interACT

Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

Virtual Final Event

Testing the interACT solutions: Methodologies and results for evaluation and impact assessment

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19-06-2020
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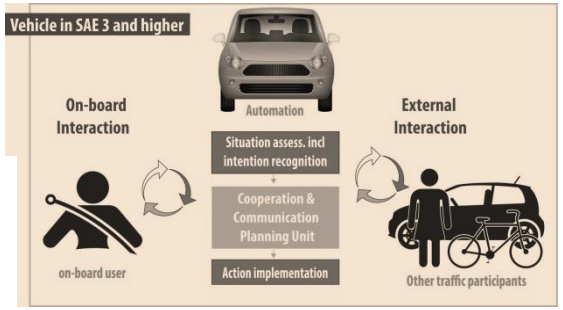
The challenge

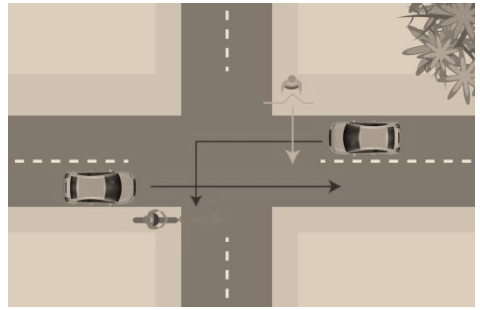
5th Objective
Methodology for assessing the quality of interaction

1st Objective
Psychological models

4th Objective
Novel HMI elements

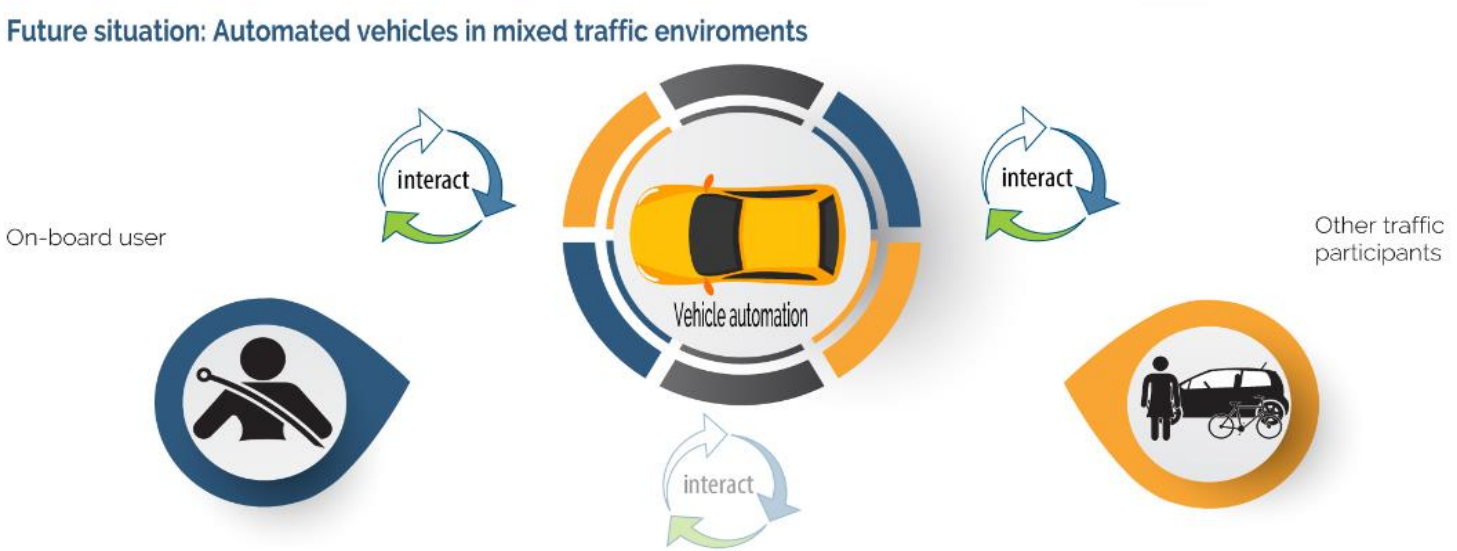


3rd Objective
CCPU & safety layer



2nd Objective
Intention recognition & behavioural predictions

Main Objective



Testing the interACT solutions: Methodologies and results for evaluation and impact assessment

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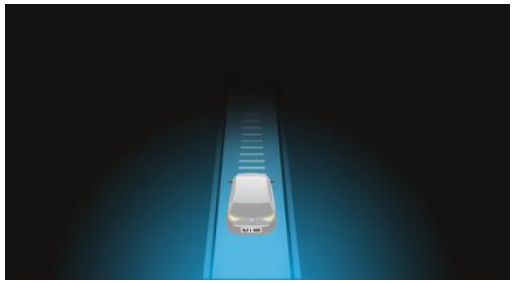
interACT Solutions

