

# CROSSING THE STREET ACROSS THE GLOBE

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



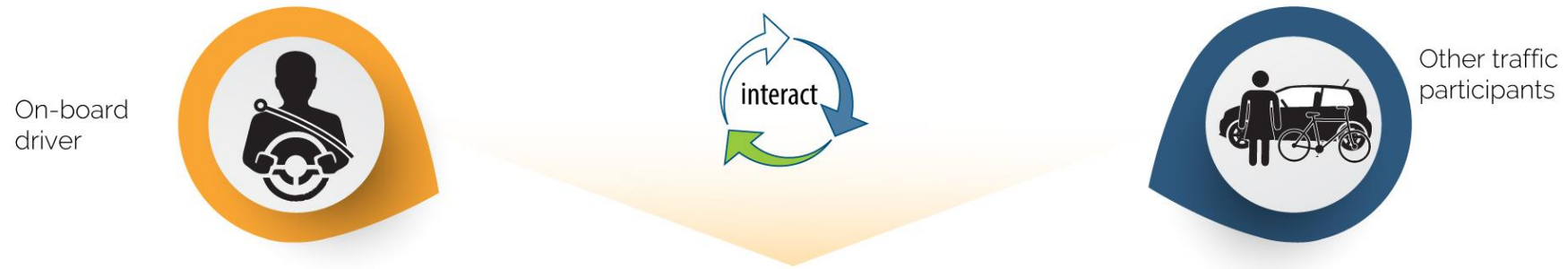
Weber, Chadowitz, Messerschmidt, Schmidt & Fuest



Rolls-Royce  
Motor Cars Limited

# THE CHALLENGE.

## Situation Today



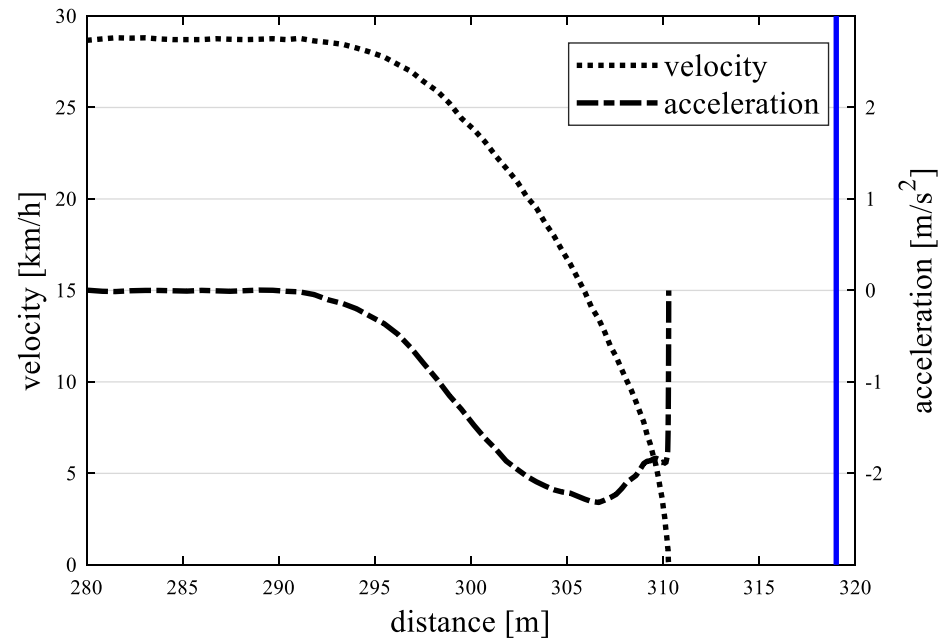
## Future situation: Automated vehicles in mixed traffic environments



