GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

内閣府
Cabinet Office

SIP

SIP-adus
Innovation of Automated Driving for Universal Services

Japanese-German Research Cooperation on Connected and Automated Driving

CAD Japan Germany

Human Factors

Prof. Klaus Bengler, Technical University Munich

Prof. Martin Baumann, Ulm University

Prof. Josef Krems, Technische Universität Chemnitz

Prof. Tibor Petzoldt, Dr. Jens Schade, Technische Universität Dresden

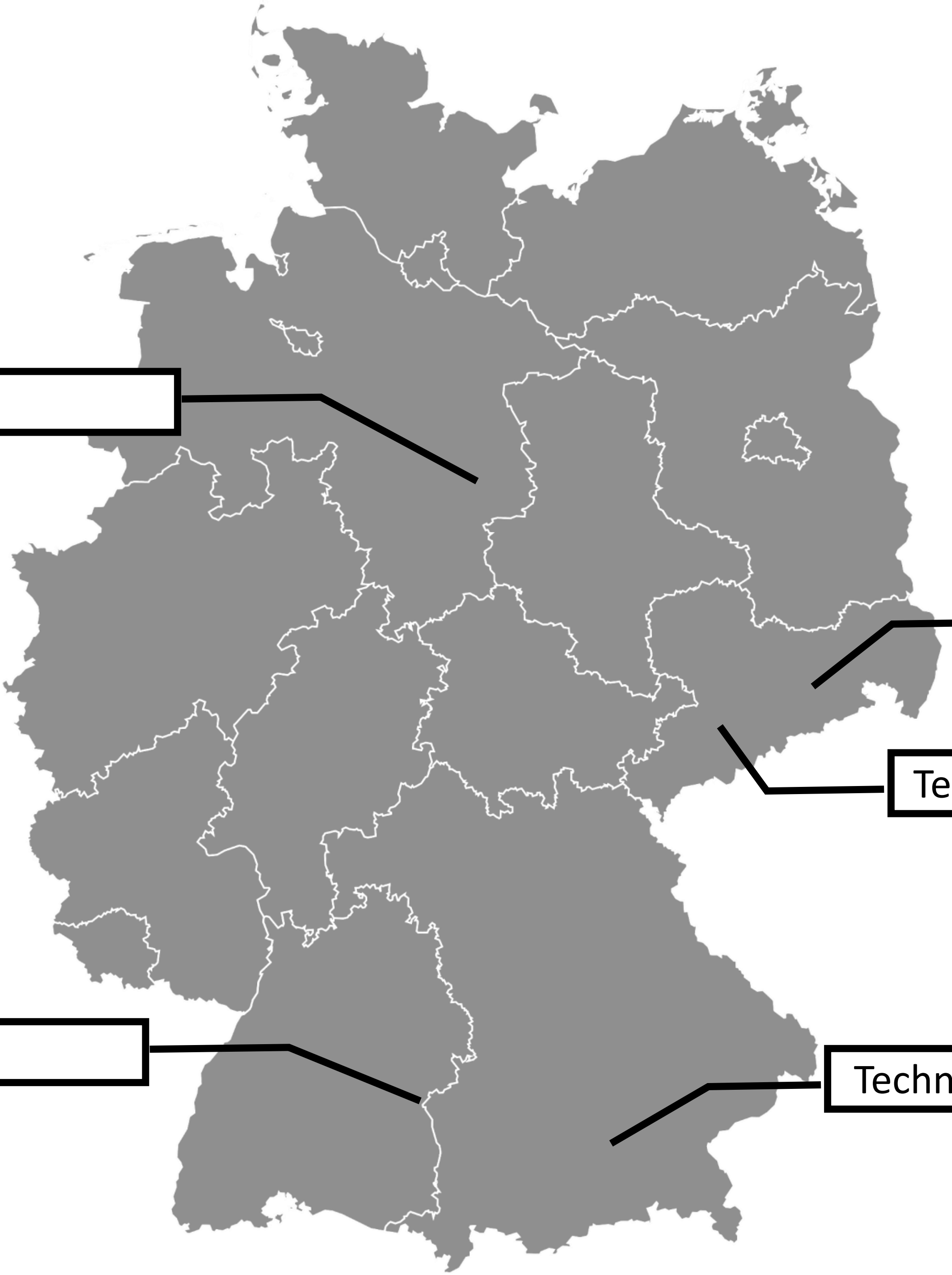
Dr. Caroline Schiessl, Dr. Michael Oehl, DLR

CAD
JAPAN & GERMANY
HUMAN FACTORS

Participating

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung



CAD Japan Germany - Human Factors

WP	Research item	Institutes
1	External communication between low-speed & fully automated vehicles and surrounding road users	TU Munich TU Chemnitz TU Dresden Ulm University DLR
2	Education and training	TU Dresden TU Munich
3	Drivers' interaction with the systems in local urban traffic	TU Munich Ulm University