Safety Layer

-To eliminate or reduce the severity of collisions and only intervene if necessary

iHMI



eHMI

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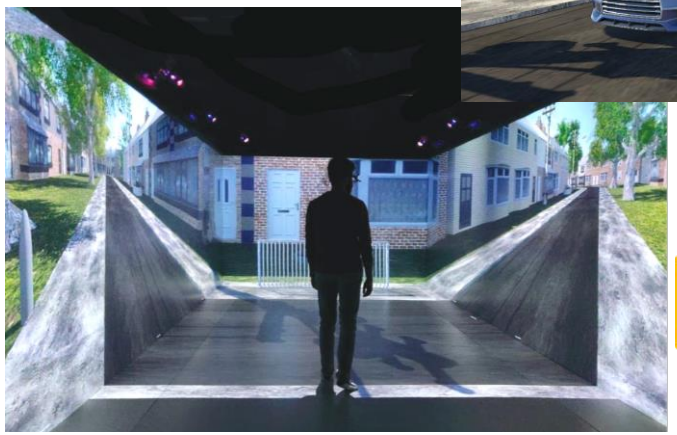
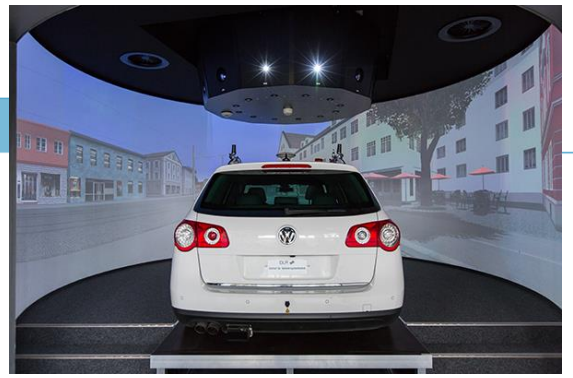
Team and Facilities

www.interact-roadautomation.





UNIVERSITY OF LEEDS

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

BOSCH Invented for life

Technical University of Munich

HELLA

CRF

ΕΠΙΣΕΥ ICCS

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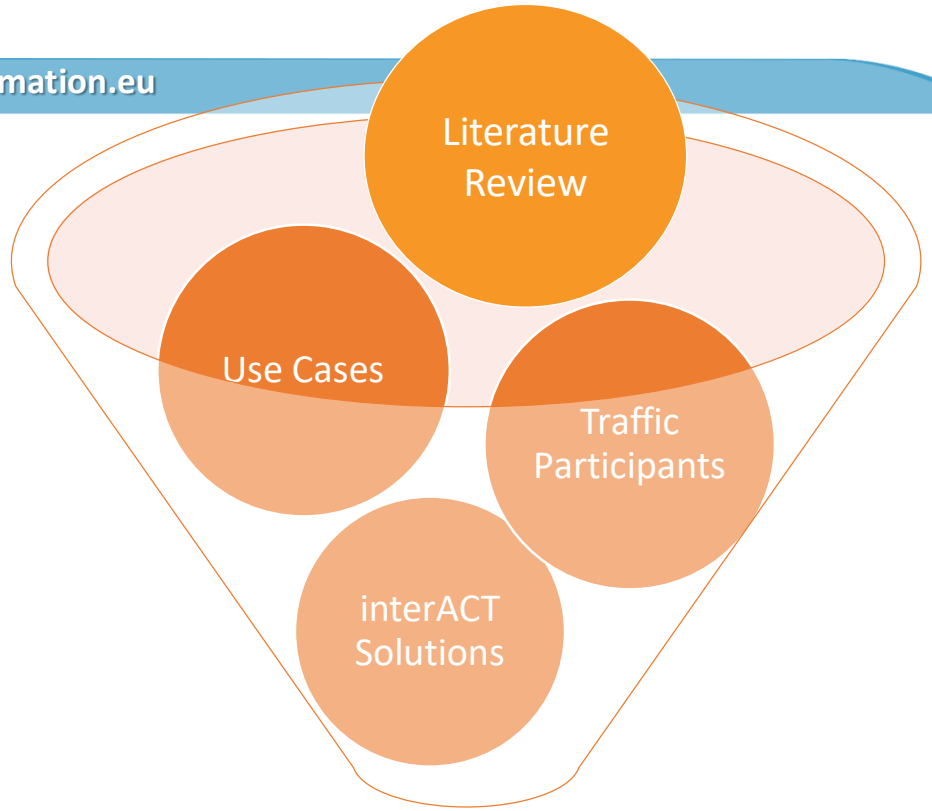
An Iterative Process

Deliverable 6.1, Lee et al. (2019)



Research Questions

Research Questions

Methodologies

~ 30 Studies

Evaluation Criteria

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Methodologies

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- 4 Test-track studies (N ~ over 100)

