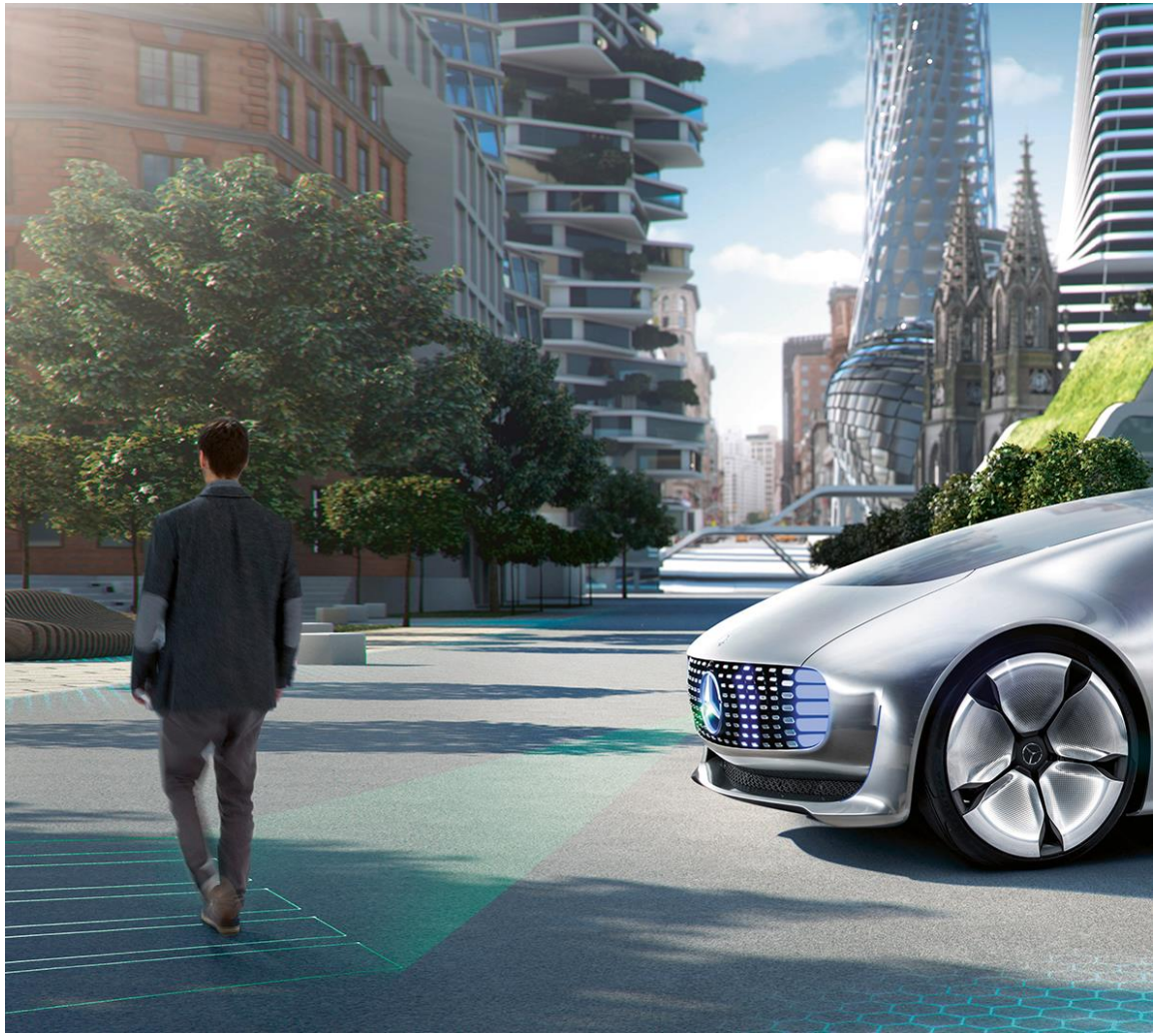
DAIMLER

eHMI of Autonomous Vehicles:
Should autonomous vehicles communicate with pedestrians, and if so, how?