Driver Training and Education
[TUD & TUM] [U Tsukuba U Kumamoto]

WP Structure

completed

Task 1:
Driver training and education in Germany

TECHNISCHE UNIVERSITÄT DRESDEN

Task 2:
Challenges of automation on driver education and training

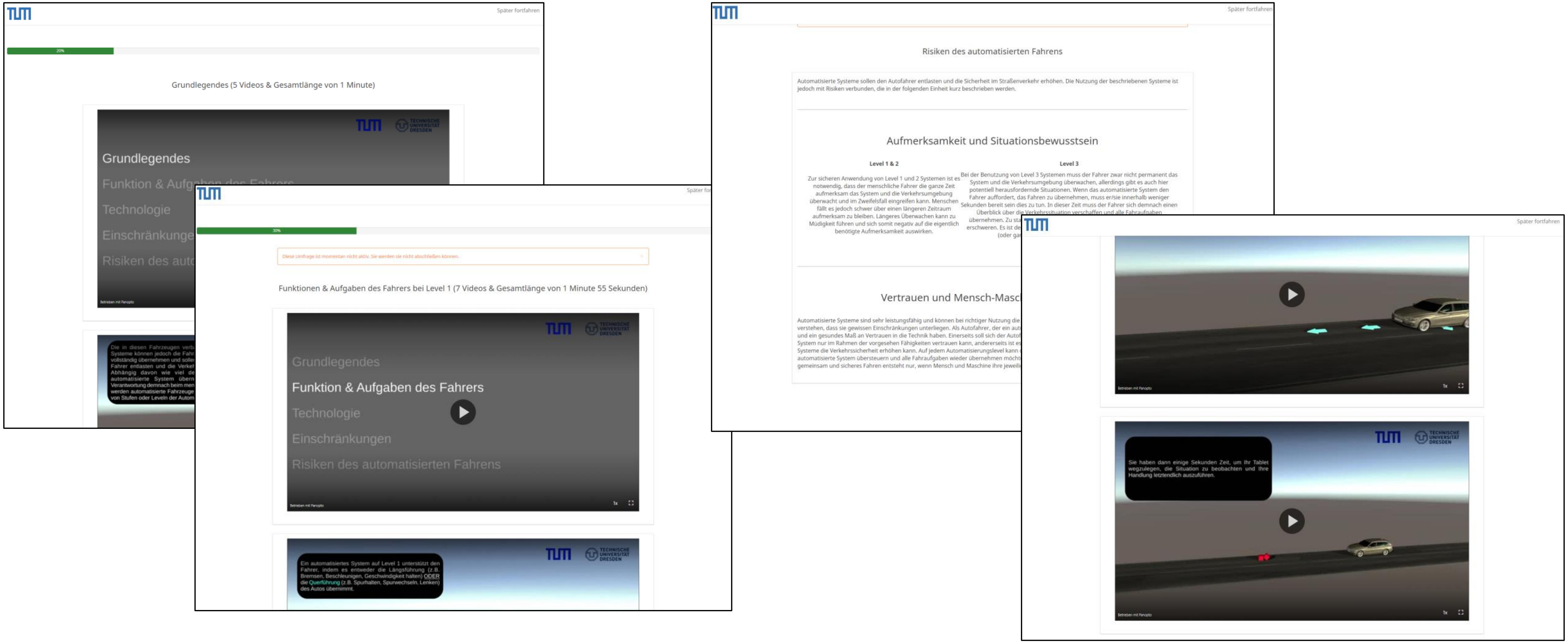
TECHNISCHE UNIVERSITÄT DRESDEN

Task 3:
Use-Case: Mental models and education concept

Task 4:
Roadmap: Synthesis of literature and identification of gaps

TECHNISCHE UNIVERSITÄT DRESDEN

Examples from Survey



Main findings

- Video-based material starting with a content to raise users' motivation to learn showed the largest effectiveness for various users, including older and female users. [U Kumamoto]

- Analysis of 11 papers investigating driver training for automated driving systems (2017-2021) [TUD]

- Training positively affects driving performance, knowledge and attitudes (esp. trust) [TUM]
  - Mix of delivery methods associated with more improvement compared to stand-alone methods

External communication of automated vehicles and interaction with different road users

[TUC, TUM, TUD, UU, DLR] [Keio U]

