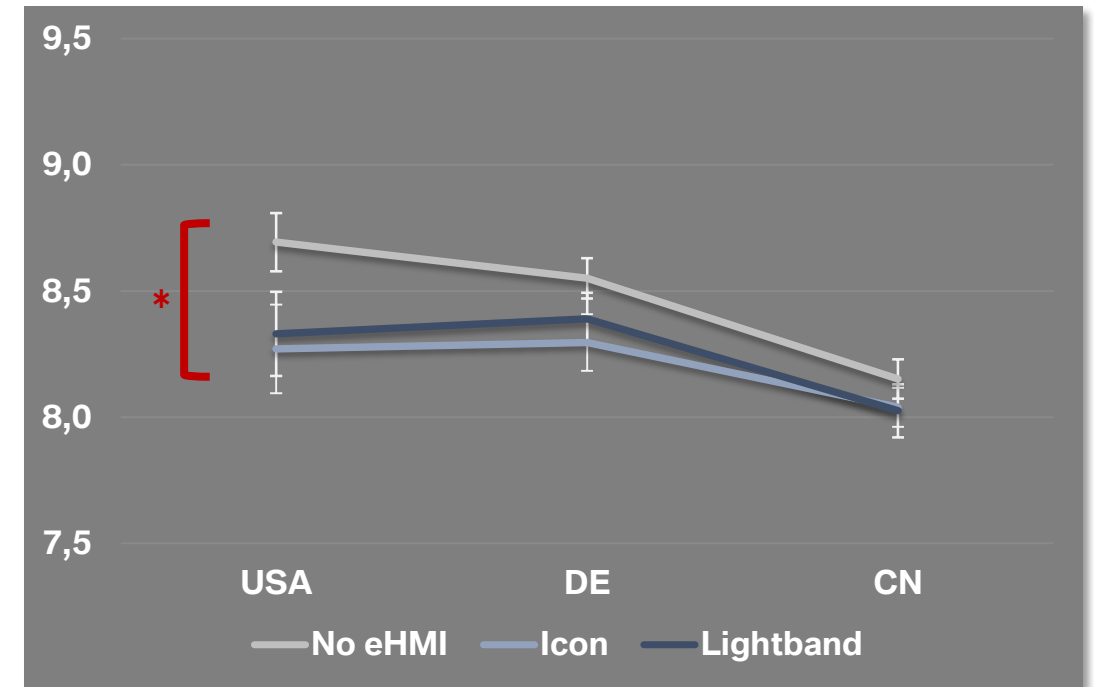
When the AV gives way eHMI worked significantly better than baseline in the US and Germany while not helping in China
eHMI significantly decreases intention recognition when the AV proceeds

INTENTION RECOGNITION TIME IN S.

