

SIP-adus Workshop 2020



**Communication between Automated Vehicle and Traffic Participants
- External HMI (Human Machine Interface) -**

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November 10th, 2020



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Introduction

Communication between AV and Traffic Participants

◆ Communication between traffic participants

- In various road environments, communication is carried out among traffic participants such as drivers, pedestrians, cyclists, etc.



Junction



Signalized intersection



Unsignalized intersection



Unsignalized crosswalk

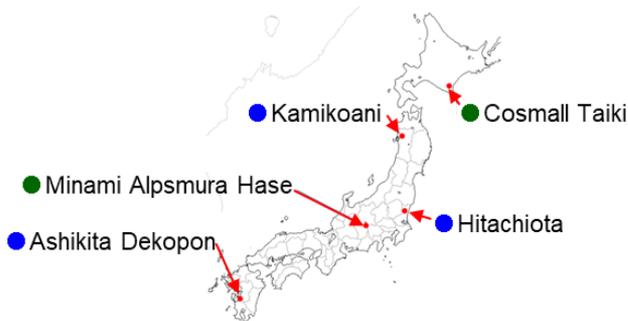
Vehicle motion, lamps, driver's gesture, eye contact, ...



Contributing to traffic safety, sense of security, traffic efficiency

Communication between AV and Traffic Participants

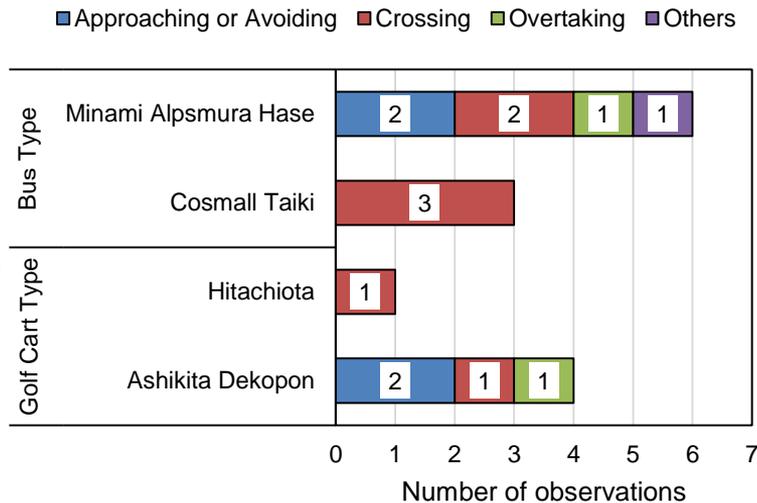
- ◆ Experimental analysis of communication based on vehicle motion and eHMI
 - Analysis of video data recorded in field operational test of automated driving (Michi-no-Eki)
 - Analyze communication discrepancies from video data for 2 days at each Michi-no-Eki



● Automated Vehicle (Golf Cart Type)



● Automated Vehicle (Bus Type)