Simulator

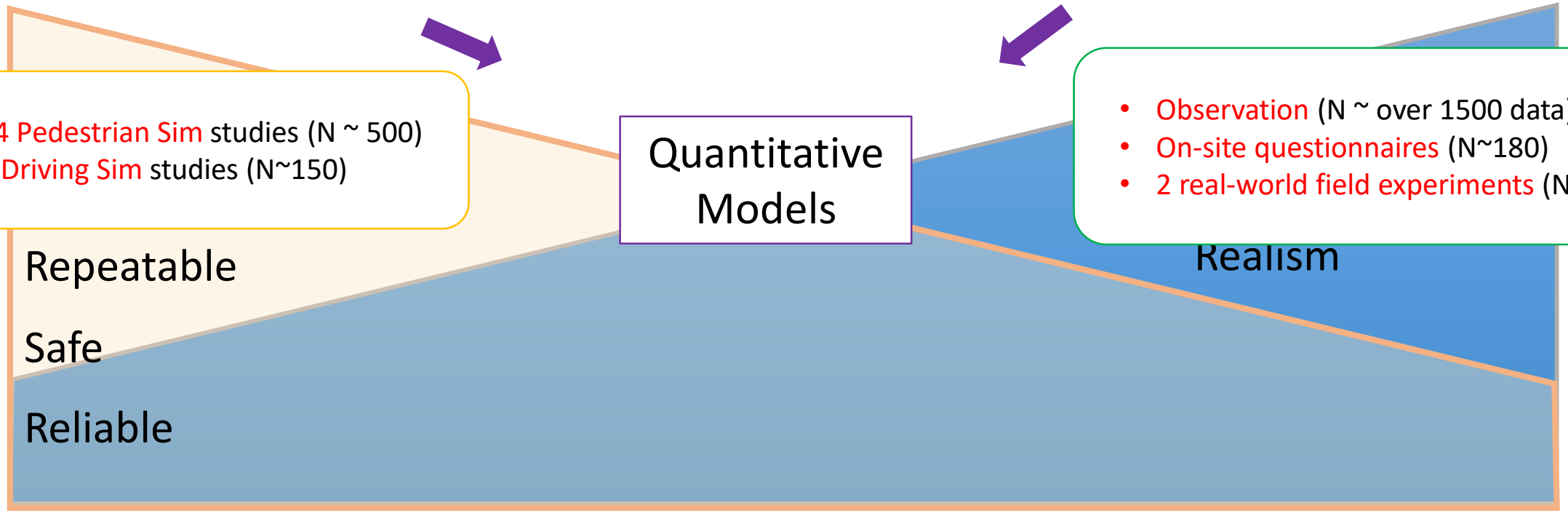
Test-Track

Real-World

- 14 Pedestrian Sim studies (N ~ 500)
- 4 Driving Sim studies (N~150)

Quantitative Models

- Observation (N ~ over 1500 data)
- On-site questionnaires (N~180)
- 2 real-world field experiments (N~50)



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(1) interACT Solutions: Safety Layer

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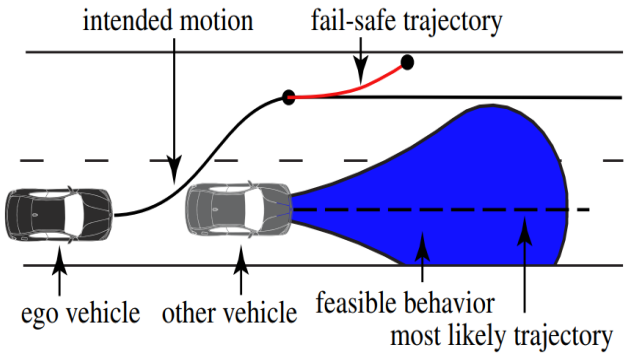

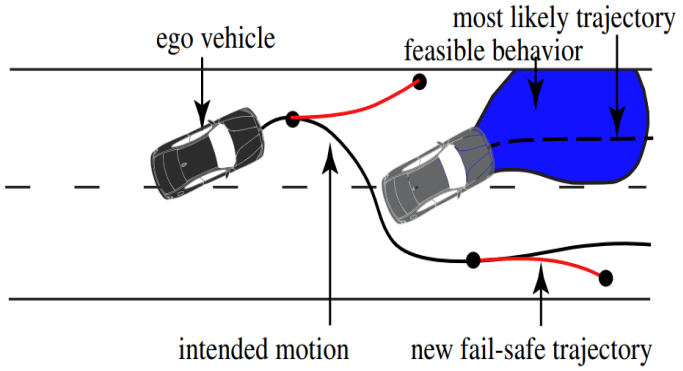

- In order to demonstrate that our on-the-fly techniques for manoeuvre and trajectory planning work, we have created several hundred realistic test scenarios. https://commonroad.in.tum.de/
- These scenarios were modelled from real-world data, or artificially created

Pek, Koschi, & Althoff (2019); Althoff, Koschi, & Manzinger, (2017)
the NGSIM US101 dataset;
TUM Threat Assessment reported in Deliverable 6.3, Lee et al. (in prep)

Threat Assessment:

- Objective Safety of Proposed Fail-safe Trajectory Approach
- Objective Criticality of Scenario (Time-To-React measures)
- Subjective Criticality of Scenario

Key Takeaways:

- Random simulations of behaviours of other traffic participants confirm the proposed safety benefits of fail-safe trajectories; in all simulations, the autonomous vehicle remains collision-free, and safely comes to a standstill.
- These fail-safe manoeuvers ensure the availability of safe actions even if vulnerable road users behave unexpectedly.

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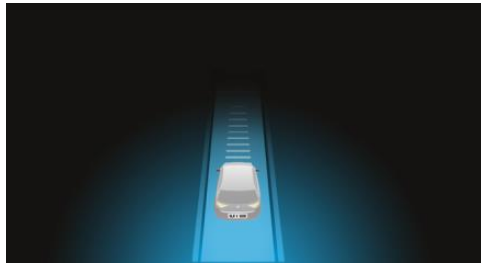
(2) interACT Solutions - iHMI

DLR Driving Sim study

Idle	Pedestrian crossing	Vehicle Turning
		

Impressions from iHMI study: (10 participants; Subjective Response Only)

- Overall, iHMI seem to be useful, satisfactory, understandable, and the vehicle movement was predictable

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DLR iHMI study reported in Deliverable 6.2, Dietrich et al. (in prep)