Stefanie Faas, PIONEER*NG* NeXt

To Find a Common Language: external Human Machine Interface (eHMI)



- When deploying autonomous vehicles it is a set goal that all road users feel safe.
- Nowadays, most pedestrians are seeking eye-contact with the driver when crossing a street.
- In the presence of automated vehicles, communication will no longer be possible between two humans (i.e. driver – pedestrian).
- An external Human Machine Interface (eHMI) provides an interface between autonomous vehicles and pedestrians.

Autonomous Vehicle to Pedestrian Communication

AVP: Focus Groups
MB Museum, December 2017

Wizard-of-Oz Field Study
Sindelfingen, October 2017

Wizard-of-Oz Field Study
Immendingen, September 2018

Autonomous Vehicle to Pedestrian Communication

AVP: Focus Groups
MB Museum, December 2017

Wizard-of-Oz Field Study
Sindelfingen, October 2017

Wizard-of-Oz Field Study
Immendingen, September 2018

Automated Valet Parking (AVP): Focus Groups

Research questions	Should the autonomous driving mode be displayed externally? Location of eHMI: Front or 360° display?
Method	Think Aloud Technique Urban Scenario: Parking Garage Role: Pedestrian
Sample	18 external participants (44% ♀, 56% ♂ // Ø 45 years) Three groups with six participants each (16-35 years, 36-55 years, 56-70 years)
Vehicle	E-Class
Survey Period	12/05/2017

Automated Valet Parking (AVP): Focus Groups

AVP is a joint pilot project of Mercedes-Benz and Bosch in Stuttgart.

We gathered focus groups on how pedestrians feel about the Automated Valet Parking system and especially the need of an eHMI.

Pedestrians Feel a Little Uncomfortable When Seeing a Driverless Vehicle

Pedestrians need to get used to autonomous driving.

- *„Bizarre because nobody is sitting behind the wheel.“*
- *„Unusual feeling to see a car driving without a driver.“*
- *„The car doesn‘t move naturally, much more evenly.“*

Most pedestrians would like to see an indication that the vehicle is driving autonomously.

- *„When I see a vehicle without any people sitting inside I want to know whether the vehicle might move eventually.“*
- *„When a vehicle is moving I am seeking eye contact with the driver. But with autonomous vehicles I don‘t have anybody to communicate with anymore. An indication is important to me so I know there is no point in seeking the driver“.*

Pedestrians Prefer 360° View for Autonomous Vehicles

Participants replied:

94%

would like to see an indication that the ADS is activated*

100%

prefer a 360° view**

* As pedestrian, would you like to see an indicator for autonomous vehicles?

** Assuming autonomous vehicles have an indicator, would you prefer a 360° view or a display at the front of the vehicle?