Work Package Structure

Task 1: Definition of **cooperative situations** between vehicles with different automation levels, cyclists and pedestrians to derive system requirements	TUC, TUM, TUD, UU, DLR
Task 2: Extraction of **interaction and cooperation patterns** in mixed urban traffic with focus on the behavioural and performance level.	TUC, TUM, TUD, UU, DLR
Task 3: Derive **recommendations for motion behavior and external HMI** of AV as communication cues for a surrounding road user (a pedestrian, a cyclist and a driver) for safety and efficiency of traffic.	TUC, TUM, TUD, UU, DLR
Task 4: Identification of additional requirements for motion behavior and external HMI of AV as communication cues for **surrounding multiple road users.**	TUM, TUD, UU
Task 5: Define recommendations for **road infrastructure** in “shared spaces” for better communication between AV and other road users.	TUC, TUM, DLR

Cycling - motion behavior and eHMI

TECHNISCHE UNIVERSITÄT CHEMNITZ

Task 3: Recommendations for motion behavior and external HMI – How can automated vehicles benefit?

research interests address i.e., gap acceptance, eHMI assessments, re-building scenarios from NDS data and manipulate specific parameters (i.e., velocity, deceleration rates, infrastructure)

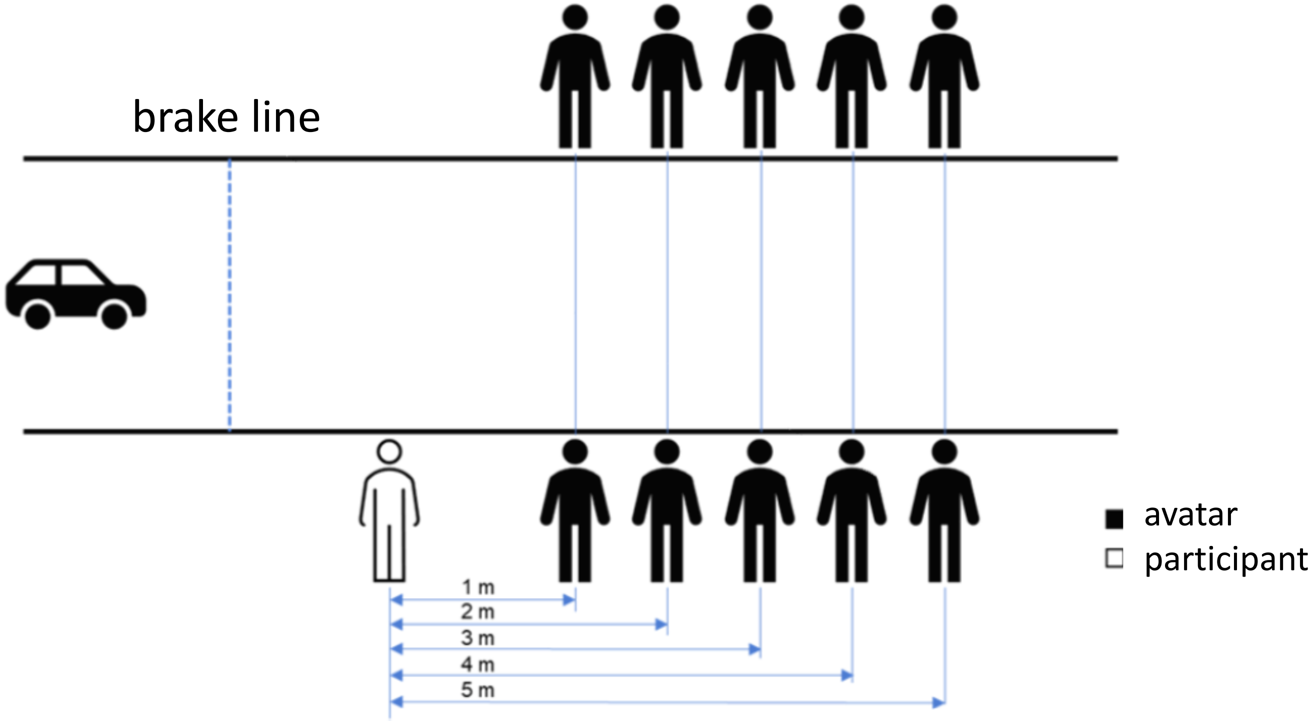
Groups of pedestrians and mixed traffic

Extraction of interaction and cooperation patterns in mixed urban traffic

What is the minimal distance between two pedestrians as the point of maximum uncertainty in an intersection scenario with an automated vehicle?