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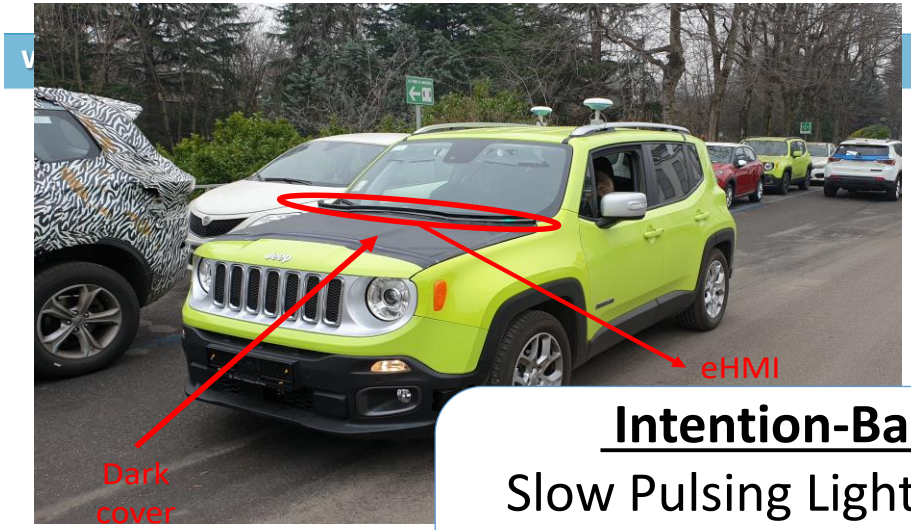
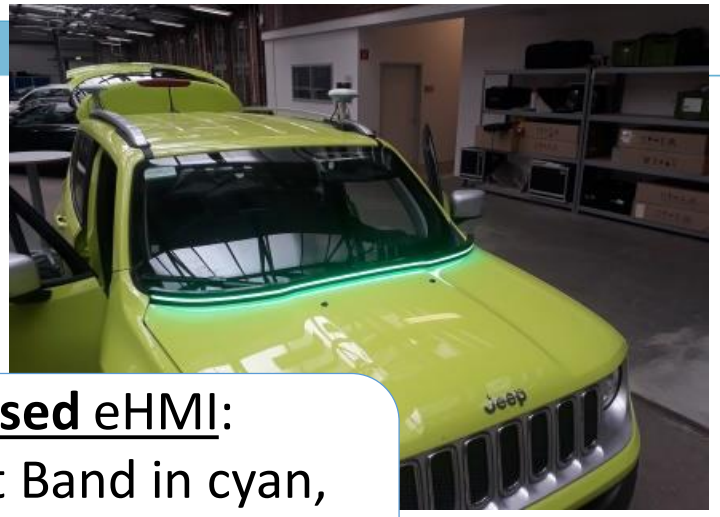
(3) interACT Solutions: eHMI





Intention-Based eHMI:
Slow Pulsing Light Band in cyan, presented at 0.4Hz (SPLB).
'I am giving way'

Perception-Based eHMI
Directed Light Band in cyan.
'I detected you'

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Research Questions, Methodologies and Measures

The effect of eHMI on road users' behaviour and subjective evaluations

- *Comprehension: Which signal is the best in conveying a particular message?*
- *Visibility of eHMI: Which signal is more visible?*
- *Objective evaluations: How do different eHMI designs affect road users' behaviour?*
- *Subjective evaluations: How do different eHMI designs affect road users' perceived safety, usability and acceptance of the eHMI?*
- *Negative effects: What happens if the eHMI fails? Ambiguous situations?*

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Pedestrian-AV: CRF Test-Track Study

ITS/CRF Test-track study reported in Deliverable 6.2, Dietrich et al. (in prep)

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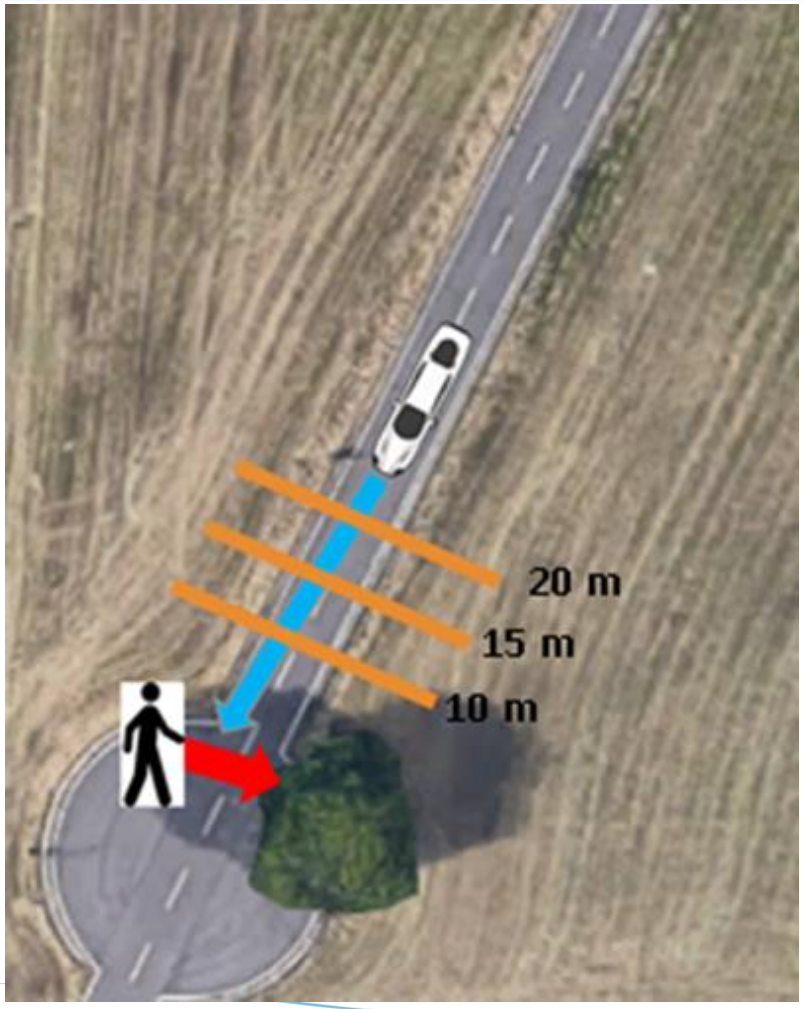

