interACT

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

Virtual Final Event

Observing human interaction in real traffic – what we learned for interACT

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18 June 2020

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Enabler Overview

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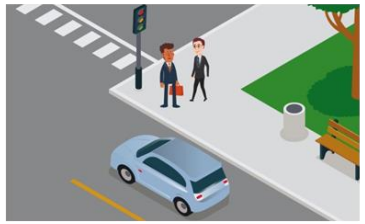
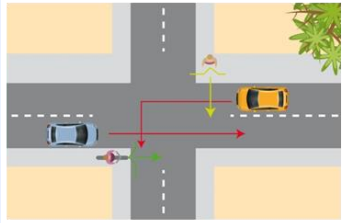
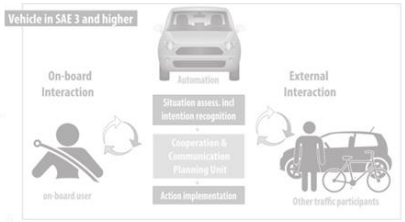
The challenge

5th Objective
Methodology for assessing the quality of interaction

1st Objective
Psychological models







2nd Objective
Intention recognition & behavioural predictions

3rd Objective
CCPU & safety layer

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Key Objectives

- **Observe** interaction in urban human traffic encounters
- **Model** the observed behavior to derive recommendations for automated vehicles
- **Predict** the behavior of traffic participants

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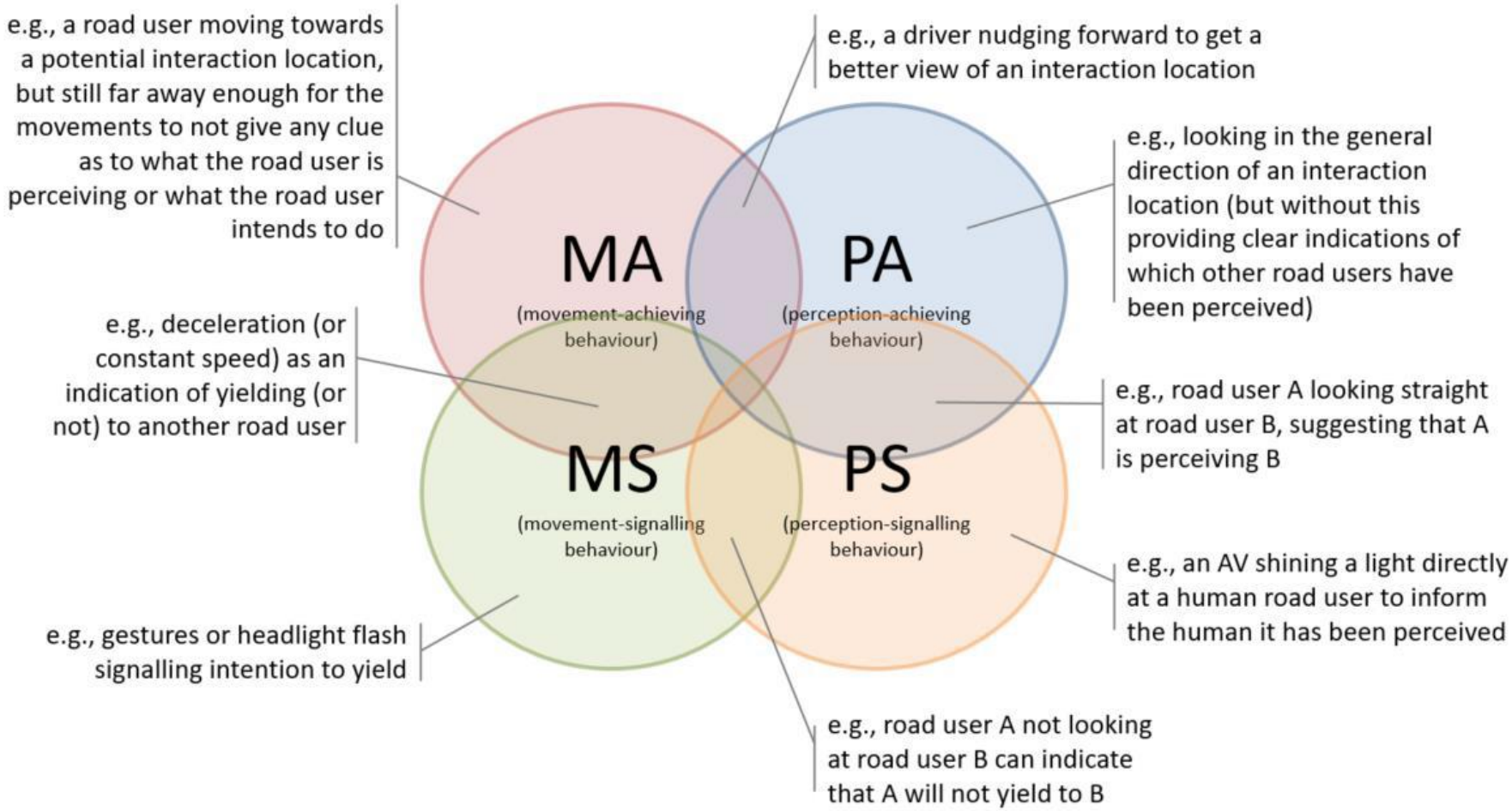
Defining Interaction



Dietrich et al. (2018)
→ Deliverable 2.1

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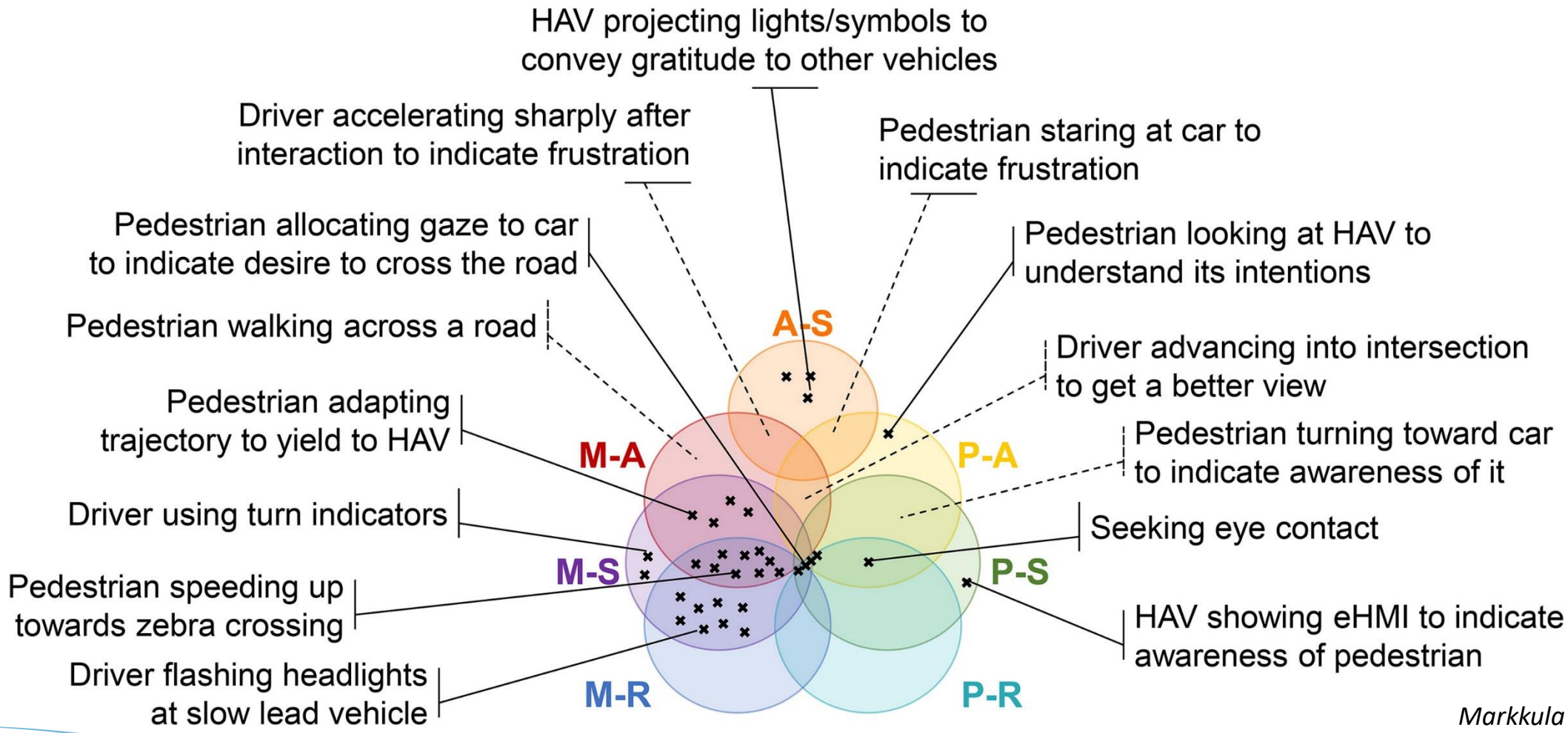
Defining Interaction