Dependent Variables:

- Decision (correct/incorrect)
- Head movements (towards
- Feeling of certainty (5-point Likert scale)



TECHNISCHE UNIVERSITÄT DRESDEN

Effects of eHMIs on willingness to cross the street

Study 3: Possible effects of automation

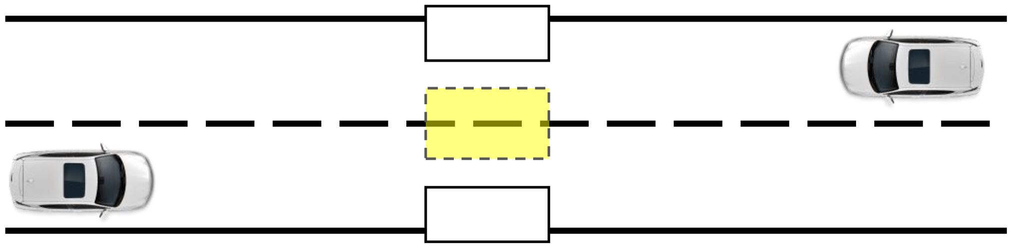
- Possible effects of an ”I am in automated mode“ eHMI on gap acceptance

Study 4: Possible effects of a frontal brake light

- We expect a greater willingness to cross in front of vehicles equipped with a frontal brake light

Motion Cues and their Value

Task 3: Recommendations for motion behavior of AV as communication cues for surrounding vehicles/drivers



- **Summary of main findings:**
  - Lateral trajectory as main cue for intention recognition
    - Is decisive for recognized intention
    - Is recognized faster
    - Is perceived more distinct
  - Early communication perceived more distinct, but recognized slower
  - Early communication, defensive intention (go second) and distinct communication more cooperative
- **Recommendations:**
  - Implicit communication via vehicle trajectory suitable for intention communication between vehicles
  - Early lateral (offensive?) communication recommended
  - Avoid incomaptible communication behaviors, including changing intention after start of maneuver
  - Driving behaviors directly related to the vehicle intention should be implemented first

Extraction of interaction and cooperation patterns in real mixed urban traffic

Real Traffic Measurements

Examples

⚠ Not enough visual search

⚠ Satisfaction of search

Tuddenham (1962): Visual search, image organization, and reader error in roentgen diagnosis: Studies of the psycho-physiology of roentgen image perception. Radiology. 78:694–704.

Design of eHMI communication strategies for different vehicle types

Experimental online study 2

Sample

- ***N*** = 149 (49 female, 2 diverse)
- **Ø Age**: *M* = 34.41 (*SD* = 12.68)
- **Affinity for Technology Interaction** (Franke, Attig & Wessel, 2019):
- *M* = 4.38; *SD* = 0.90 (from 1 = "completely disagree" to 6 = "completely agree")

Overview of the experimental setup: Pedestrian and automated bus interacting on a shared space designed in virtual reality (VR) with the 3D creation software "Unreal Engine" (Version 4.24.2).