// AV gives way



// Proceed

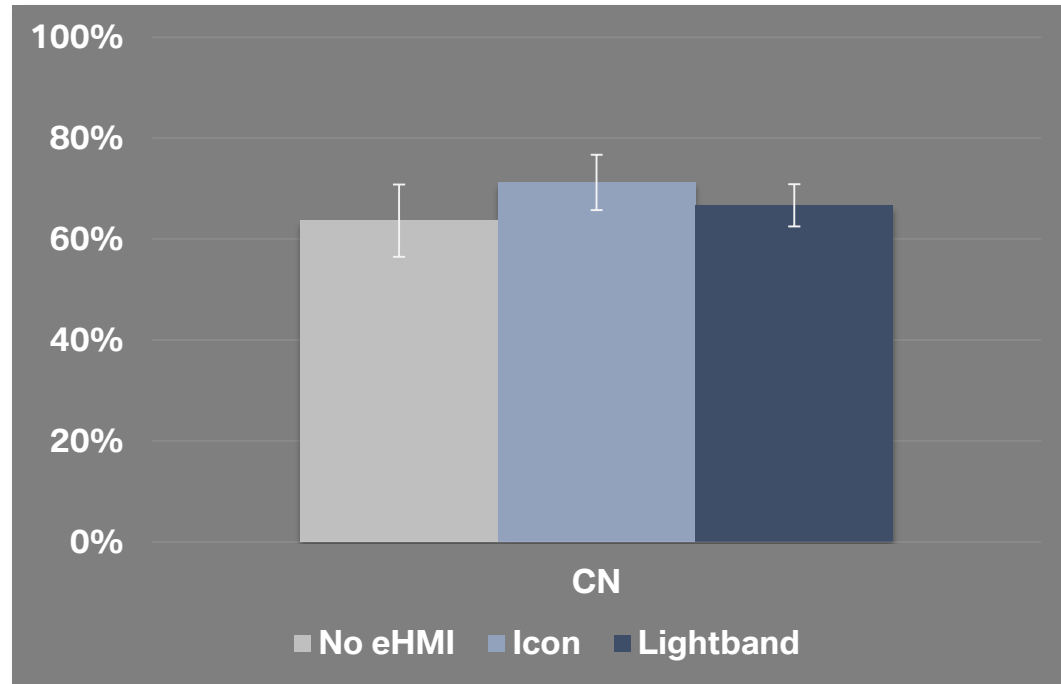


In the US eHMI generally speeds up intention recognition for both AV intentions
In China intention recognition is faster with eHMI present in the give way condition

AV INTENTION GIVE WAY. CORRECT INTERPRETATION & IRT IN CHINA.



// Correct interpretation



64%

77%

87%



64%

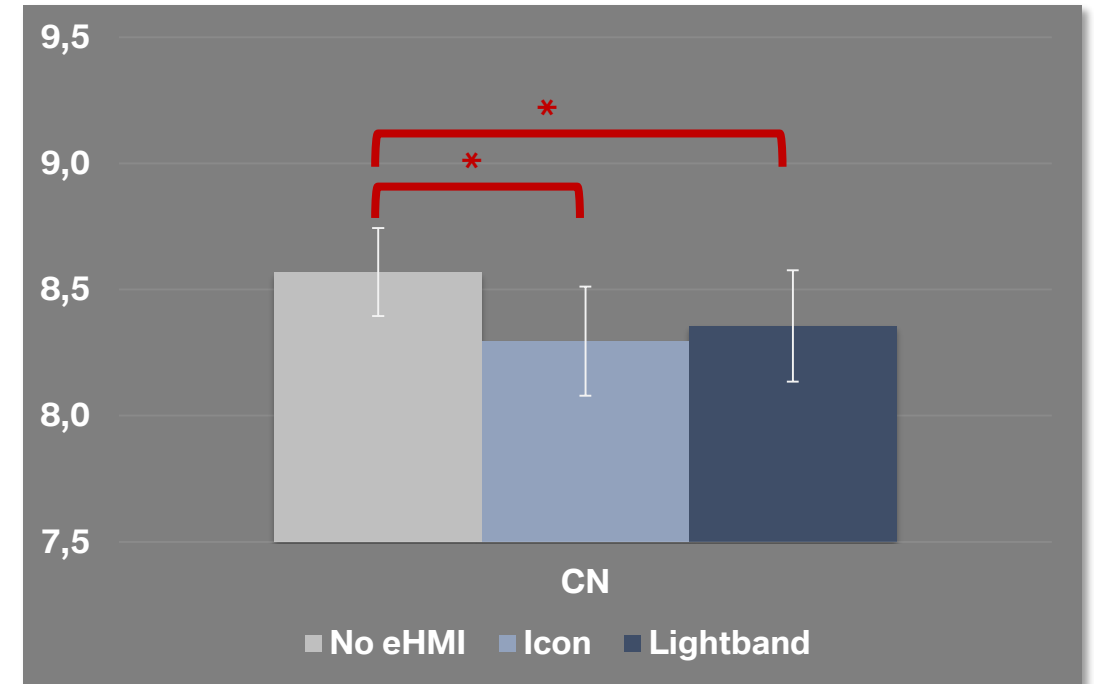
73%

87%



No Significant differences between variants in correct decision.
Significantly faster IRTs with eHMI compared to baseline

// IRT



9,1

8,8

8,8





















9,1

8,9

8,8

SUMMARY OF RESULTS.

				
eHMI	Correct interpretation of AV intention	 With eHMI when AV gives way	 With eHMI when AV gives way	 No differences
		 Deteriorated with eHMI when AV proceeds	 Deteriorated with eHMI when AV proceeds	 Deteriorated with eHMI when AV proceeds
	IRT	 Faster response with eHMI	 No differences	 Faster response with eHMI
	Certainty of choice	 No systematic influence	 No systematic influence	 No systematic influence
Priority		 No systematic influence	 No systematic influence	 No systematic influence

EHMI TO COMMUNICATE INTENTIONS OF THE AV.