Markkula et al. (2020)

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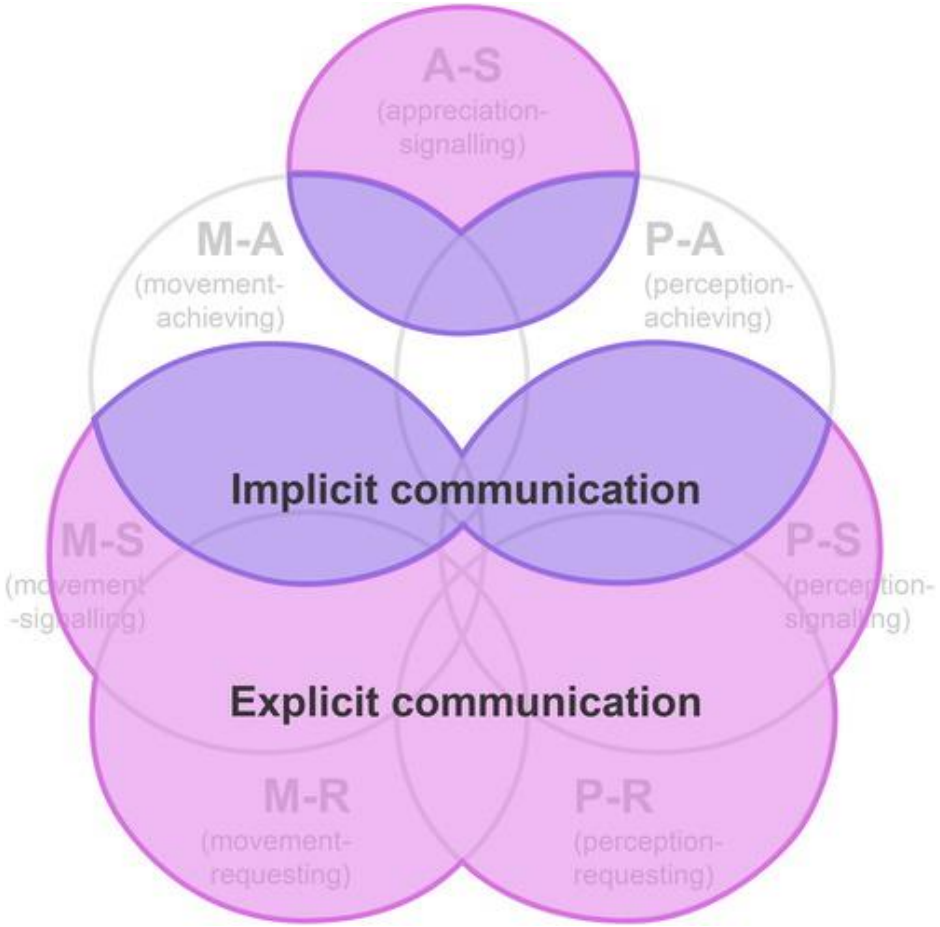
Defining Interaction



Implicit Communication:
Any form of communication through motion and motion-related effects

Explicit Communication:
Any form of communication where one road user intentionally broadcasts his/her message

Markkula et al. (2020)

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Observing Traffic

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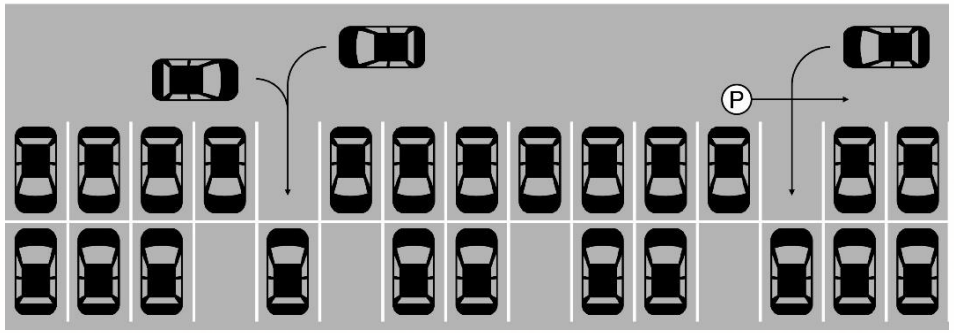
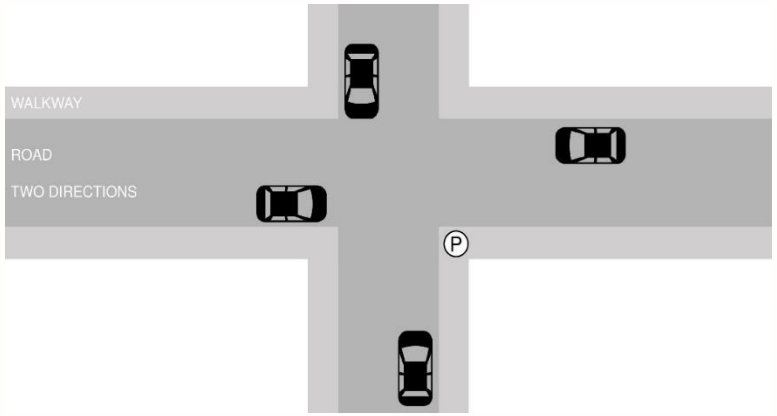
- 3 countries

- 4 use cases





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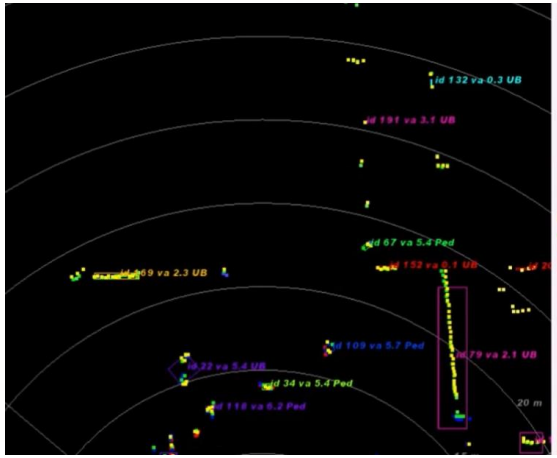
Observing Traffic