Main Findings

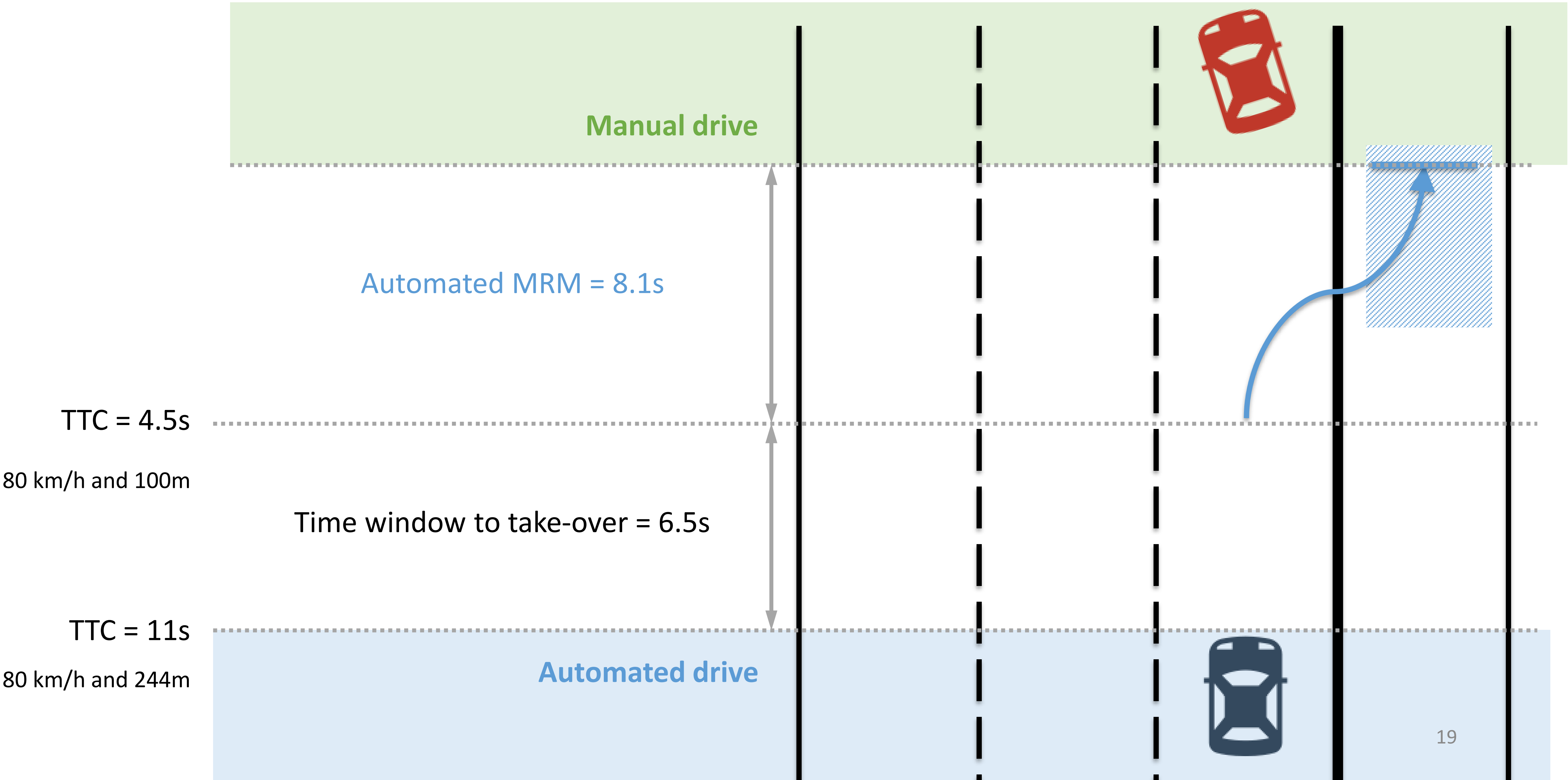
- Traffic **context** (e.g., traffic regulation, model behavior) helps to interpret eHMIs correctly.
- **Motion dynamics** of the vehicle (e.g., approach speed) and **eHMIs have to be thought together**
- **Messages** about an AV’s **intention** (e.g., I am yielding) are better than messages about an AV’s current behavior (e.g., I am braking).
- A **group of VRU** shows different and more complex behavior and interaction patterns than a single VRU
- Drivers expected AVs to yield the right-of-way in narrow passages and manual vehicles (MVs) to insist on their priority
- Behavior of AVs that conformed to those expectations (yielding) lead to faster passing times than the same behavior of MVs
- **Yielding** was subjectively evaluated more positively than insisting in terms of, e.g., comfort, trust, and cooperativeness
- Pedestrians’ willingness and trust was higher when a **dynamic eHMI** was presented compared to static eHMI or no eHMI, even if false indication
- Positive effects of a cyclist warning system

Designing driver interaction and investigation of driver behavior during transitions
[TUM & UU] [AIST]

Work Package Structure

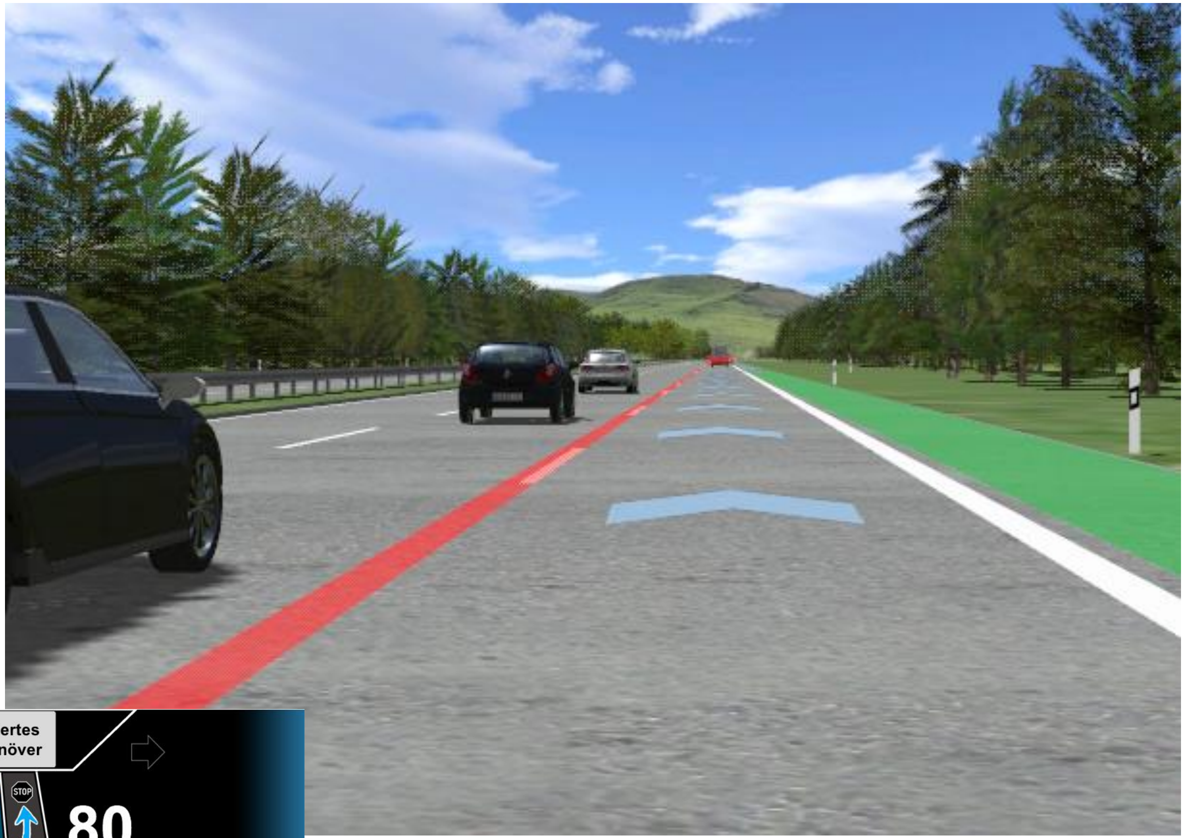
Task 1: Investigation of the transition phase between different levels of automation, scenario and transition definition and development of HMI prototype	TUM | UU
Task 2: Development and validation of driver model of influence of driver state on driver vehicle interaction	TUM | UU
Task 3: Evaluation methodology	TUM | UU