Crossing

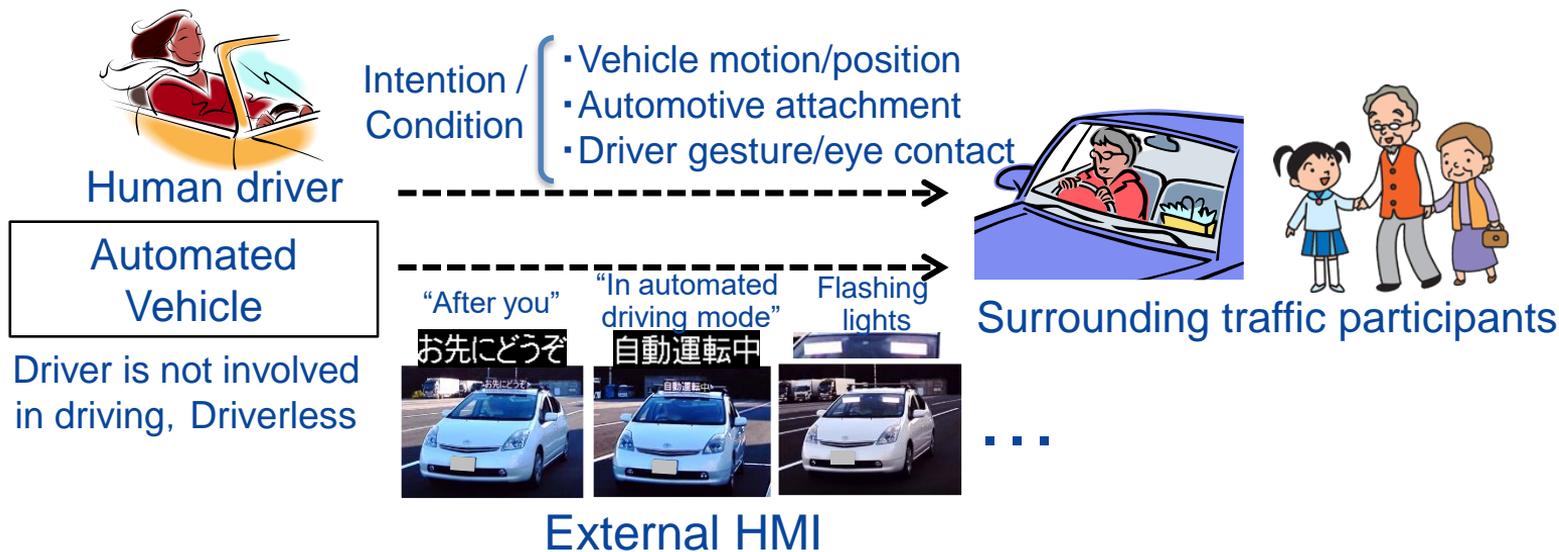


There observed some surrounding traffic participant's confusions when encountering AV.

Operators who monitored safety of AV complementally gave eye contact to them.

Communication between AV and Traffic Participants

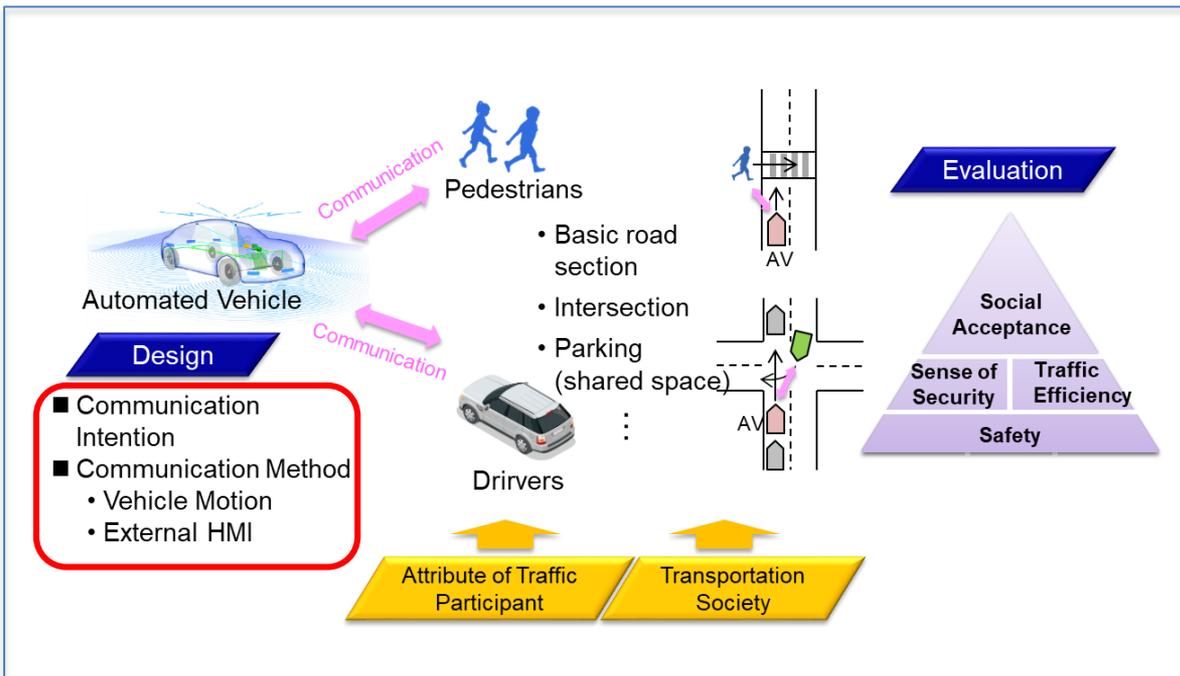
- ◆ Experimental analysis of communication based on vehicle motion and eHMI
 - How to convey the intention and condition of AV to surrounding traffic participants?