<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

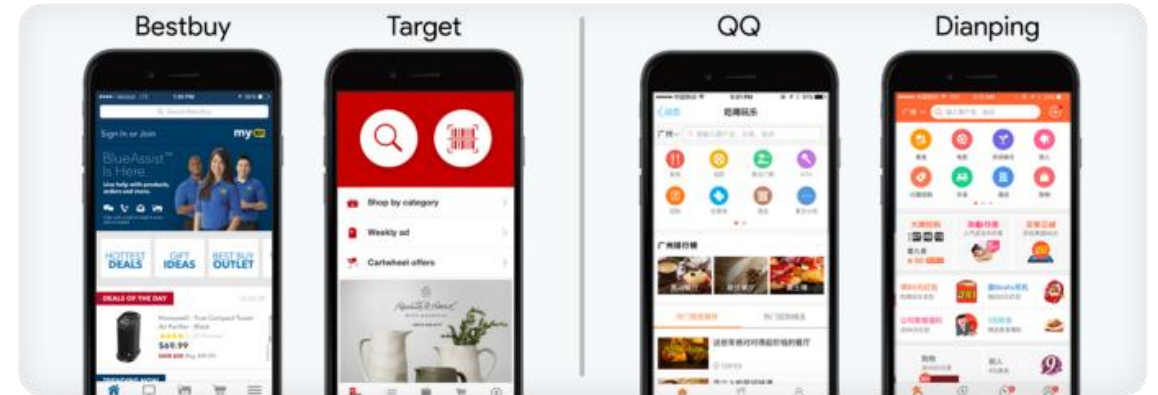
- HMIs differ depending on the cultural background
- Mental models and expectations of HMIs differ between cultures.