Methods:

- Video
- LiDAR
- Questionnaires
- Manual Observation



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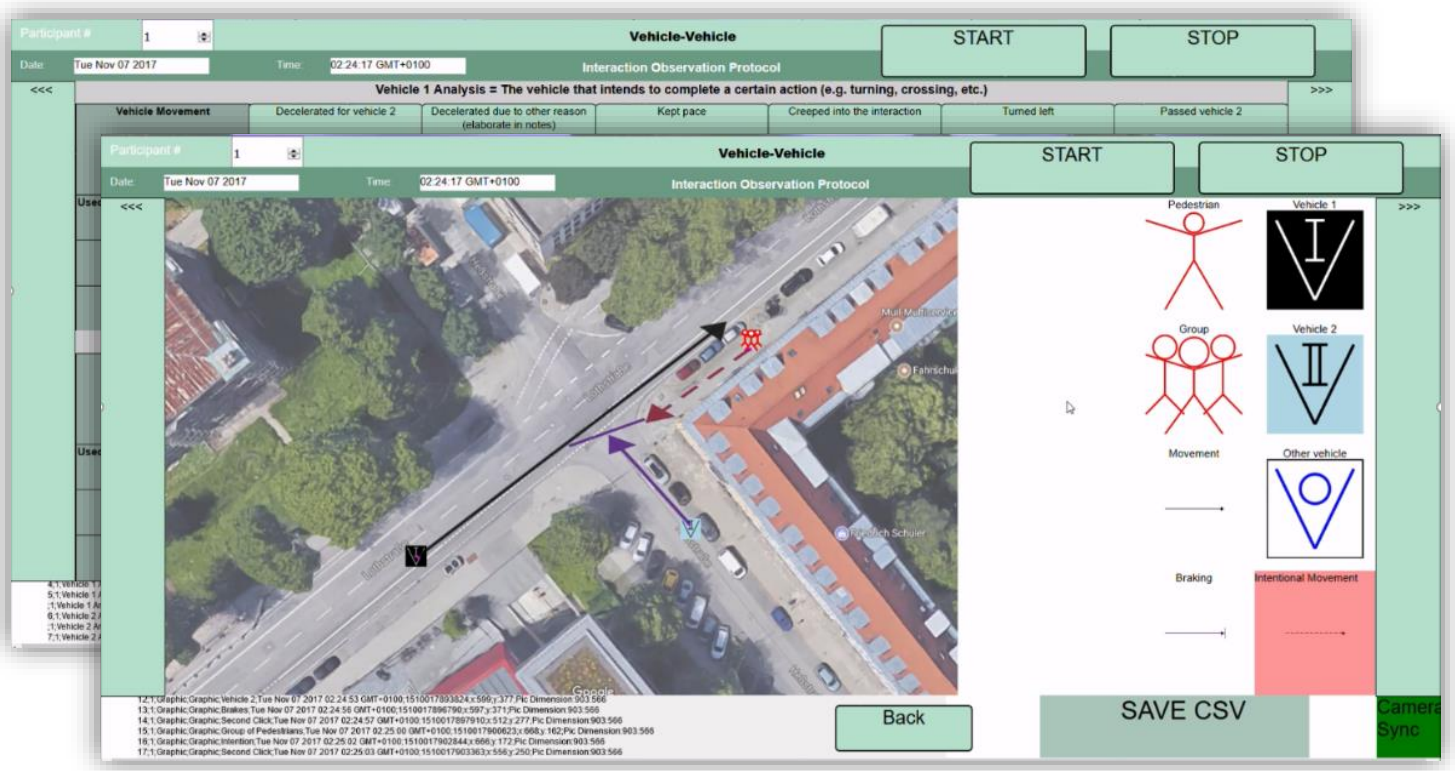
Observing Traffic



- Manual observation was conducted with an HTML app
- Observers drew the observed encounter and indicated the sequence of events occurring in the interaction

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Generalizable Findings

- Occurrence and **necessity of interactions** highly depends on the situation and a variety of **other influences**, such as traffic density, time of day and specific traffic conditions
- **Explicit communication (e.g. gesturing, flashing lights etc.) happens rarely** - most potential interaction-demanding situations are resolved before they actually arise, mostly by adjusting kinematic motion
- **Cooperation, communication and thus interaction** between human road users takes place at **low speeds**, usually below 20 km/h
- At **higher speeds conflict avoidance** is predominant – pedestrians use large enough inter-vehicle gaps to cross without expecting the second vehicle to adapt
- **Self reports ≠ reality**: some pedestrians reported to use some sort of visual information from the driver – even when the driver could not have been physically perceived

For more Results see Lee et al (2020), Uttley et al. (2020), Camara et al (2018), Camara et al. (2018)

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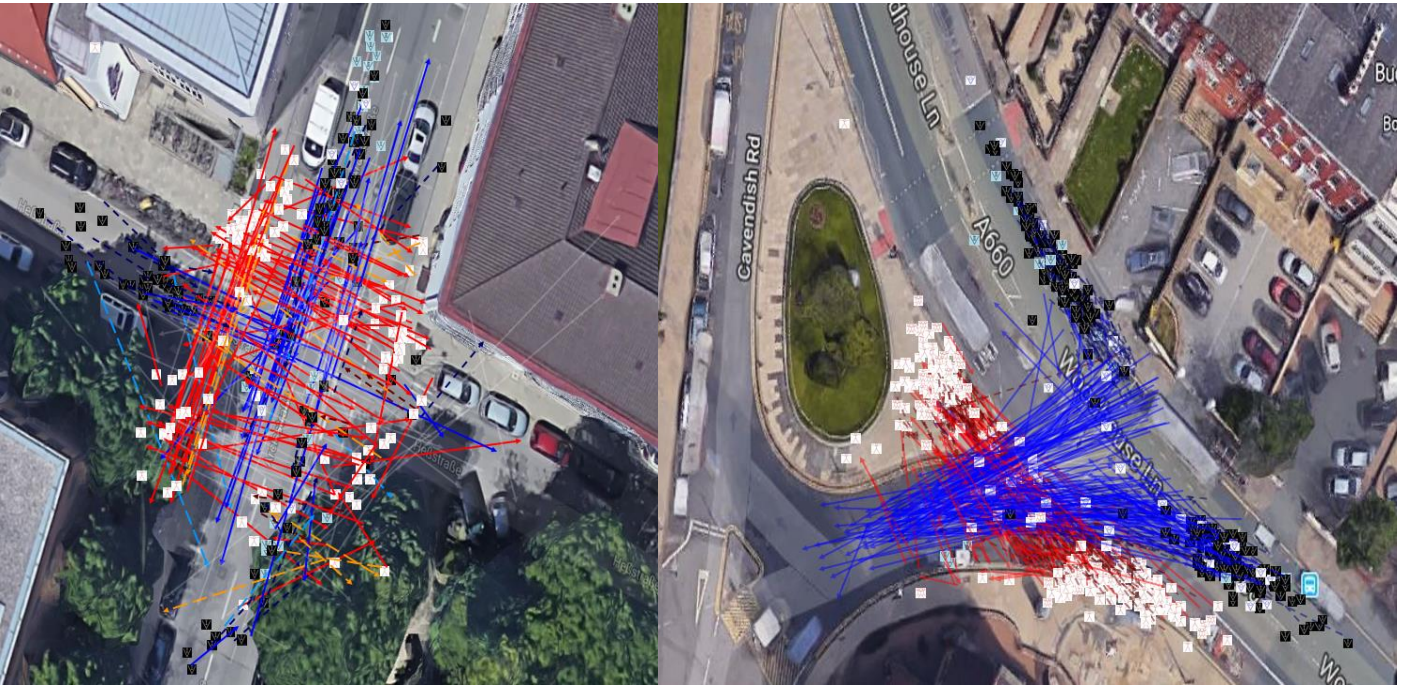
The Problem of Observations