CRF demonstrator manipulations: ~12km/h

(1)eHMI: no eHMI, Directed Light Band, Slow Pulsing Light Band

(2)Distances: 10, 15, 20m

Task: Raise your hand if:

(1) deceleration perceived

(2) eHMI perceived

(3) crossing decision – confidence, safety

Assessment:

(1) System Usability Scale

(2) Acceptance scale (van der Laan et al., 1997)

(3) Learnability and Effectiveness (Jander et al., 2012)

(4) Comfort and Safety

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Pedestrian-AV: CRF Test-Track Study

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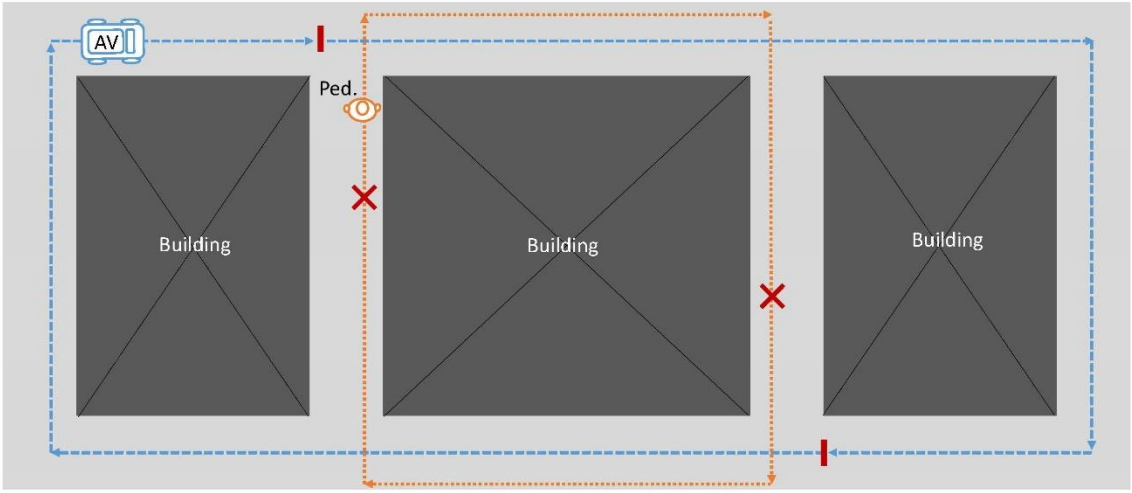
TUM/BMW test-track and real world study reported in Deliverable 6.2, Dietrich et al. (in prep)

Pedestrian-AV: BMW Test-Track & Real-World Study



Study 1:
BMW demonstrator manipulations (30km/h):
(1) 3 Deceleration Onset distances
(2) 4 eHMI conditions (Intention-Based, Perception-Based, combined, no eHMI)

Pedestrian's Task:
(1) Press a button if you understand what the vehicle is doing/will do
(2) Take a step forward to cross the light barrier to record crossing decision

Study 2:
BMW demonstrator real-world (on-campus) field test (20km/h)
(1) 4 eHMI conditions (Intention-Based, Perception-Based, combined, no eHMI)
(2) Crossing site 1 and site 2

Pedestrian's Task:
(1) Walk on the predesignated route
(2) They met the AV at two stopping points
(3) Structured interview, perceived safety, acceptance

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Pedestrian-AV: BMW Real-World Study

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Some of the Findings (Pedestrian-AV)

- *Visibility of eHMI: Which signal is more visible?*

Deliverable 6.2, Dietrich et al. (in prep)
Deliverable 6.3, Lee et al. (in prep)

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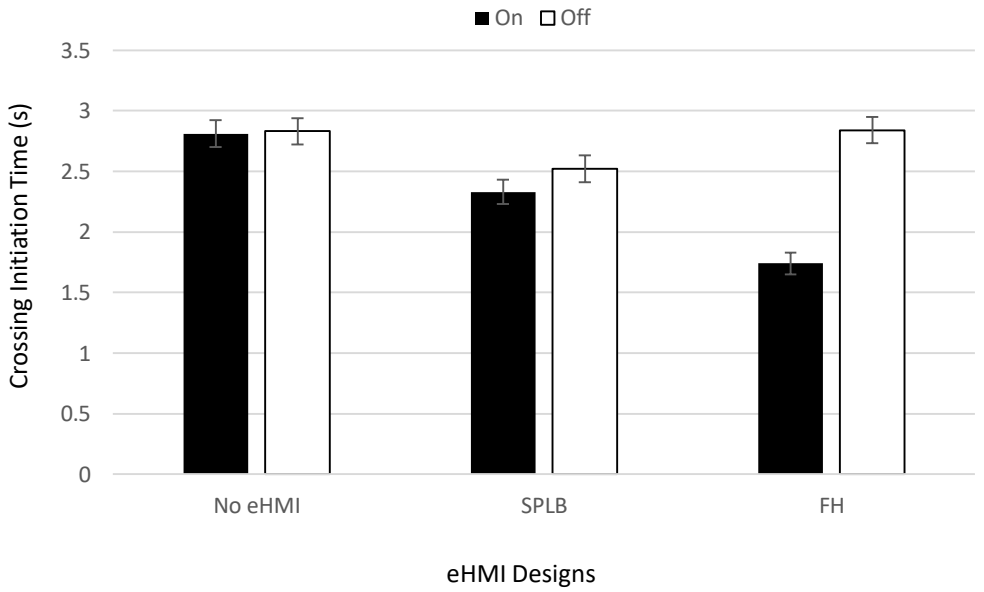
ITS Ped Sim (HIKER) study reported in Deliverable 6.2, Dietrich et al. (in prep) Lee et al. (in prep)