Autonomous Vehicle to Pedestrian Communication

AVP: Focus Groups
MB Museum, December 2017

Wizard-of-Oz Field Study
Sindelfingen, October 2017

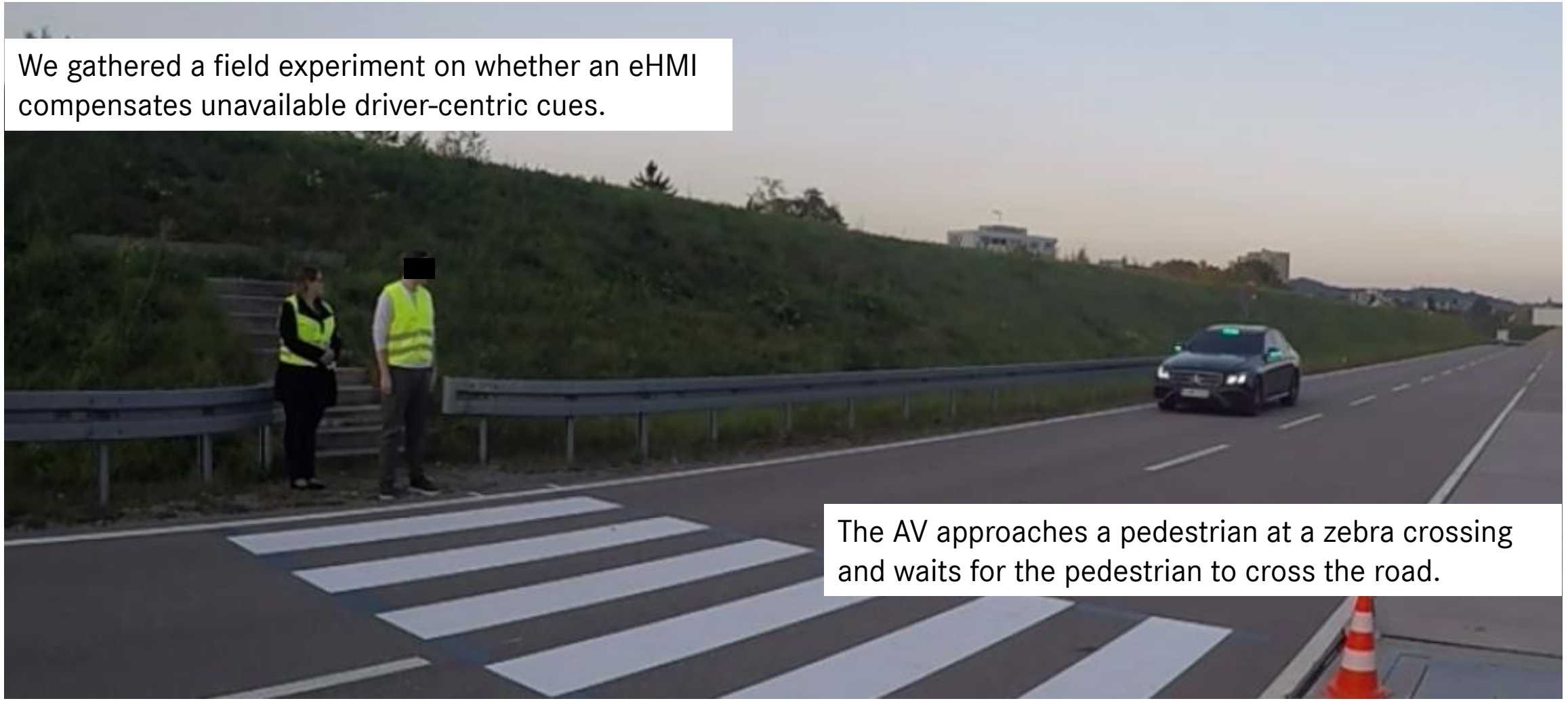
Wizard-of-Oz Field Study
Immendingen, September 2018

Testing and Technology Center Sindelfingen: Wizard-of-Oz Field Study

Research questions	Should the autonomous driving mode be displayed externally? Should autonomous vehicles signal their intention? Location of eHMI: Front or 360° display? Colour of eHMI: Turquoise or yellow?
Method	Field Study Urban Scenario: Zebra-Crossing Role: Pedestrian
Sample	65 external participants (46% ♀, 54% ♂ // Ø 43 years)
Vehicle	E-Class
Survey Period	09/25/2017 to 10/06/2017

Stefanie M. Faas, Vanessa Stange, and Martin Baumann. 2018. Autonomous vehicle-to-pedestrian communication: Is an external HMI needed?. Manuscript in preparation.

Testing and Technology Center Sindelfingen: Wizard-of-Oz Field Study



Two Test Vehicles

Right-Hand Drive: Wizard-of-Oz

Interior

Exterior

Driver-Centric Cues: Three Test-Conditions

Right-Hand Drive: Transparent

Eye Contact

The driver makes eye contact. Hands are not on the steering wheel.

Reading Newspaper

The driver is distracted and does not represent the actions of the vehicle.

Left-Hand Drive: Tinted

Tinted Windshield

No driver-centric cues available.
Unclear whether there is a driver or not.

An eHMI Helps Pedestrians to Interpret a Driverless Vehicle as Being no Threat

Without an eHMI, pedestrians take driver-centric cues into account. Compared to a driver making eye contact, pedestrians felt less safe when the driver was reading a newspaper or being invisible.

Eye contact

Reading newspaper

Tinted windshield

With an eHMI, pedestrians do not take driver-centric cues into account. Pedestrians felt equally safe regardless of the actions of the driver.