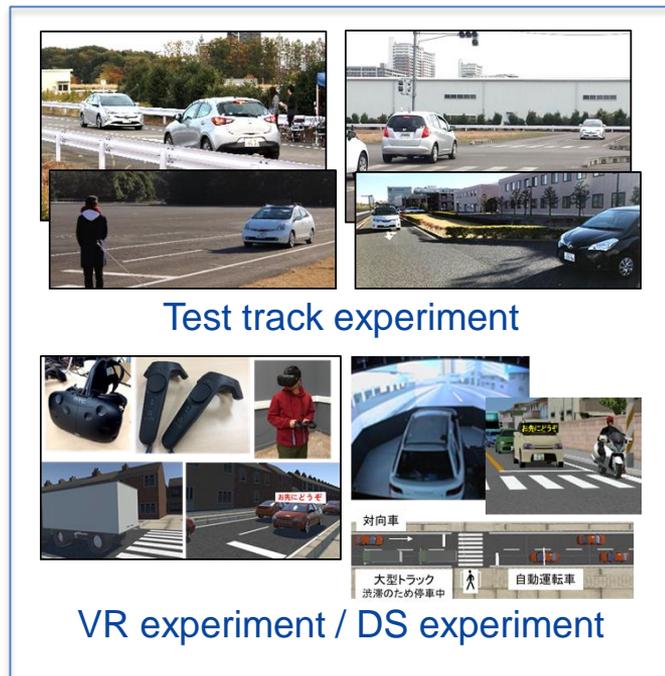
How to communicate from AV to surrounding traffic participants

Communication between AV and Traffic Participants

◆ Design and development of communication between AV and traffic participants



Construction of design recommendation / guideline for communication method



Analysis of traffic participant's recognition, judgement and behavior

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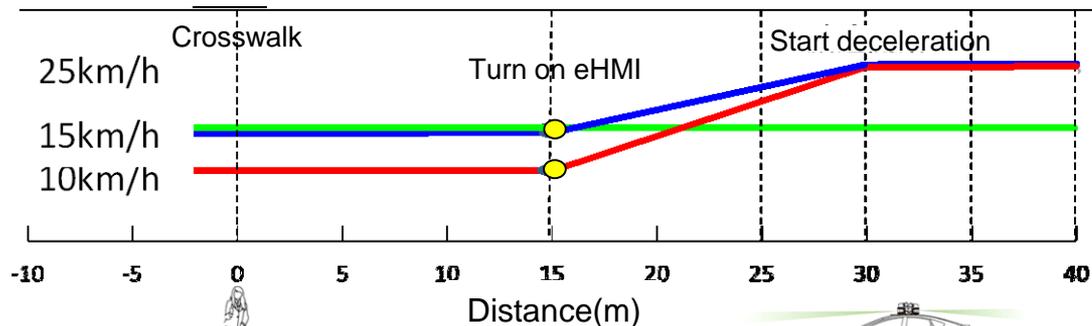
Experimental analysis of communication based on vehicle motion and external Human Machine Interface (eHMI)



Communication between AV and Traffic Participants

◆ Pedestrian's recognition and judgement to be yielded by AV

■ Effect of vehicle motion and eHMI



Small deceleration (25km/h → 15km/h, Ave. -1.03m/s^2)
 Large deceleration (25km/h → 10km/h, Ave. -1.35m/s^2)