- Within one location, different starting positions lead to different interactions
- Infrastructure (e.g. road layout, points of interests) influences traffic encounters and resulting interactions
- Comparing locations consistently is complicated, especially with different observers

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Sequence Diagrams

Intersection – vehicle goes first

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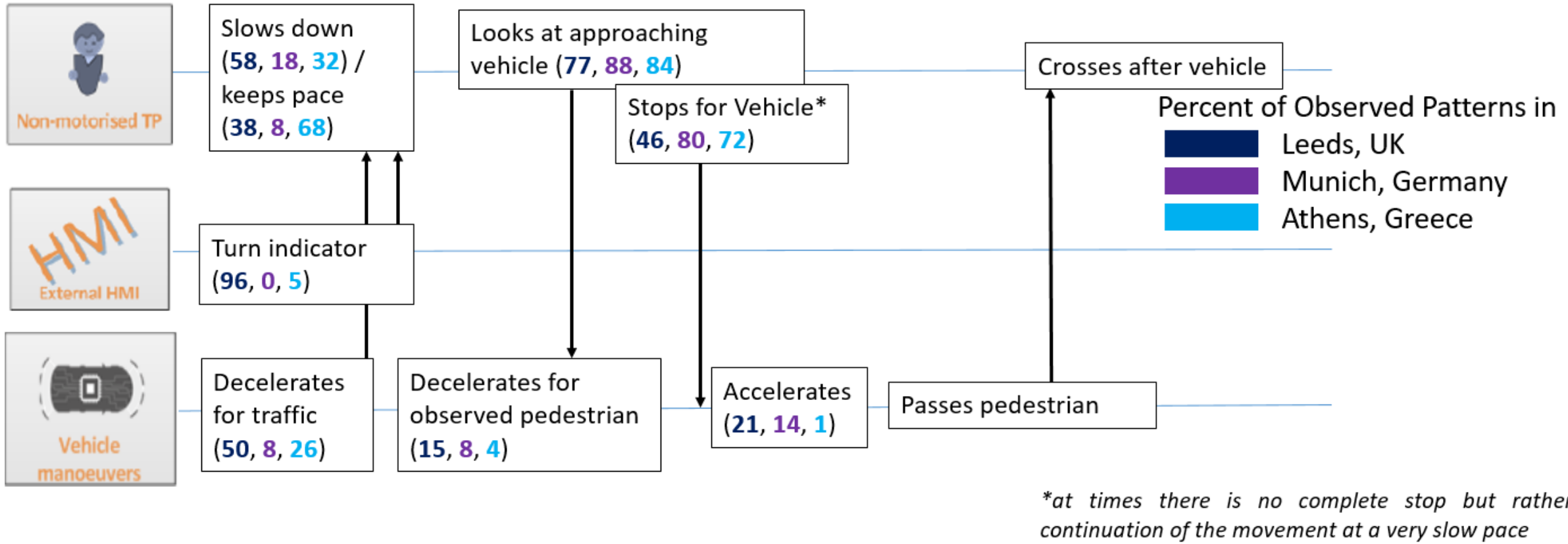

*at times there is no complete stop but rather a continuation of the movement at a very slow pace

For further Results see Lee et al (2020), Uttley et al. (2020), Camara et al (2018), Camara et al. (2018)

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Sequence Diagrams

Intersection – pedestrian goes first

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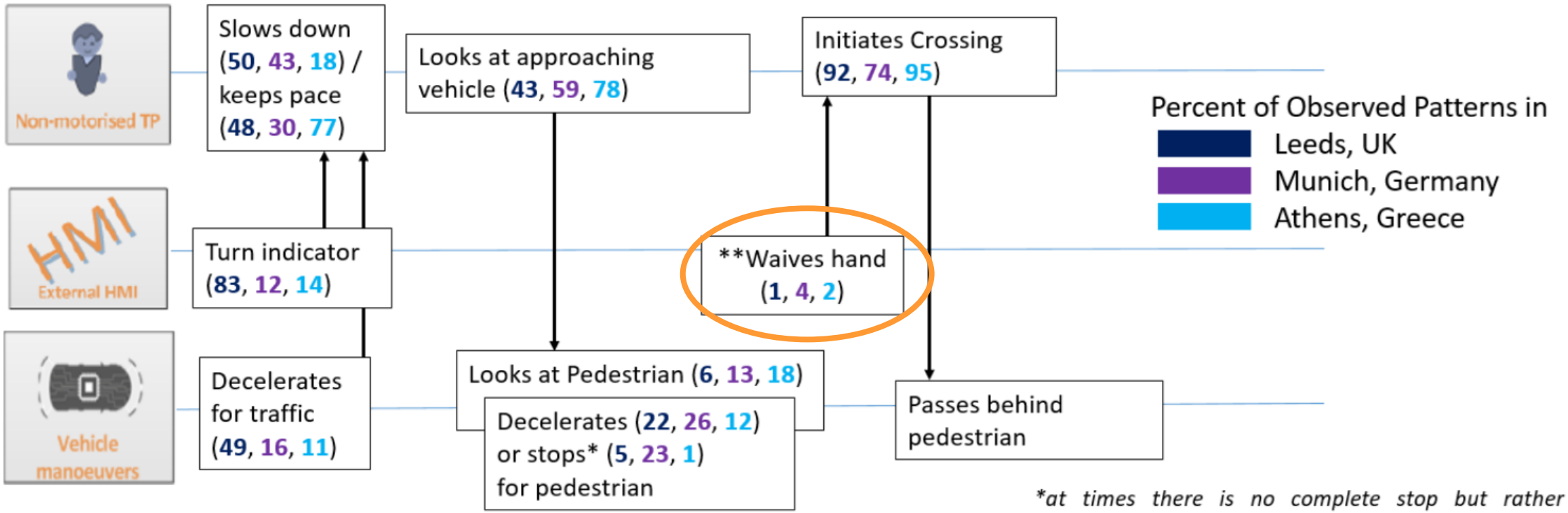

*at times there is no complete stop but rather a continuation of the movement at a very slow pace

**in some cases there was no hand waiving and the scenario played out comparably

For further Results see Lee et al (2020), Uttley et al. (2020), Camara et al (2018), Camara et al. (2018)

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Understanding Visual Perception of Traffic