Some of the Findings (Sim: Pedestrian-AV)

- *Objective evaluations: How do different eHMI designs affect road users' behaviour?*

✓ *Reduced Crossing Initiation Time (Induced early crossing)*

- *Increased Drivers' Gap Acceptance*
- *Decreased the Duration of Interactions*



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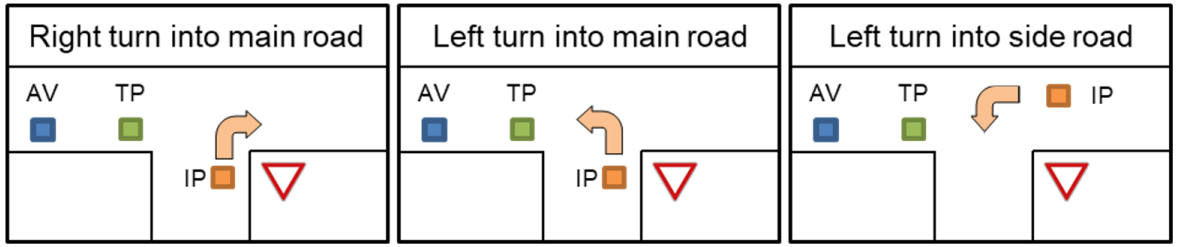
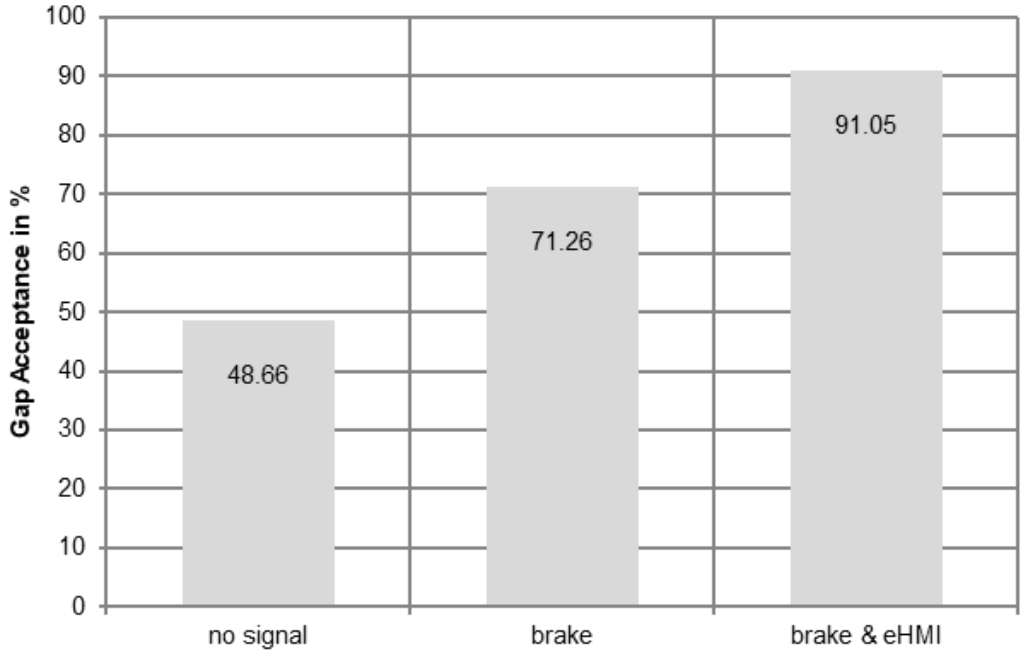
DLR driving simulator study reported in Deliverable 6.2, Dietrich et al. (in prep)

Some of the Findings (Sim: Driver-AV)

- *Objective evaluation: How do different eHMI designs affect road users' behaviour?*
  - *Reduced Crossing Initiation Time (Induced early crossing)*
  - ✓ *Increased Drivers' Gap Acceptance*
  - *Decreased the Duration of Interactions*





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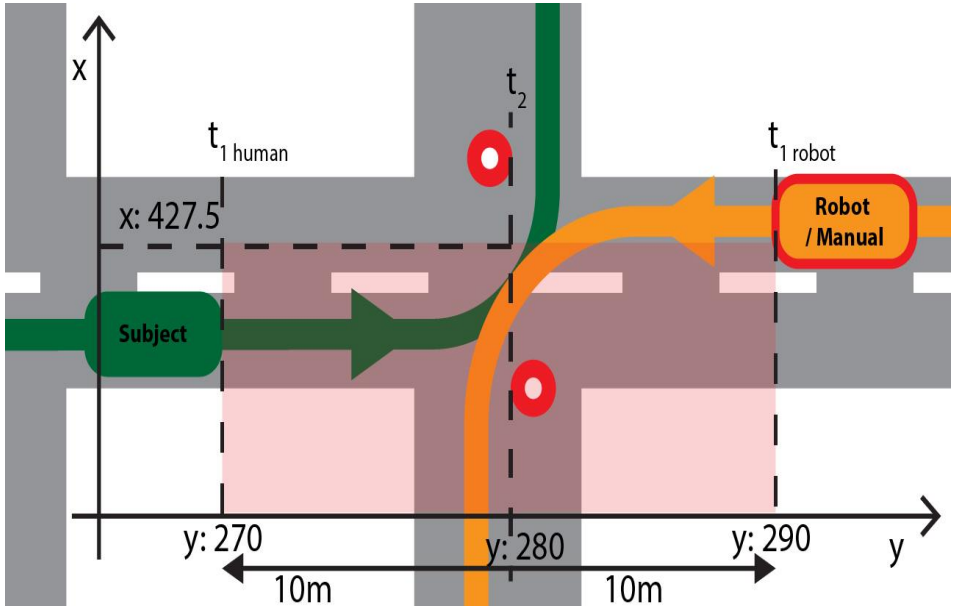
ICCS test-track study reported in Deliverable 6.2, Dietrich et al. (in prep)