Text message

Flashing lights

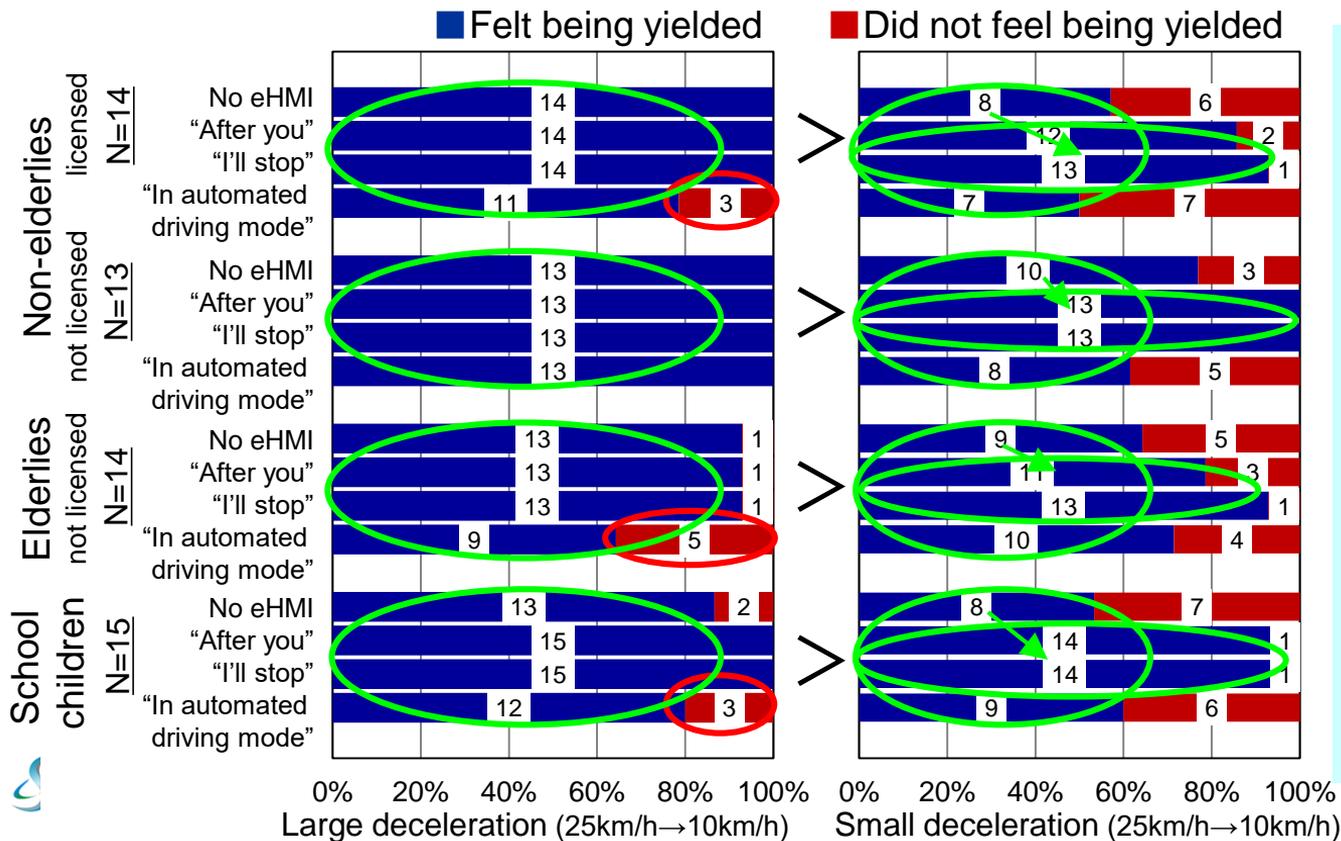
Convey the intention and condition of AV

- Non-elderlies (driving license holder)
- Non-elderlies (non-driving license holder)
- Elderlies (non-driving license holder)
- School children