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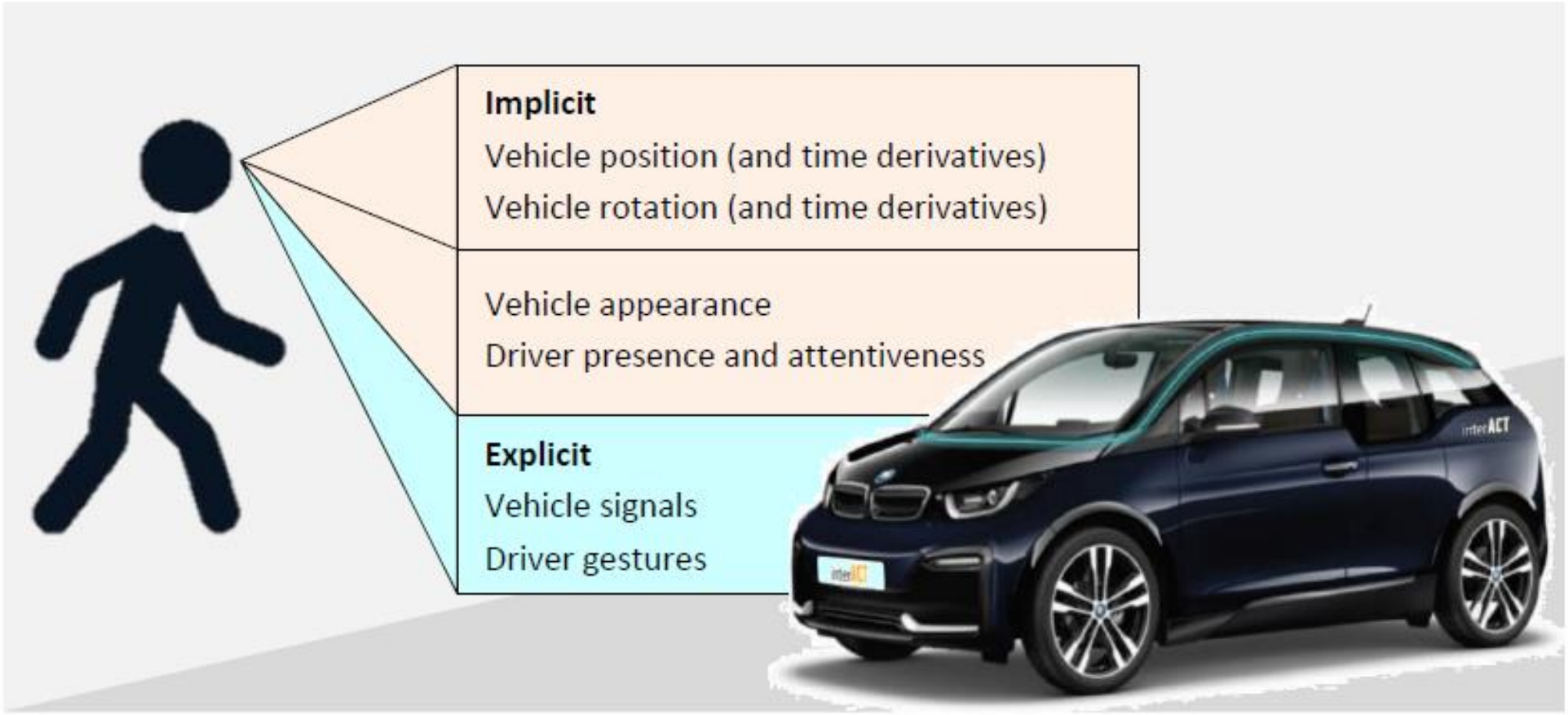

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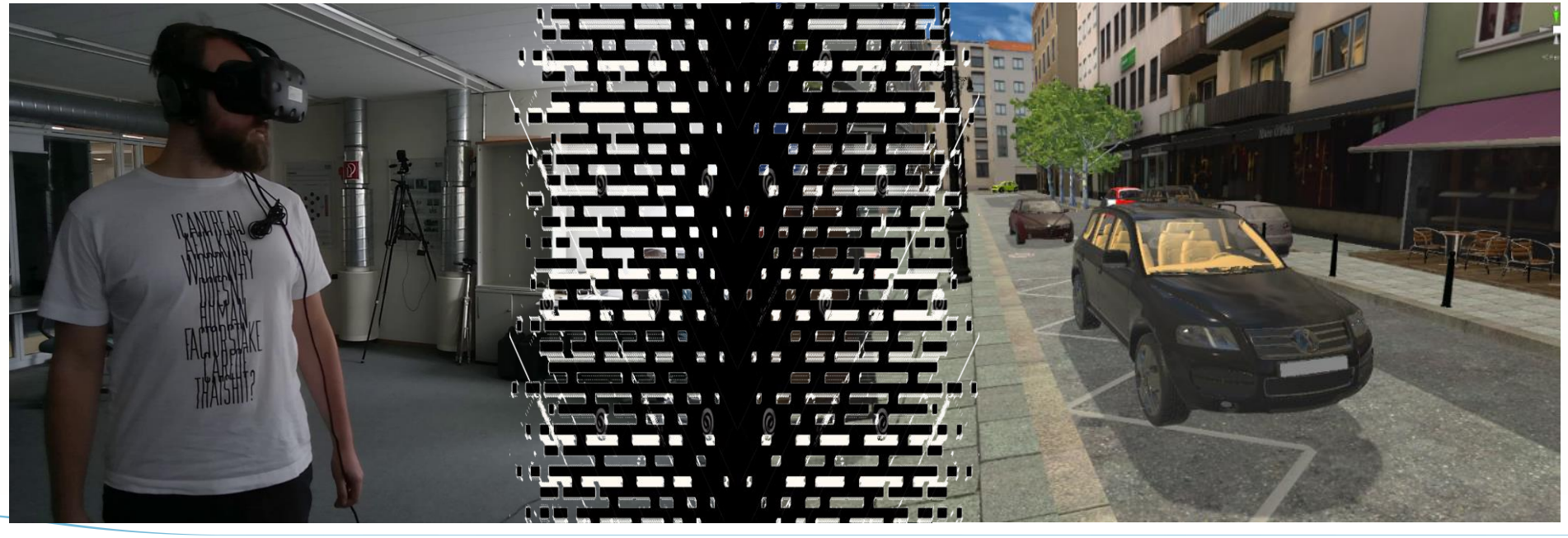
Understanding Visual Perception of Traffic

- Numerous experiments in VR pedestrian simulators to investigate the effects of implicit and explicit communication of vehicles



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Understanding Visual Perception of Traffic

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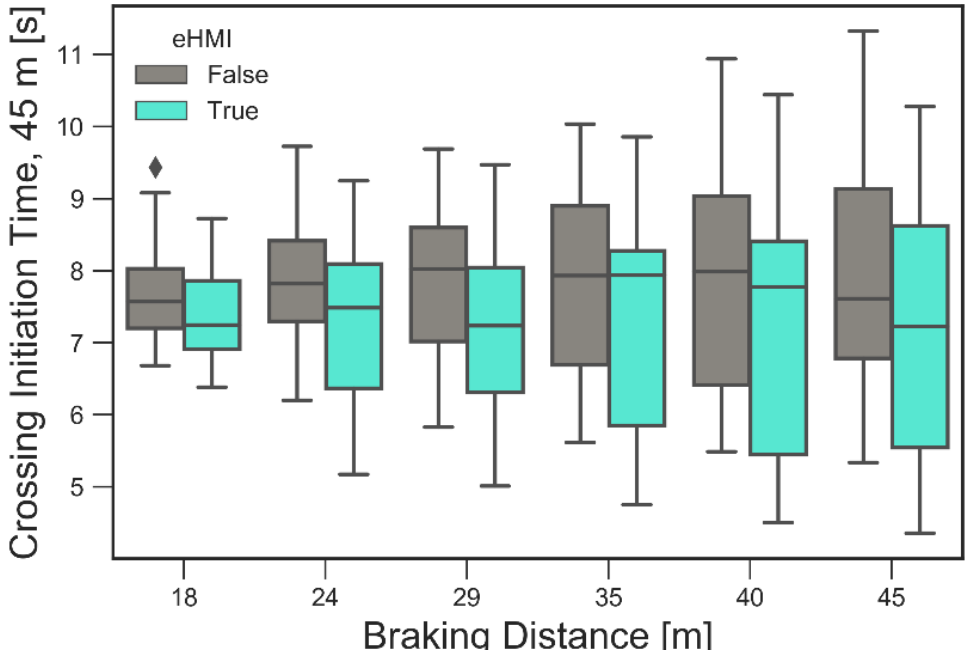
- Early deceleration leads to earlier crossing initiations by pedestrians
- Explicit communication leads to earlier crossing initiations when the vehicle is yielding
- The presence or attentiveness of a driver does not seem to be a big factor for the crossing decision of pedestrians but affects their perceived safety and perceived control