Some of the Findings (Test-tack: Driver-AV)

- *Objective evaluation: How do different eHMI designs affect road users' behaviour?*
  - *Reduced Crossing Initiation Time (Induced early crossing)*
  - *Increased Drivers' Gap Acceptance*
  - ✓ *Decreased the Duration of Interactions*



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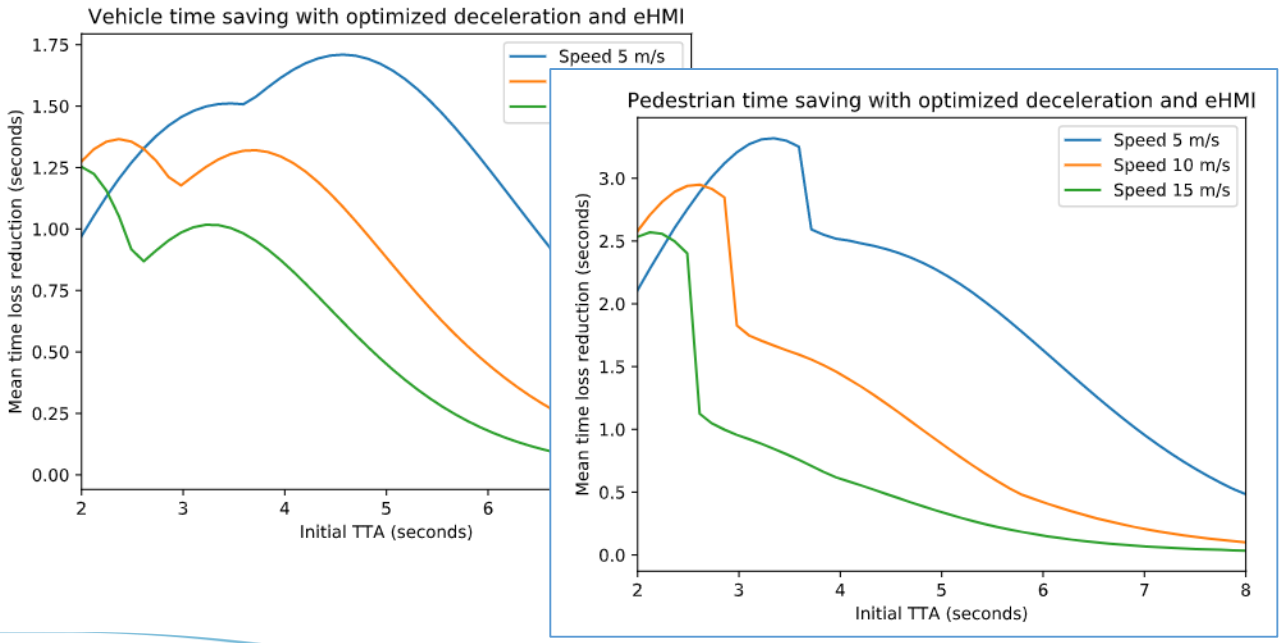
ITS Quantitative Modelling reported in Deliverable 6.3, Lee et al. (in prep) Pekkanen et al. (in prep)

Some of the Findings

(Quantitative Modelling: Pedestrian-AV)

- Objective evaluation: How do optimised (exaggerated) deceleration and eHMI impact interaction efficiency?

Simulations with quantitative models of interaction:



Key takeaways:

- Both optimised deceleration and eHMI save time
- Up to ≈1.5 s (AV) and 3 s (ped.) saved per average interaction
- With eHMI, optimal deceleration is milder
- Greater time savings in situations with larger safety margins (JPN vs UK; driver turning vs ped crossing)

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Some of the Findings (Subjective)

- ✓ *Pedestrians generally felt safe and comfortable interacting with the AV with an eHMI (CRF demonstrator study)*
- ✓ *eHMIs were generally well-received, with high ratings of usability, acceptance and learnability (from both Pedestrians' and Drivers' perspectives)*

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Some of the Findings: Negative Effects