Vehicle motion × eHMI

Communication between AV and Traffic Participants

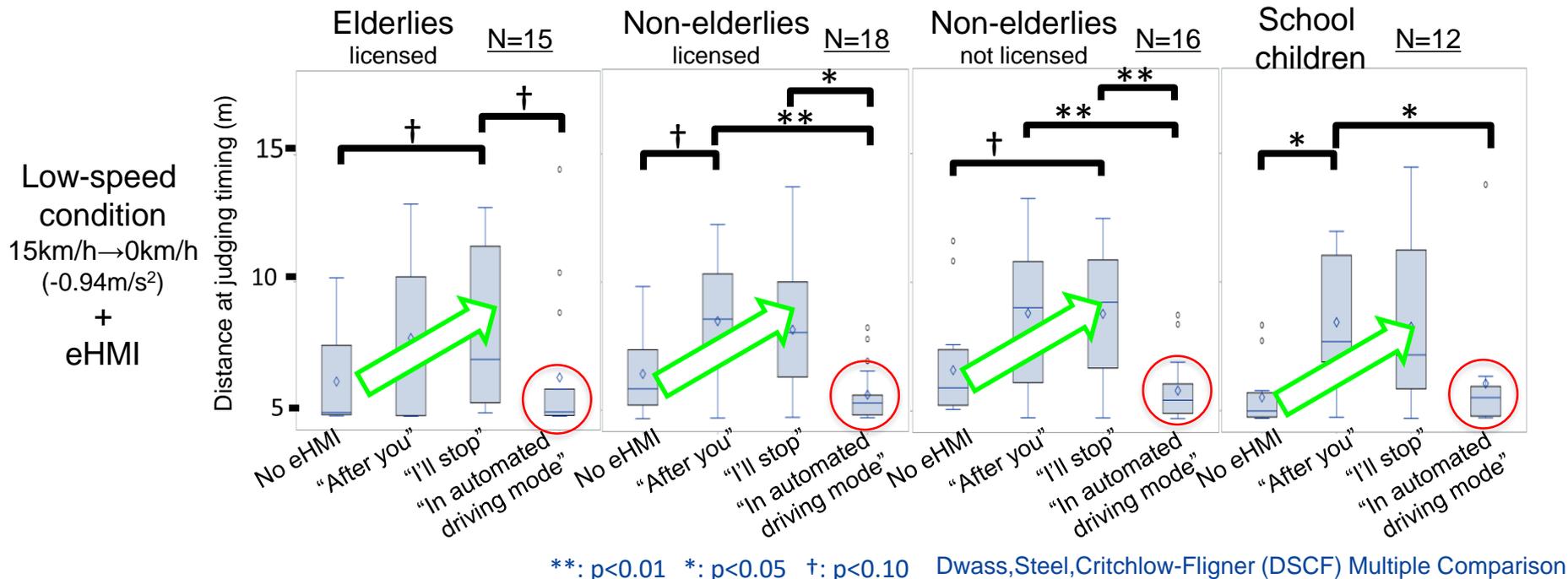
◆ Pedestrian's recognition on whether AV was yielding to you or not



1. Large deceleration of AV was a clear sign of "Yielding" for the pedestrians.
2. Small deceleration of AV was not a clear sign of "Yielding" but the eHMI such as "After you" and "I'll stop" compensated it.
3. The eHMI of "In automated driving mode" decreased or did not increase the rate of interpretation as "Yielding" by some types of pedestrians.

Communication between AV and Traffic Participants

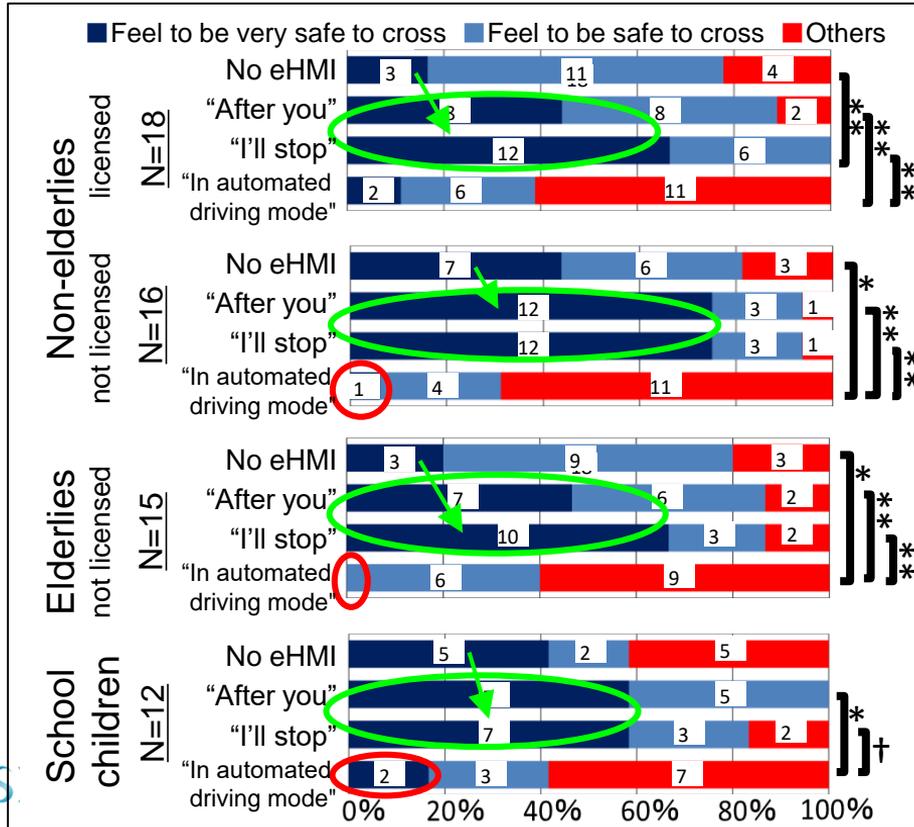
◆ Timing of pedestrian crossing judgement for low-speed AV