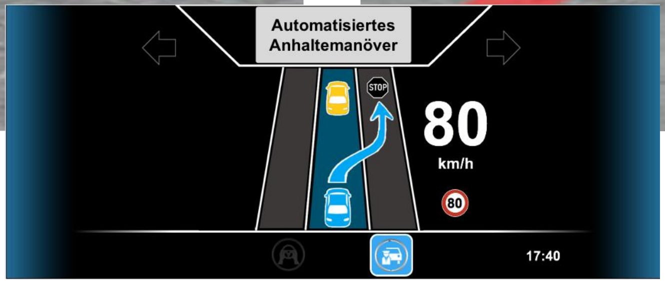
Experimental study



Study on Transition Recommendations

HMI with recommendations





Scenario 1

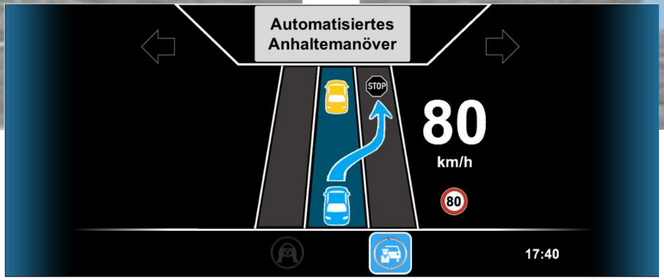
free middle lane

Scenario 2

middle lane blocked

Study on Transition Recommendations

HMI without recommendations (Baseline)