AV intention to yield

- eHMI (lightband) improves intention recognition when the AV's intention is to yield. → potential benefits for reinforce the AV's intention to let a pedestrian cross.
- Improved intention recognition might lead to quicker street crossings and / or improved trust and acceptance → Further research
- Causes for lack of effect of the Icon eHMI
 - shortcomings of specific eHMI design
 - Icon eHMI might be more difficult to process
 - visible at a later point in time → both icons difficult to distinguish.

AV intention to proceed

- Intention recognition when the AV proceeds is best in baseline
- A vehicle approaching at 40 km/h seems to be enough communication.
- We can't conclude that participants would have stepped on the street
- Results correspond to observational studies, where no interaction is observed when the AV is not yielding.
- eHMI to communicate intention to proceed should be avoided

EHMI AND CULTURE. WESTERN WORLD VS. CHINA.

Interpretation of eHMI

- We expected the light-based eHMI to be less susceptible to cultural influence
- Chinese participants did not fully profit from any eHMI showing the AV's intention to yield.
- Post study interviews:
 - misinterpretations of the eHMI.
 - slow pulsing = warning signal
 - eHMI = decorative design element without meaning.
- eHMI solutions might not have been apt for the chinese market!

Influence of general traffic culture

- Cultural differences in general traffic behavior in China
- The traffic scenarios used were rated by as very suitable for China
- Typical behavior of Chinese drivers encountering pedestrians might differ fundamentally from German or US drivers in equal scenarios.
- Very low expectancy of Chinese pedestrians that any car will yield to them → No meaning of eHMI communicating intention to yield

LIMITATIONS OF RESULTS.

Restricted traffic scenarios

- Very controlled traffic scenarios to isolate differences in the comprehensibility of the eHMI.
- Scenarios with only one pedestrian and one AV → excerpt of actual traffic.
- “Clean traffic scenarios” might overestimate effects

Limitations of VR

- Constraints in resolution, brightness, or angle of view → impact on effects such as the difference between a light-band and an icon eHMI.
- Pedestrians’ perception of the AV’s braking behavior in VR might be different from the one they have for manually driven vehicles.
- VR effects might underestimate effects of eHMI

CONCLUSIONS & FUTURE RESEARCH.

Conclusions

- We should not communicate the intention not to yield with additional eHMI
- We need to take culture and consistency into account
 - Conflict: eHMIs might need to be localized / eHMIs should be consistent across the world
 - We need to consider specific traffic cultures in research

Future research

- More complex scenarios including additional traffic participants and different approach speeds
- Different methodological setups
 - Critical gap acceptance
 - Behavioral measures (such as crossing initiation)
- Negative effects of eHMIs
- Real road testing to overcome VR effects and validation of methodologies for studying AV – pedestrian interaction
- Testing localized eHMI concepts



BACKUP Q&A

Q&A BACKUP

Question	Answer
Why different Sample sizes in US, DE, CN	Due to time and cost efficiency a larger sample was not possible in China. It would surely have been optimal to have equal sample sizes in all 3 countries. The lack of effects in intention recognition in china can however most likely not be attributed to the sample size.
Why the methodology: Button press, when intention was recognized	We wanted participants to be free to decide when they feel certain enough to really have recognized the intention and grasp the moment the decision was taken. This obviously leads to methodological issues such as the quicker responses in china while interpretation rates stay the same but with a system that was frozen at particular points in time (standardized across all participants) we might not have grasped the crucial decision point at all and would not have been able to further talk to participants in the debriefing interview about what they experienced with the AV and the eHMI

Q&A BACKUP 2

Question	Answer
What was the exact pedestrian simulator setup	The pedestrian simulator consists of a standard HTC Vive Pro VR setup (head mounted display, and two infrared trackers, as well as the HTC VIVE's remote control) and a computer, running the simulation software which is based on Unity 3D. During the simulation, participants were immersed in an urban environment, standing on the sidewalk of a street and encountering an AV, a BMW i3.