Eye contact

Reading newspaper

Tinted windshield

Pedestrians Prefer 360° View and Turquoise Light for Autonomous Vehicles

turquoise
lighting colour

Participants replied:

81%	79%	92%
would like to see an indication that the ADS is activated*	prefer a 360° view**	prefer turquoise over yellow as ADS lighting colour***

* As pedestrian, would you like to see an indicator for autonomous vehicles?
** Assuming autonomous vehicles have an indicator, would you prefer a 360° view or a display at the front of the vehicle?
*** Assuming autonomous vehicles have a specified lighting colour, do you prefer turquoise or yellow as lighting colour for autonomous vehicles?

Pedestrians Would Like to See an Indication that the Autonomous Driving System is Activated

81% pro Status Lamp

19% against Status Lamp

Gives me a sense of safety. With an indicator for autonomous vehicles I can assess the situation in a better way.
#Safety

The indicator confirms that the autonomic system is paying attention. Then I can be sure, the system is on.
#Awareness

One is less dependent of what happens in the vehicle. If the driver is distracted, the indicator provides feedback and security.
#No driver

Because I don't trust the system yet..
#Raising trust

Especially for the introduction phase of autonomous vehicles. So that you can somehow recognize and identify autonomous vehicles.
#Introduction

If the system works, you don't need an indicator. What should be the benefit?
#No benefit

Because pedestrians are overwhelmed with information. That wouldn't go well. Pedestrians must always be careful, you can't just walk across the street.
#Distraction

* Assuming you are a pedestrian, would you like to see an indicator for autonomous vehicles? Why? (*N*=62)

Reasons why Pedestrians Prefer a 360° View

#Visibility

“Because you don't always encounter the car from the frontal perspective” [Examples stated:]

Vehicle reverses

Pedestrian approaches from side

Vehicle makes a turn

#Perceptibility

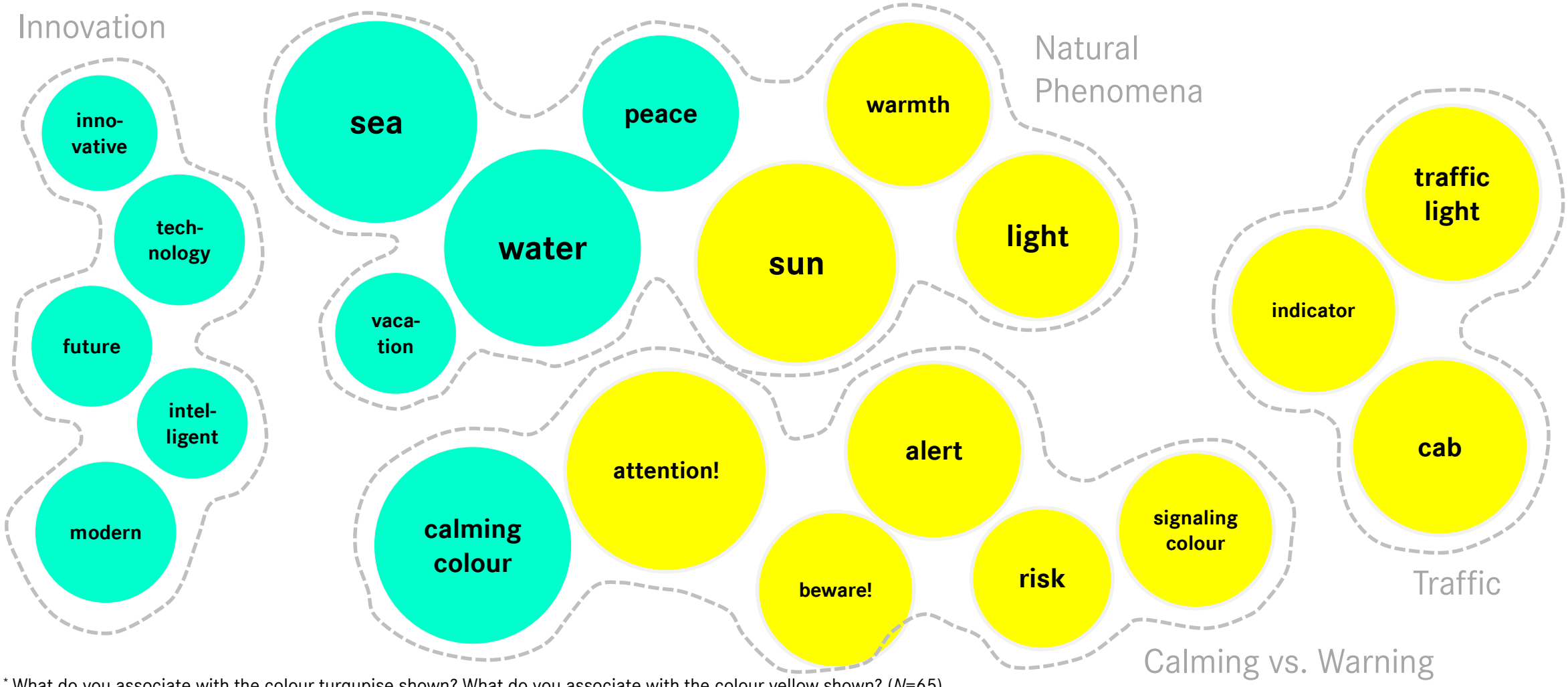
“I think the 360° view is simply more obvious, at first glance. A single point of light can be easily overlooked.”