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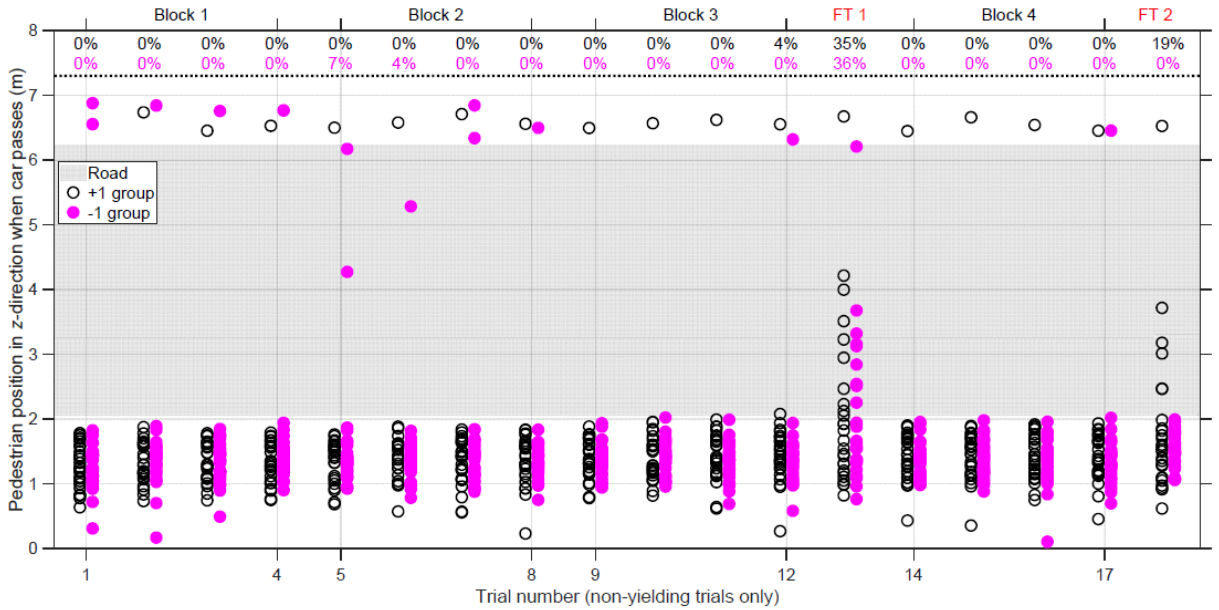
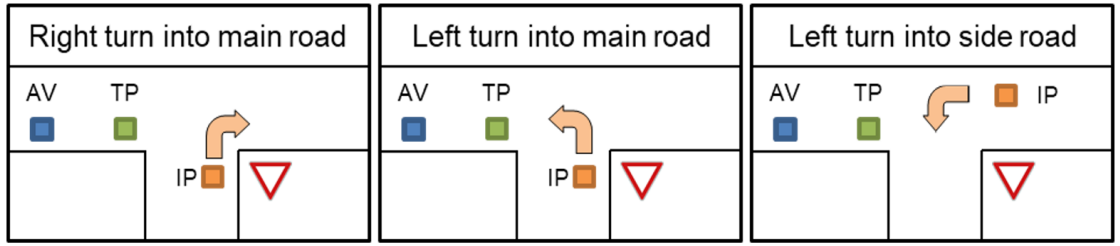
Sim, Pedestrian-AV: *What happens if the eHMI fails? eHMI on but not yielding*

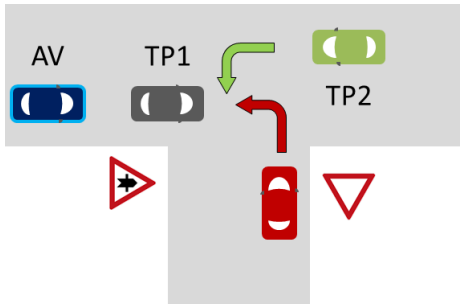


~ 30% collisions

ITS ped sim (HIKER) study reported in D6.2, Dietrich et al. (in prep), Kaleefathullah et al. (under review)

Sim, Driver-AV: *What happens in a more ambiguous situation?*





- 4/22 (18%) crashed
- 6/22 (27%) near miss
- 12/22 (55%) safe

Deliverable 6.2, Dietrich et al. (in prep)

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'If eHMI was present, participants relied on the eHMI to infer intention. However, when the eHMI was absent, they used vehicle kinematics to infer intention.'

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Summary / Conclusions (1)

- The incorporation of the interACT safety layer proving that the vehicle never causes an accident. These fail-safe manoeuvers ensure the availability of safe actions even if vulnerable road users behave unexpectedly.
- In turn, we expect that the proposed safety layer will increase the comfort and trust of humans in AVs.
- Our observation studies in conventional traffic situations showed that explicit communication rarely happens, interactions are mainly is resolved by implicit communication (at least in our chosen sites).
- However, we observed more explicit communication in parking scenarios. e.g. driver who used signal are more likely to take priority than drivers who do not.

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Summary / Conclusions (2)

- Our evaluation studies showed that participants are able to use kinematics information as a cue, without the need for eHMIs:
    - No difference in crossing decisions (BMW Pedestrian Simulator study)
    - No difference in crossing decisions (CRF demonstrator test track study)
    - BUT mixed findings in BMW real-world study
- However, eHMIs induced earlier crossings, and shortened the interaction time, and therefore improved flow, if visibility and consistency of eHMI are ensured.
- Overall, a positive experience was reported for eHMIs by participants
- But we need to be cognisant of the potential of new types of crashes. Consequences of eHMI failure/miscommunication can be severe, and therefore public guidance around eHMI capability will be required. More studies required on the potential negative effects of eHMI.

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Summary / Conclusions (3)

- CAVEAT: conclusions are based on a small number of studies and analyses are still on-going, and there will be more/new findings. (We are all still learning!)
- More studies should be developed, to understand interactions in more complex scenarios (e.g. more than one to one interactions), across different situations and scenarios (e.g. parking, deadlock). Understanding long-term effects and behavioural adaptation are also important.
- In terms of methodologies, more effects of eHMI seem to be found in Simulator than Test-track or Real world studies. Could it be the methodology/environment? The speed? The visibility?

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interACT
Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

Thank you!

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