Dietrich et al., 2020; Velasco et al. 2019

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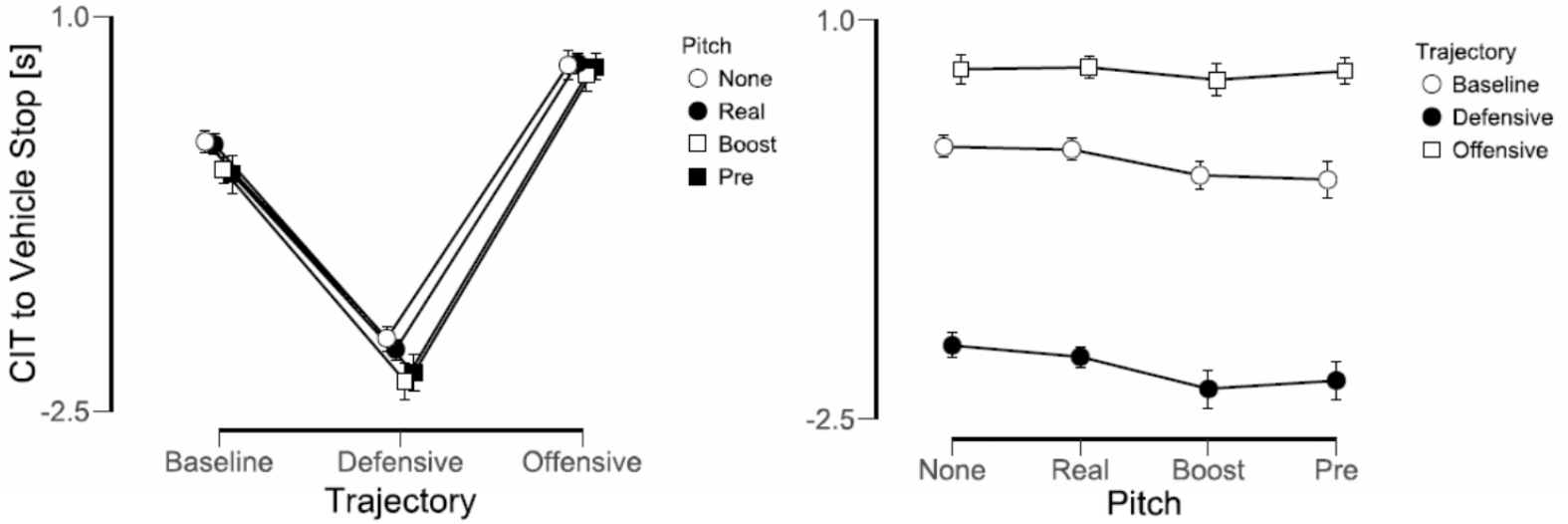
Understanding Visual Perception of Traffic

- Defensive decelerations (initially braking more than needed) decreases the crossing initiation time of pedestrians
- Artificial pitching of the vehicle seems to have a smaller effect on pedestrian crossings



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Quantitative Models of Interaction

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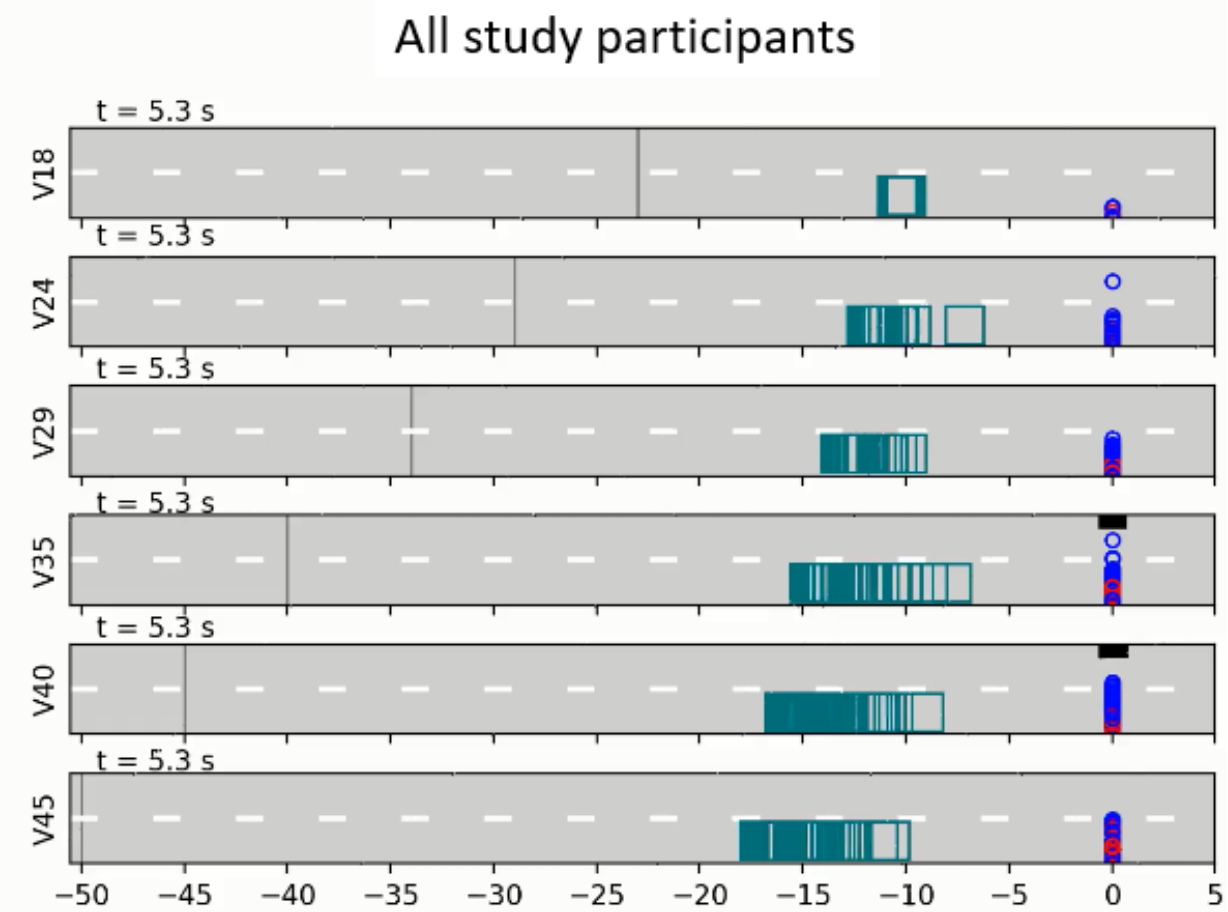