#Safety

“The 360° view is more reassuring as you are able to tell from every point of view whether the vehicle is autonomous.”

* Assuming you are a pedestrian, would you prefer a 360° view or a display at the front of the vehicle? Why a 360 ° view? (*N*=51)

Colour Associations: Turquoise is Associated with Innovation. Danger of Confusion Regarding Yellow in Traffic.



* What do you associate with the colour turqupise shown? What do you associate with the colour yellow shown? (*N*=65)

Autonomous Vehicle to Pedestrian Communication

AVP: Focus Groups
MB Museum, December 2017

Wizard-of-Oz Field Study
Sindelfingen, October 2017

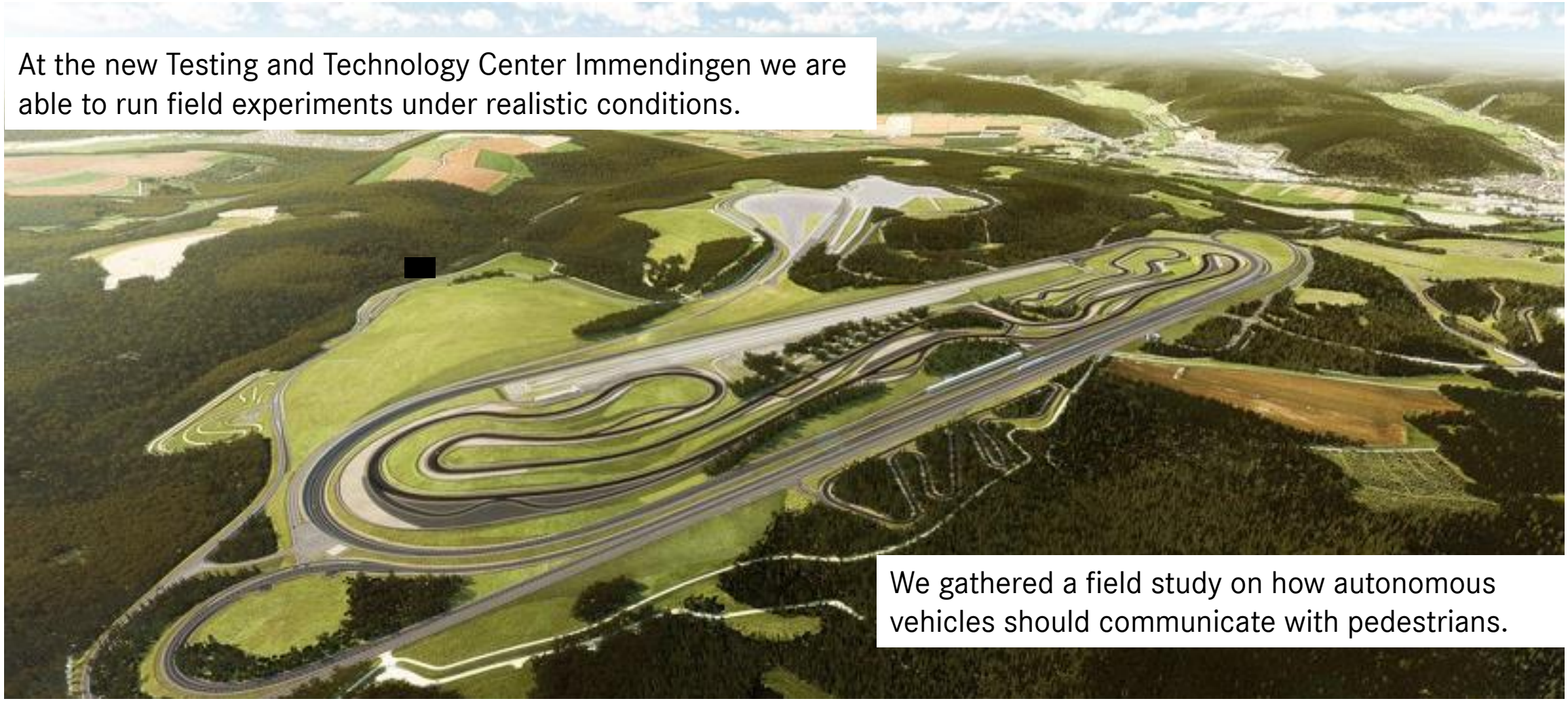
Wizard-of-Oz Field Study
Immendingen, September 2018