## 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.

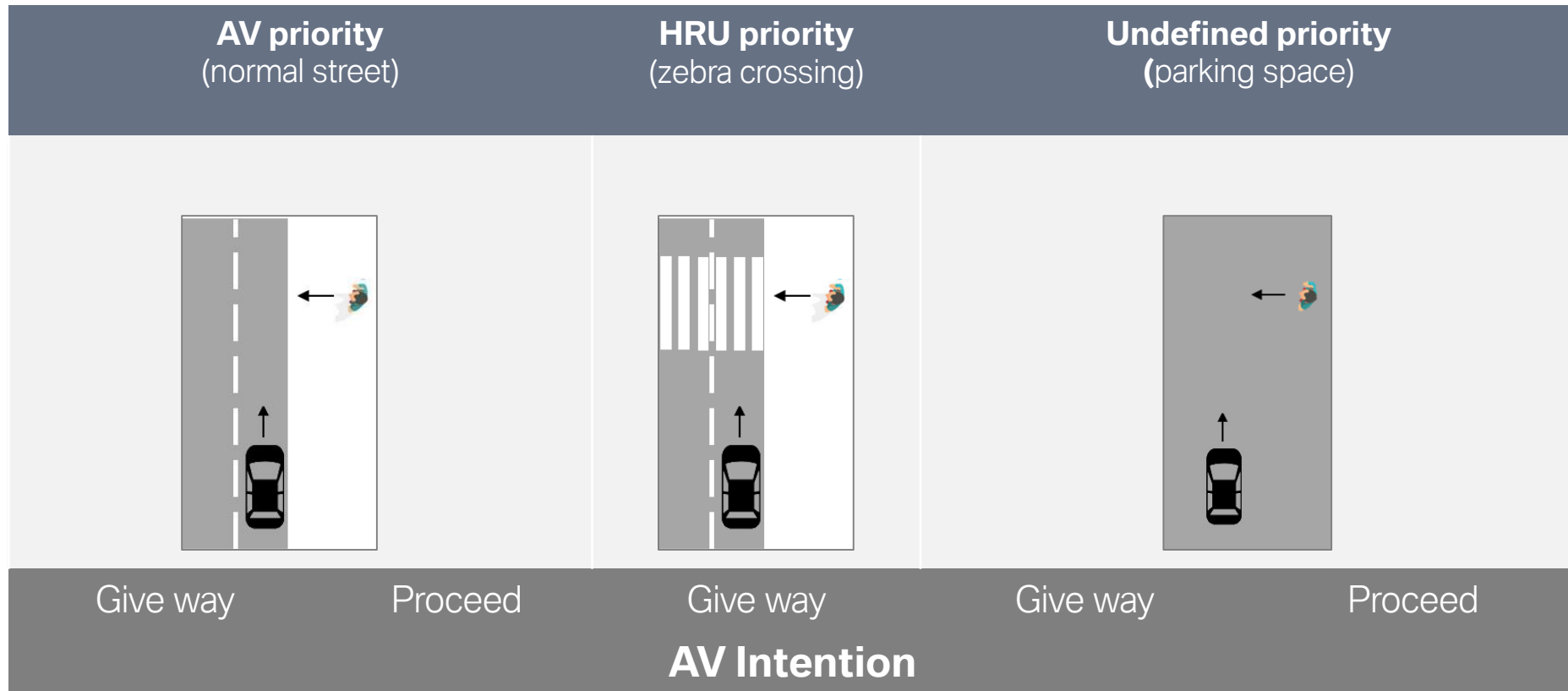


## Study overview