Scenario 1

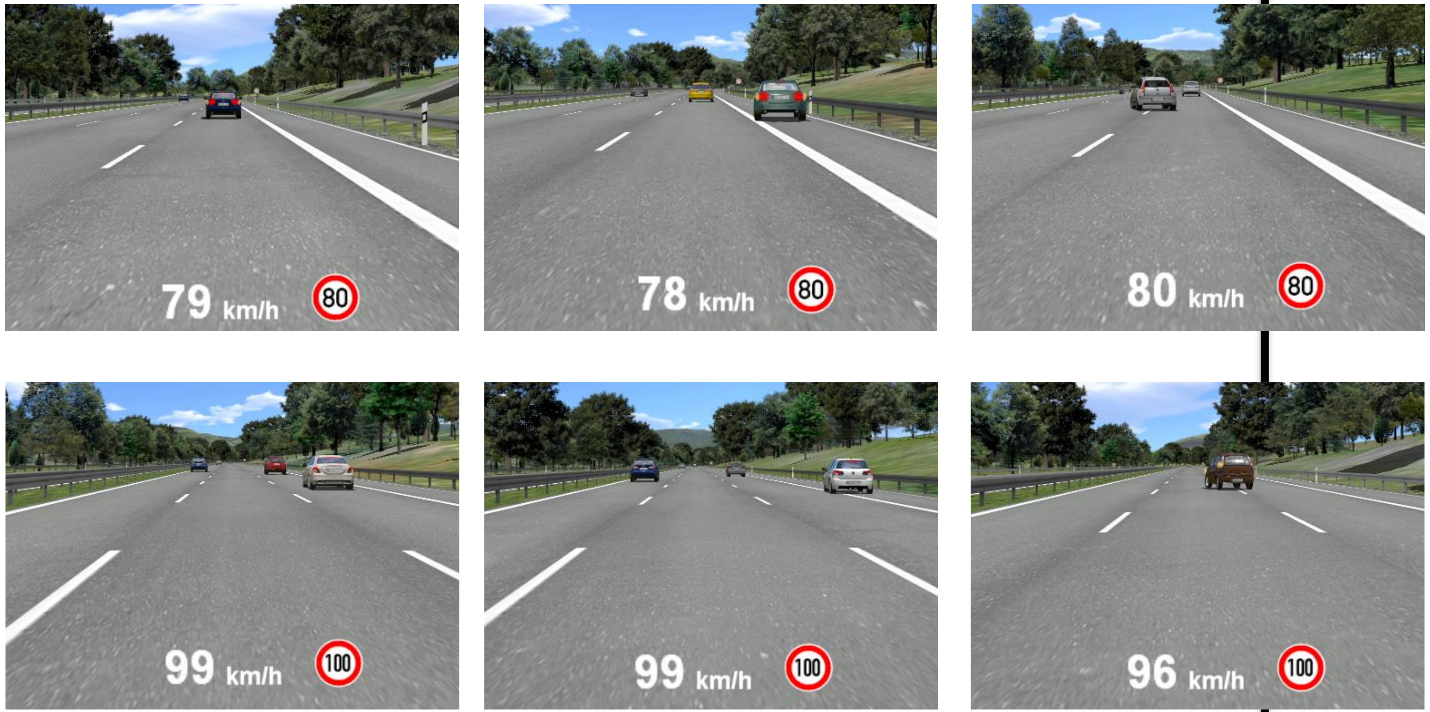
free middle lane

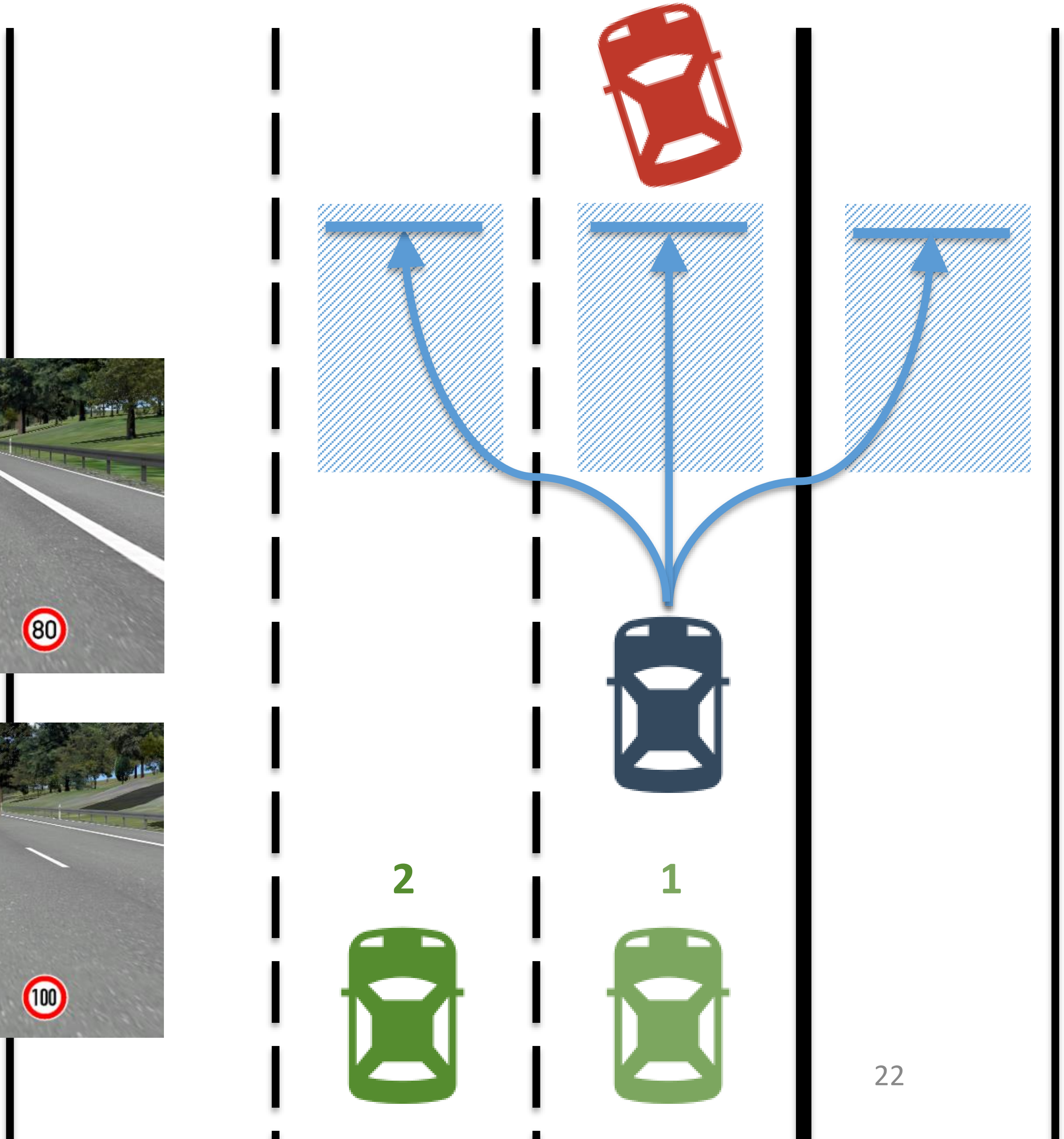
Scenario 2

middle lane blocked

Study on Evasive Manouvers

Generated 6 scenarios
2 perspectives and 3 MRMs of vehicle in front





Results and Findings

- **Discrepancy** of drivers' understanding of uncritical MRMs and literatures' perspective
- Drivers **prefer a maneuver to the left** over right and coming until standstill
- **High intervention rate** of drivers, Strategy to **re-enter into traffic is risky**
- **Supporting driver decisions and actions during the transition phase** reduces the risk of an accident

Transition Design

- The inclusion of an **unspecific environment monitoring** message before the actual Request to Intervene
  - **improves gaze behaviour and driving performance** during the TOR
  - leads drivers to suspend the NDRT after TOR more frequently

- Drivers need to be reminded on monitoring by system message
- Unneccessary reminder messages might decrease trust in automation

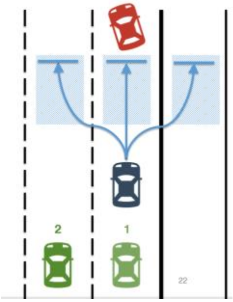
Online Lectures & Training of Young Scientists

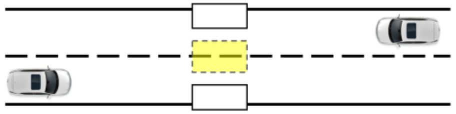
- Two Webinar series

  - 2020/2021 Ten presentations on Human Factors topics from PI‘s and other senior researchers
  - 2022 PhD presentations on current reserach

  - Exchange of Japanese and German research results outside of CADJapanGermany on current Human Factors Research
  - Open discussion of topics with international audience

Wie thank our Research partners from Univs. Tsukuba, KEIO, Kumamoto and AIST





Source: Unicaragil 2022

Joint Publications (planned/tentative titles)

Task A：On road communication

- Jieun Lee, Linda Miller, Martin Baumann, Tatsuru Daimon, Satoshi Kitazaki Designing Communication between AV and Alien Pedestrian: A Case Study in Japanese Countryside