1. It is possible for pedestrians to judge whether they can cross at an early timing even if an low-speed AV has vehicle motion of small deceleration.

Communication between AV and Traffic Participants

◆ Pedestrian's psychological aspect for AV when decided to start crossing



From low-speed driving to deceleration
(15km/h→0km/h, -0.94m/s^2)

** : $p < 0.01$ * : $p < 0.05$ † : $p < 0.10$

Dwass,Steel,Critchlow-Fligner (DSCF) Multiple Comparison

1. The eHMI such as "After you", "I'll stop" tends to make that pedestrians feel to be safe to cross after making a crossing decision.
2. The eHMI of "In automated driving mode" tends to make that pedestrians do not feel to be safe to cross.

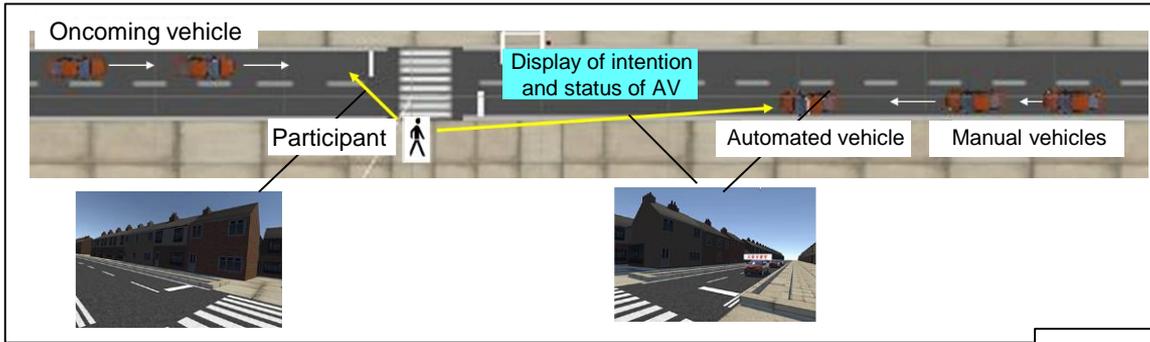


Communication between AV and Traffic Participants

◆ Negative effect to pedestrians by repeated experiencing eHMI

■ Impact of the use of eHMI on pedestrian's safety confirmation behavior

Repeated experiences to be yielded by using the eHMI of AV



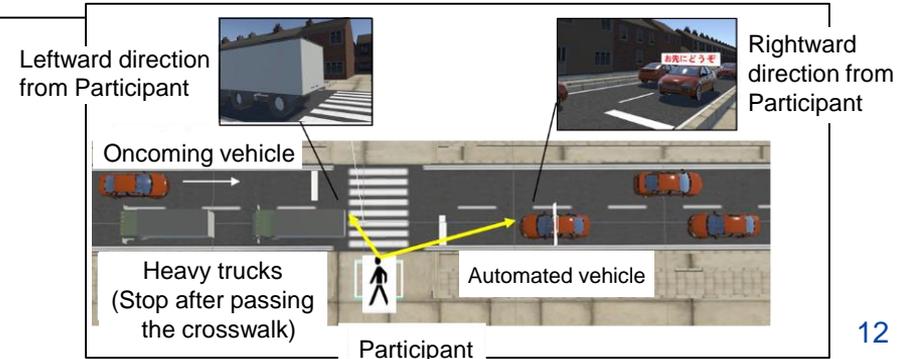
eHMI conditions:

- No eHMI
 - "After you"
 - "I'll stop"
 - "In automated driving mode"
- (Additional baseline: manual vehicle)

Participants: Non-elderlies (licensed)

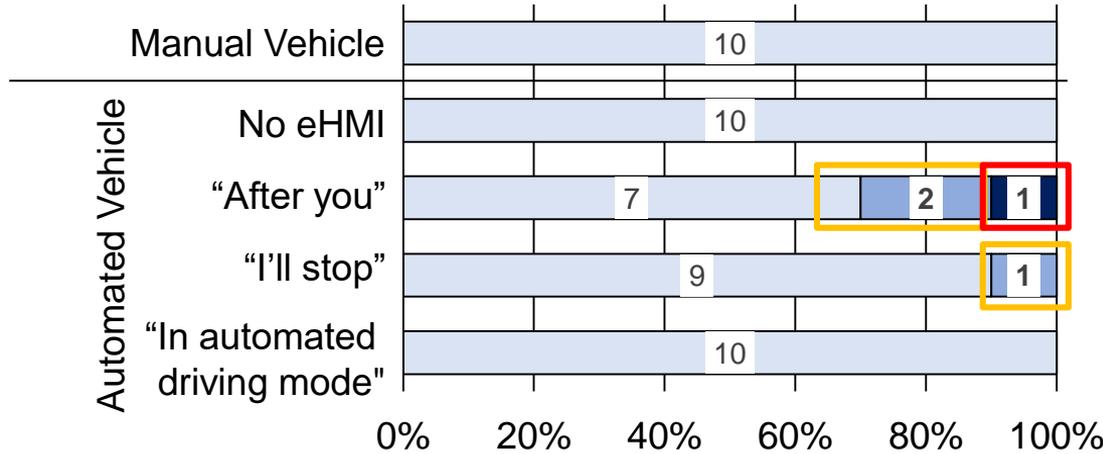


VR apparatus and environment



Communication between AV and Traffic Participants

◆ Pedestrian misunderstanding, collision or near-miss with AV

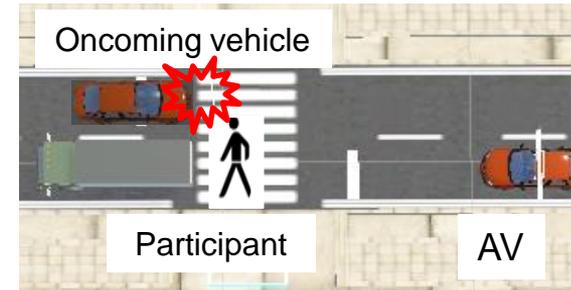


- No misunderstanding, no collision, no near-miss
- Misunderstanding of eHMI, no collision, no near-miss
- Misunderstanding of eHMI, collision or near-miss

In the condition of no eHMI, the experiment observed pedestrian's safety confirmation to oncoming vehicle and no collision/near-miss.

(Interviews with participants who misunderstood eHMI)