- 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



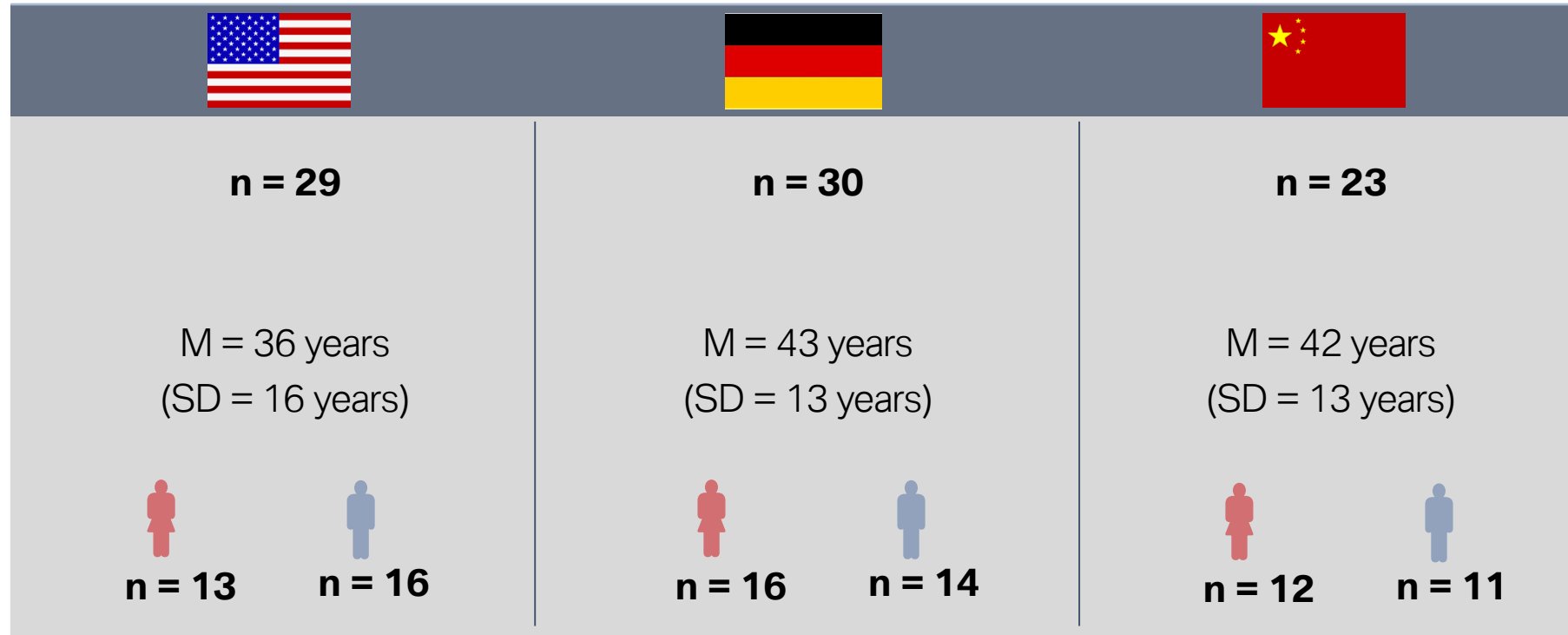
# EXPERIMENTAL SETUP.