Testing and Technology Center Sindelfingen: Wizard-of-Oz Field Study

Research questions	Should the autonomous driving mode be displayed externally? Should autonomous vehicles signal their intention? Should autonomous vehicles signal their perception? Colour of eHMI: Turquoise or white?
Method	Field Study Urban Scenarios: Street-Crossing, Parking Space Role: Pedestrian
Sample	60 external participants (47% ♀, 53% ♂ // Ø 43 years)
Vehicle	E-Class
Survey Period	09/10/2018 to 09/21/2018

Stefanie M. Faas, Lesley-Ann Mathis, and Martin Baumann. 2018. Autonomous vehicle-to-pedestrian communication: What should an eHMI communicate?. Manuscript in preparation.

Testing and Technology Center Immendingen: Wizard-of-Oz Field Study



At the new Testing and Technology Center Immendingen we are able to run field experiments under realistic conditions.

We gathered a field study on how autonomous vehicles should communicate with pedestrians.

Street Crossing Scenario

Parking Space Scenario

Wizard-of-Oz: Seat Costume

Pedestrians Prefer Turquoise Light for Autonomous Vehicles

turquoise
lighting colour

Participants replied:

85%

would like to see an indication that the ADS is activated*

93%

prefer turquoise over white as ADS lighting colour***

* As pedestrian, would you like to see an indicator for autonomous vehicles?
*** Assuming autonomous vehicles have a specified lighting colour, do you prefer turquoise or white as lighting colour for autonomous vehicles?

Autonomous Vehicle to Pedestrian Communication

AVP: Focus Groups
MB Museum, December 2017

Wizard-of-Oz Field Study
Sindelfingen, October 2017

Wizard-of-Oz Field Study
Immendingen, September 2018

Pedestrians Prefer 360° View and Turquoise Light for Autonomous Vehicles

turquoise
lighting colour

Participants replied:

94%[1] / 81%[2] / 85%[3]	100%[1] / 79%[2]	92%[2] / 93%[3]
would like to see an indication that the ADS is activated[*]	prefer a 360° view[**]	prefer turquoise over yellow resp. white as ADS lighting colour[***]

[1] Automated Valet Parking: Focus groups (*N*=18)
[2] Testing and Technology Center Sindelfingen: Field study (*N*=65)
[3] Testing and Technology Center Immendingen: Field study (*N*=60)
[*] As pedestrian, would you like to see an indicator for autonomous vehicles?
[**] Assuming autonomous vehicles have an indicator, would you prefer a 360° view or a display at the front of the vehicle?
[***] Assuming autonomous vehicles have a specified lighting colour, do you prefer turquoise or yellow resp. white as lighting colour for autonomous vehicles?

Key Findings

- Pedestrians feel a little uncomfortable when seeing a driverless vehicle
- An eHMI helps pedestrians to interpret a driverless vehicle as being no threat
- Pedestrians prefer a 360° eHMI
- Pedestrians prefer turquoise as autonomous vehicle lighting colour.