- Visualizing of acquired data allows to understand decision making processes
- Modelling these processes allows to identify optimal AV strategies to maximize efficiency

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Quantitative Models of Interaction

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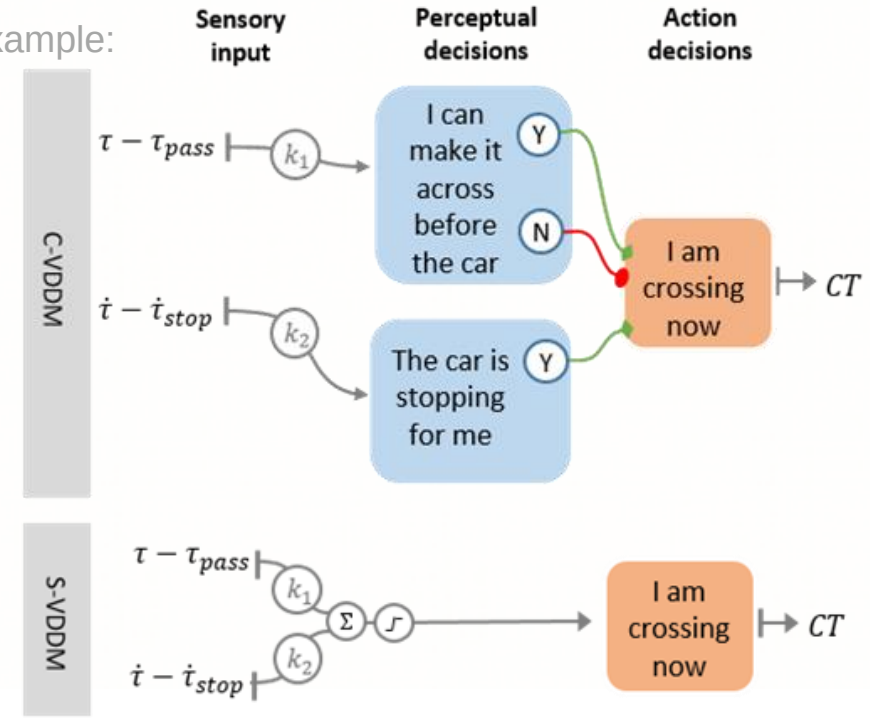
Modelling road-crossing decisions of:

Markkula et al., 2018; Giles et al., 2019; Dietrich et al., 2019; Lee et al., in prep.; Pekkanen et al., in prep.

”Variable-drift diffusion models” (VDDM) based on cognitive neuroscience models of decision-making

For example:



Also simpler ”threshold distribution models” (TDMs)

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Quantitative Models of Interaction

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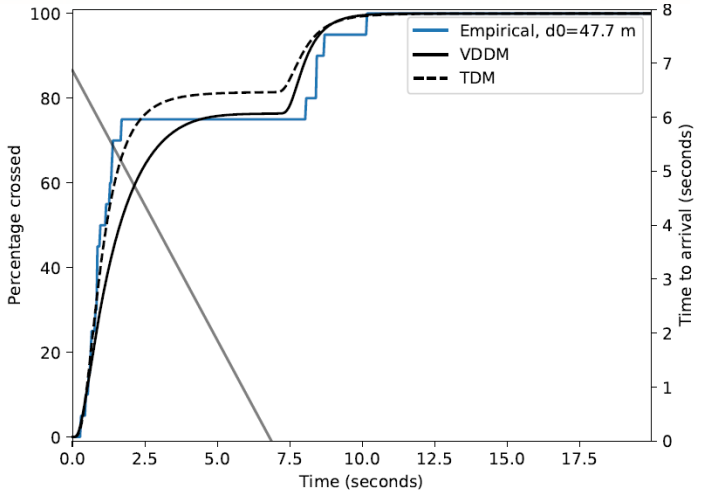
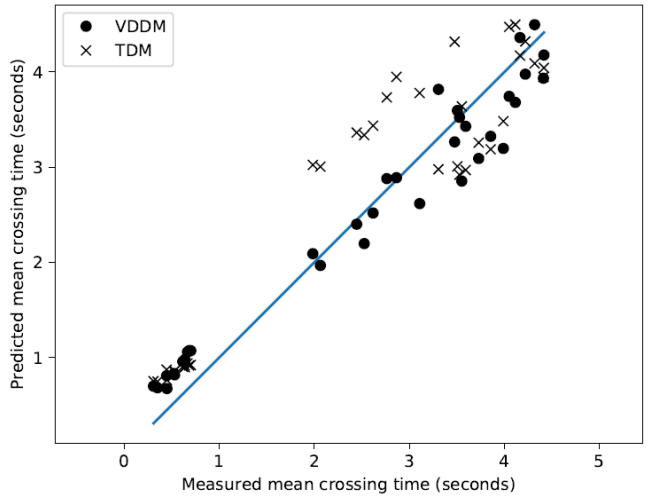
Modelling road-crossing decisions of:

Markkula et al., 2018; Giles et al., 2019; Dietrich et al., 2019; Lee et al., in prep.; Pekkanen et al., in prep.

The developed models reproduce full probability distributions of crossing time, incl effects of:

- AV kinematics (time gap, distance, deceleration)
- Activation of eHMI indicating yielding





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Quantitative Models of Interaction

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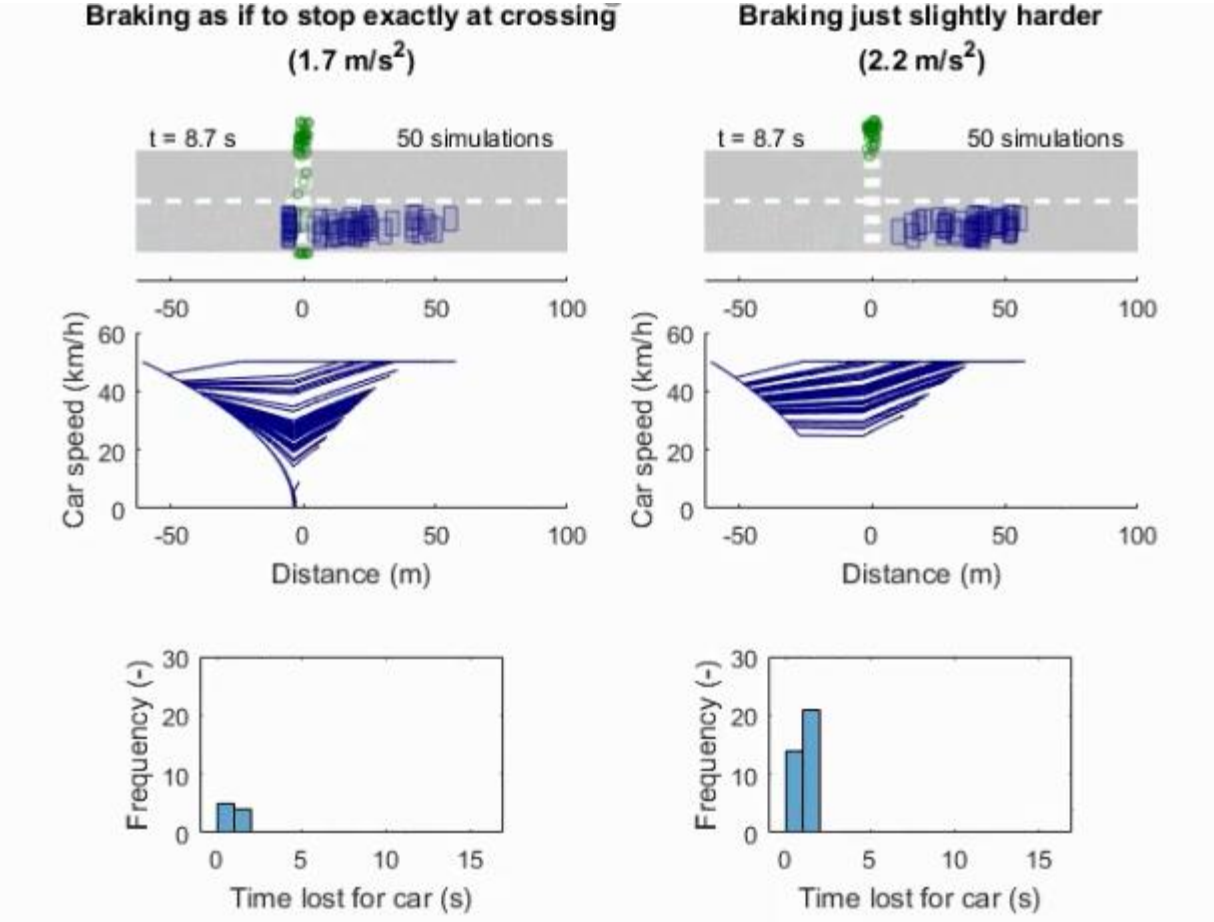
- Models allow us to study any scenario – and optimise AV behaviour