## // eHMI Variants

	No Signal (baseline)	Icon	Lightband
Give way			
Proceed			

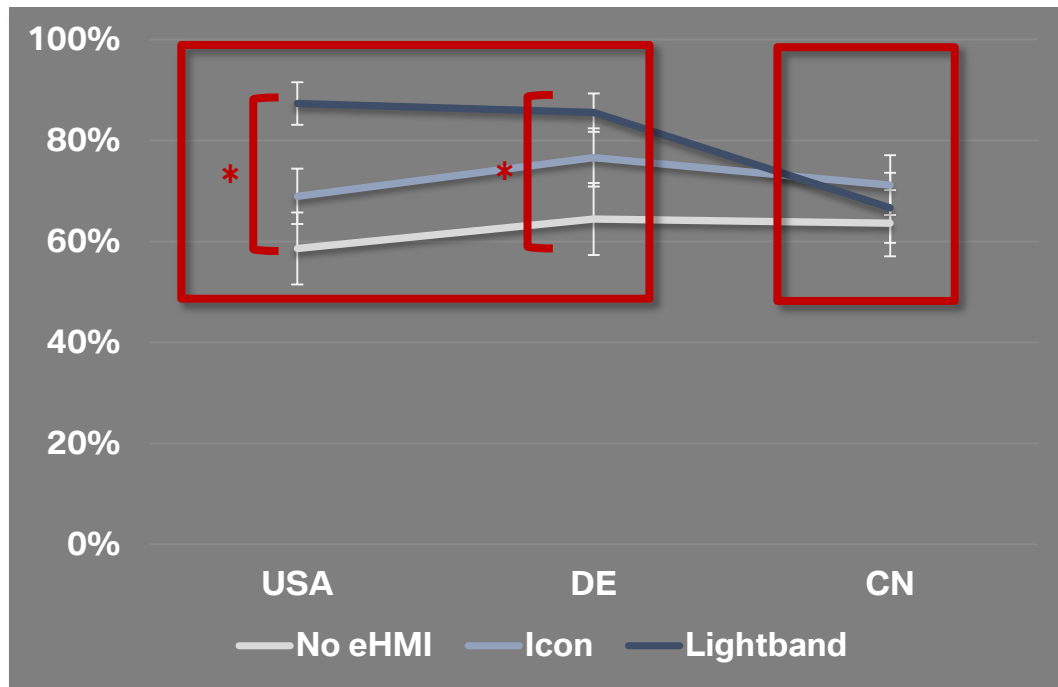


# DEMOGRAPHICS AND SAMPLE.

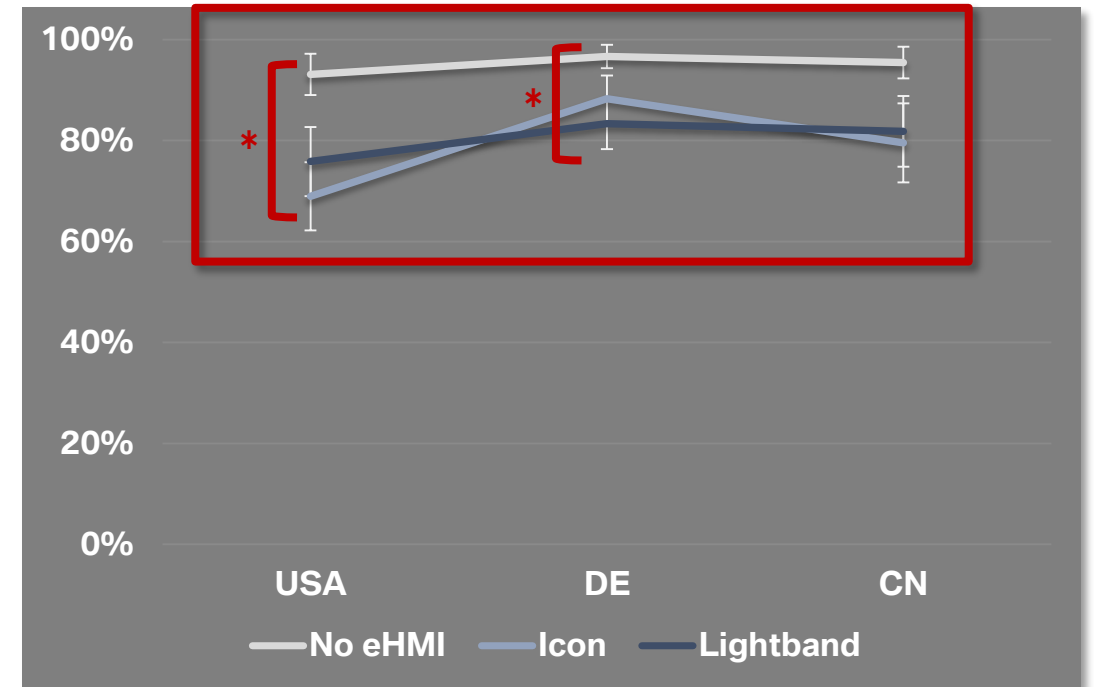


# CORRECT INTERPETATION OF AV INTENTION.

## // AV gives way



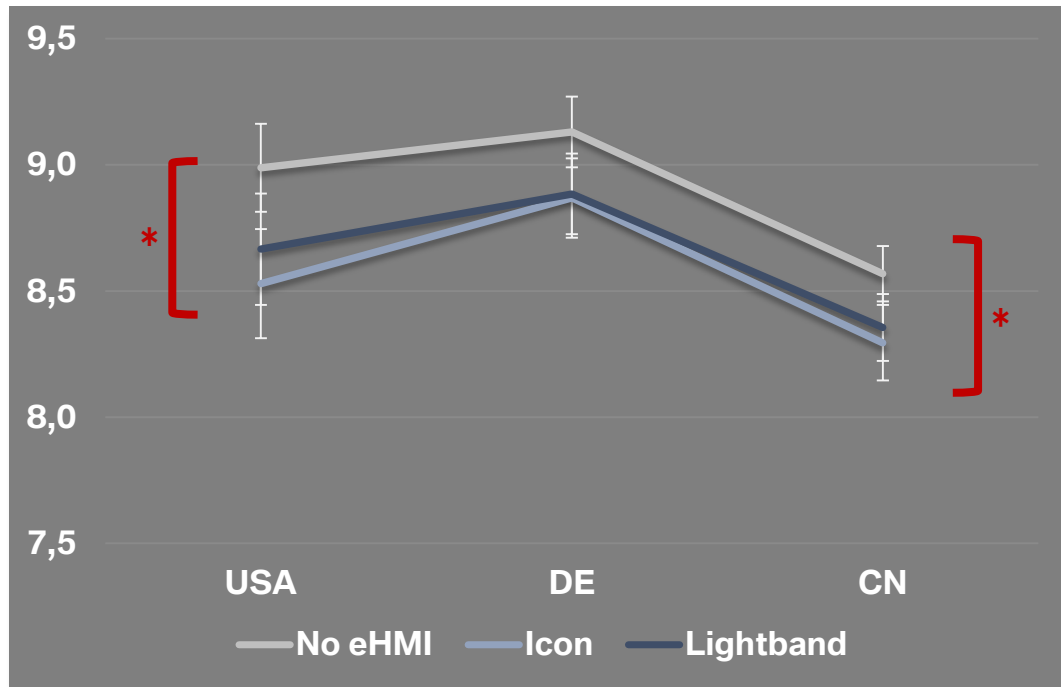