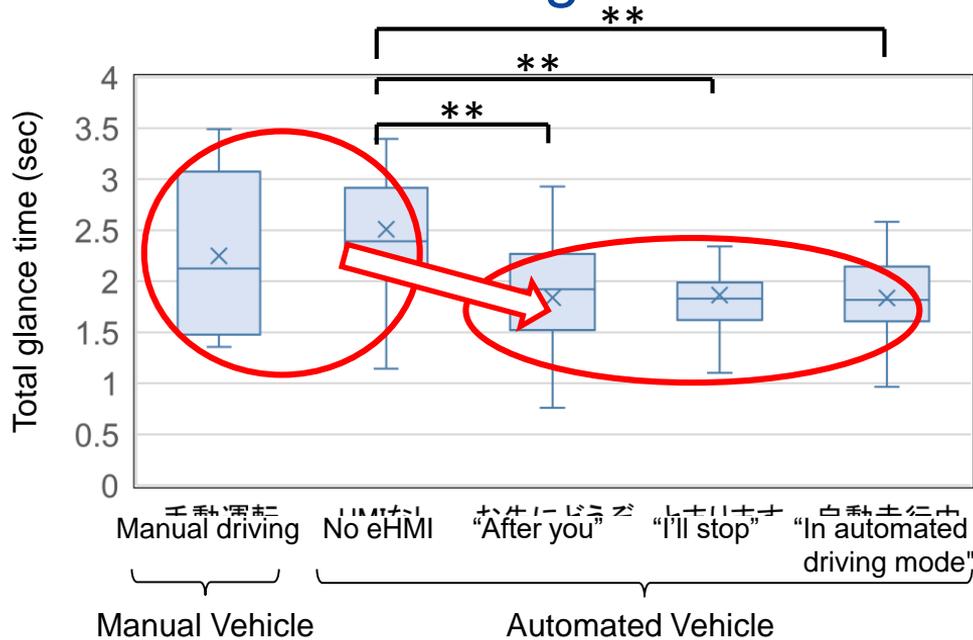
- The oncoming vehicle was also looking at the eHMI and the oncoming vehicle would stop at the stop-line.
- The oncoming vehicle was checking the status of AV and that the oncoming vehicle would stop at the stop-line.
- Since the AV stopped and displayed "I'll stop", the oncoming vehicle would slow down and stop.



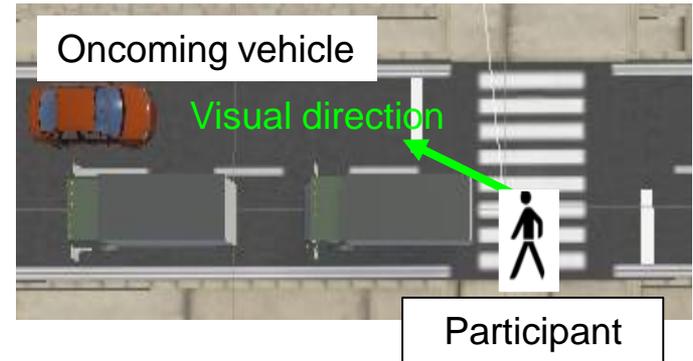
Pedestrians may misunderstand the eHMI ("After you" or "I'll stop") of AV.
The use of eHMI may reduce their own safety confirmation to AV.

Communication between AV and Traffic Participants

◆ Pedestrian's total glance time to the oncoming lane



* $p < 0.05$, ** $p < 0.01$
(Mann–Whitney U-test)



Pedestrian's safety confirmation depends on the eHMI of AV, as a result, their glance time to oncoming lane decrease.

Design of eHMI and education of communication with AV are required to prevent pedestrians from depending on the eHMI for surrounding safety confirmation.

◆ Summary of communication from AV by using eHMI

- In order to convey the intention of AV to pedestrians, it is first necessary to design a deceleration profile that makes them easy to recognize the intention.
- In situations where the deceleration motion does not allow sufficient communication with pedestrians, it is recommended to use an external HMI to recognize the intention of AV at an early timing, and to make decisions and actions safely.
- It is implied that repeated experiences of eHMI may cause pedestrians to not confirm their surroundings well and induce negative effects such as collision with other vehicles and near-misses.



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Current research status and future works



◆ Current research status

- In cooperation with “Michi-no-Eki, Field Operational Test for Automated Driving”, extract and analyze the current communication (use-case) between low-speed AV and traffic participants from the viewpoint of safety and efficiency

- Road environment:

 - Straight section (narrow), intersection, parking area, ...

- Encounter situation:

 - Approaching(same direction, facing), crossing, overtaking, passing

- Traffic participant:

 - Local residents, tourists, elderly people, school children, ...



- Application and verification of vehicle motion and eHMI for communication

- Knowledge to be prepared for local residents / traffic participants on AV

◆ Future works

- Study of changes in traffic behavior and interpretation associated with traffic participants' learning and long-term use for eHMI
- Proposal and verification of methodologies for controlling the negative impact on traffic participants when using eHMI
- Application and verification of vehicle motion and eHMI for communication from a low-speed AV to surrounding traffic participations in consideration of the features and limitations of the road environment

**Thank you for
your attention**