Model code released:
https://osf.io/49awh/

See also Deliverable 2.2 (Dietrich et al., 2019)



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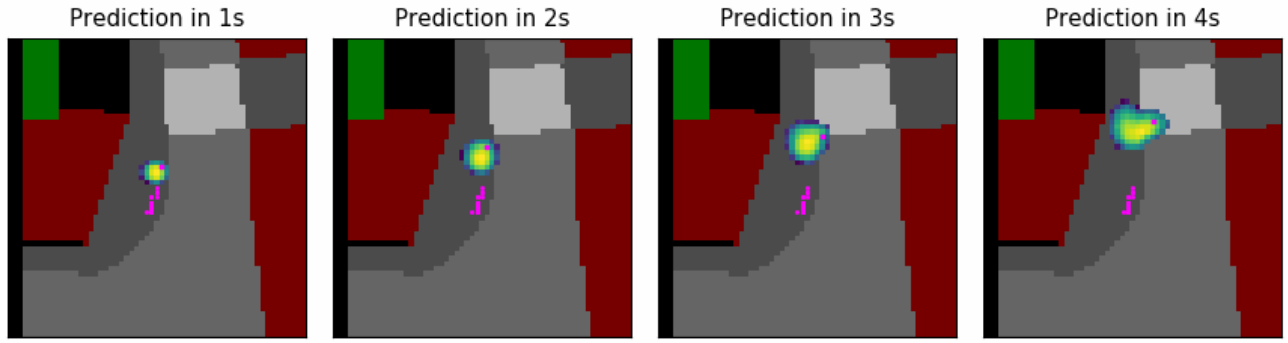
Behavior prediction of other traffic participants

Developed advance long-term behavior prediction taken into account the interaction with other traffic participants.

- (Past trajectory of other traffic participants)
- (Dynamic motion models)
- Semantic map
- Interaction models
- Goal estimation

Example pedestrian prediction



(J. Wu et al., 2018; J. Wu et al., 2019)

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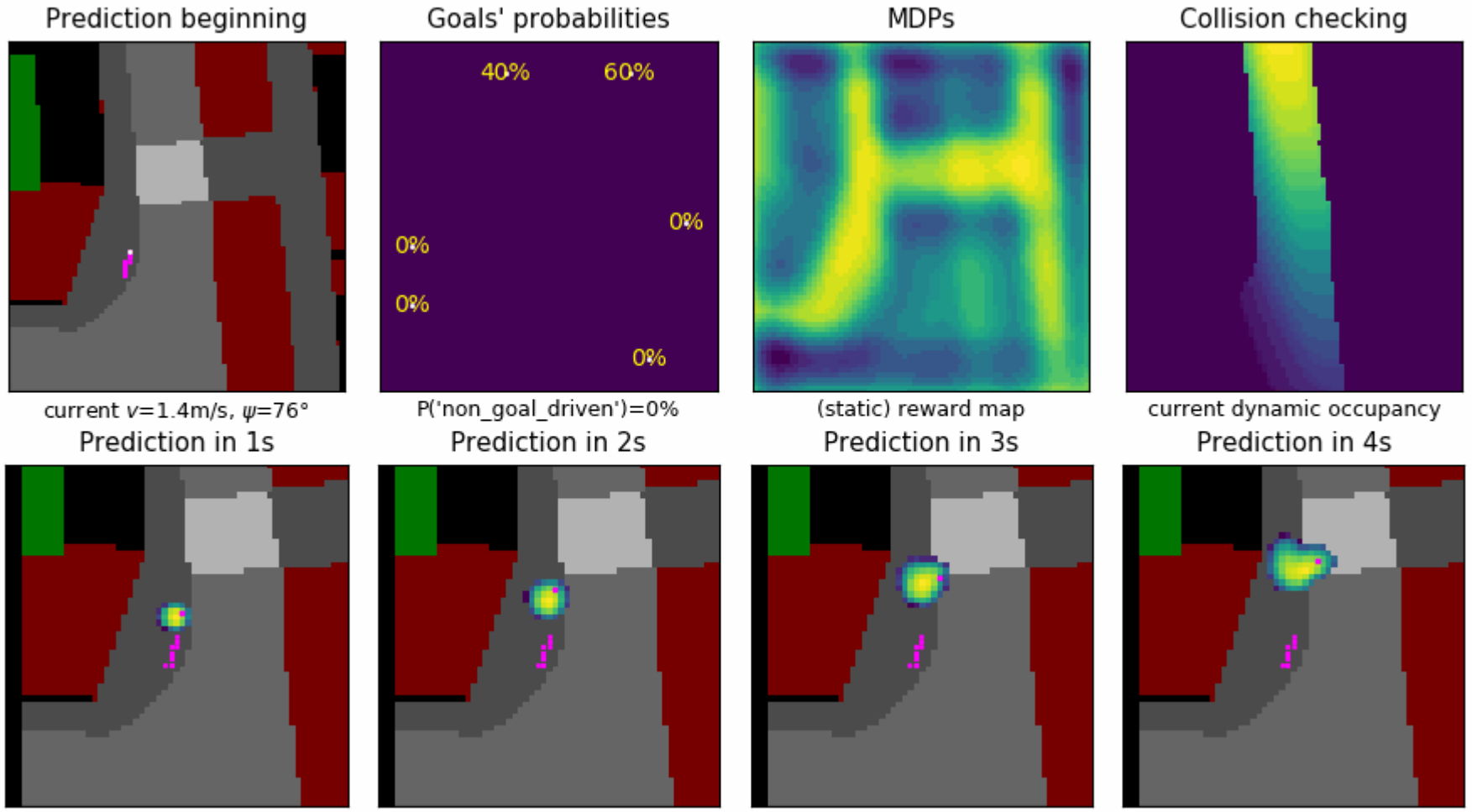
Behavior prediction of other traffic participants



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Interaction feature detection of pedestrians

- Head orientation estimation
- Detection of hand waving gestures

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Thank you!

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