## // Proceed



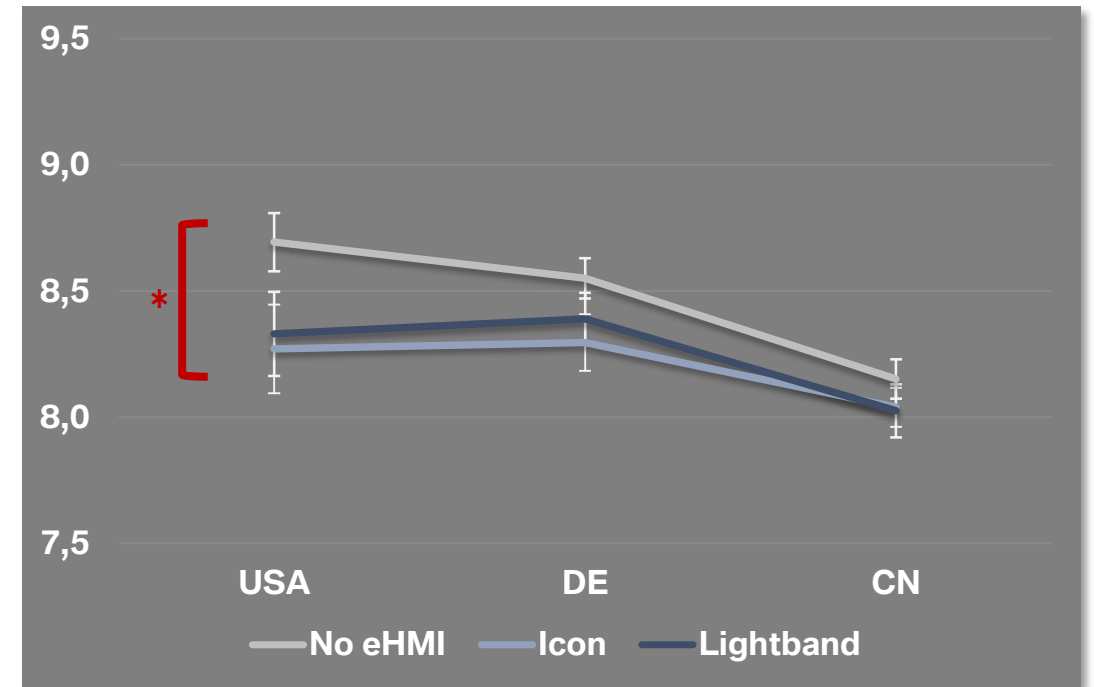
When the AV gives way eHMI worked significantly better than baseline in the US and Germany while not helping in China  
eHMI significantly decreases intention recognition when the AV proceeds

# 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

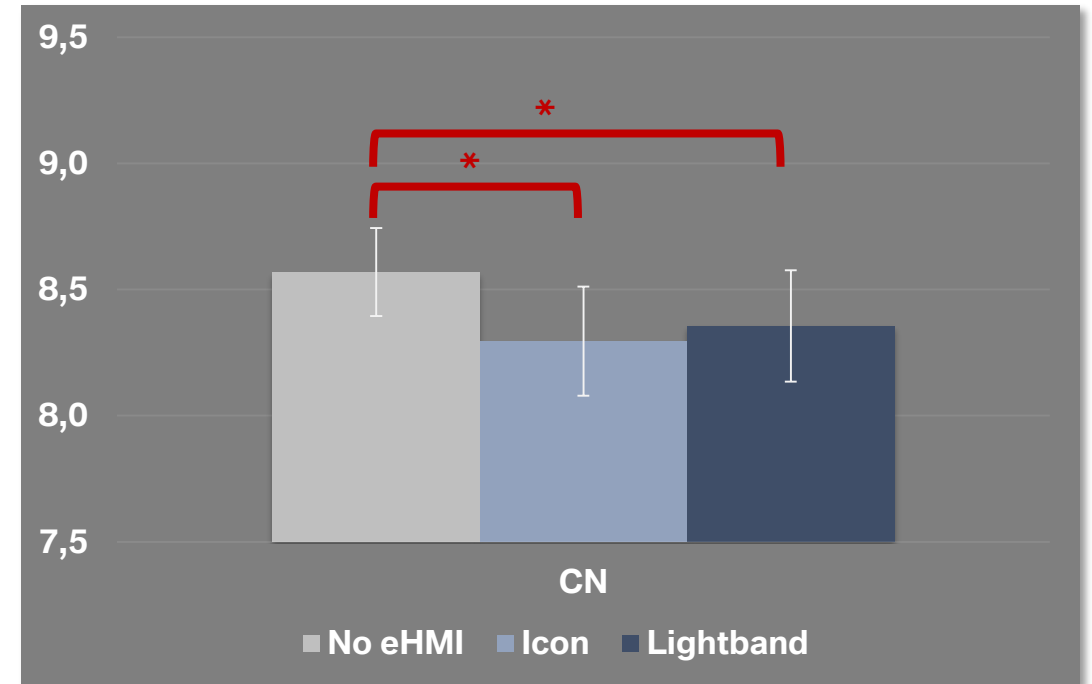
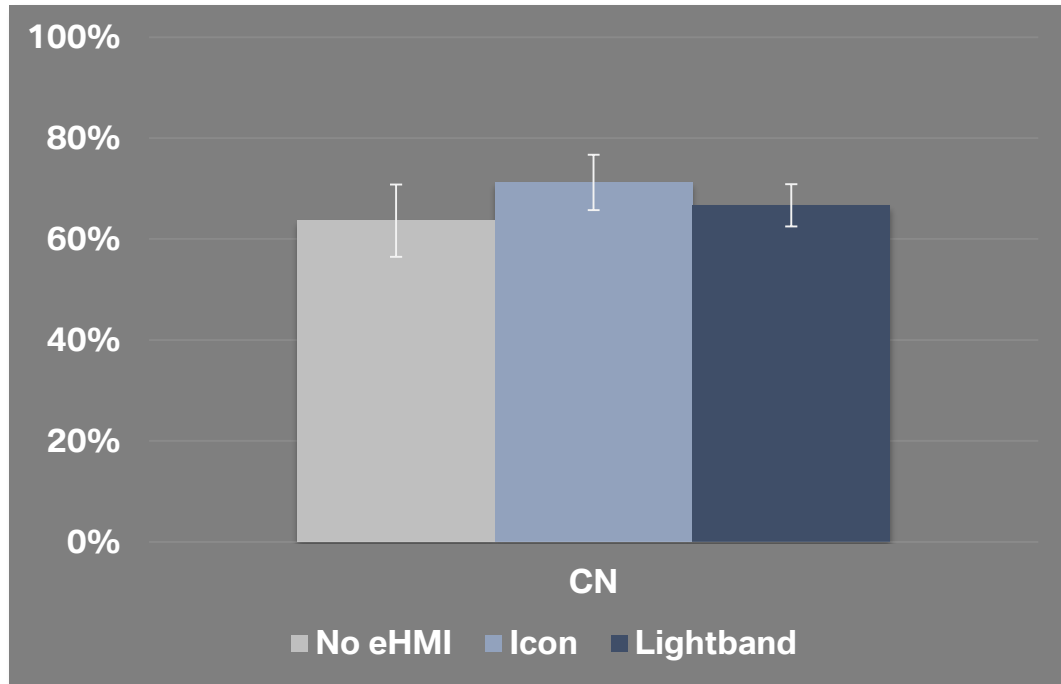


# AV INTENTION GIVE WAY. CORRECT INTERPRETATION & IRT IN CHINA.



## // Correct interpretation

## // IRT



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

# 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