  Planned submission: January, 2022
- Jieun Lee, Claudia Ackermann, TUC PhD student, Josef Krems, Tatsuru Daimon, Satoshi Kitazaki: AV's Overtaking Signal toward Drivers in Following Car: Japan-Germany Cross-Cultural Study
  Planned submission: July, 2022
- Merle Lau, Michael Oehl, Jieun Lee, Masahiro Taima, Tatsuru Daimon, Satoshi Kitazaki: Possible negative effects of eHMI for automated service vehicles based on cultural differences between Japan and Germany
  Planned submission: by December 2022
- Linda Miller, Jasmin Leitner, Jieun Lee, Tatsuru Daimon, Satoshi Kitazaki, Martin Baumann: Time-to-arrival as predictor for cooperative driving decisions in highly automated driving in narrow road passages. Conference proceedings of IEEE IV in Aachen

Joint Publications (planned/tentative titles)

Task A：On road communication

- Jieun Lee, Linda Miller, Martin Baumann, Tatsuru Daimon, Satoshi Kitazaki Designing Communication between AV and Alien Pedestrian: A Case Study in Japanese Countryside
  Planned submission: January, 2022
- Jieun Lee, Claudia Ackermann, TUC PhD student, Josef Krems, Tatsuru Daimon, Satoshi Kitazaki: AV’s Overtaking Signal toward Drivers in Following Car: Japan-Germany Cross-Cultural Study
  Planned submission: July, 2022
- Merle Lau, Michael Oehl, Jieun Lee, Masahiro Taima, Tatsuru Daimon, Satoshi Kitazaki: Possible negative effects of eHMI for automated service vehicles based on cultural differences between Japan and Germany
  Planned submission: by December 2022
- Linda Miller, Jasmin Leitner, Jieun Lee, Tatsuru Daimon, Satoshi Kitazaki, Martin Baumann: Time-to-arrival as predictor for cooperative driving decisions in highly automated driving in narrow road passages. Conference proceedings of IEEE IV in Aachen
- Linda Miller, Jieun Lee, Luisa Heinrich, Tatsuru Daimon, Satoshi Kitazaki, Martin Baumann: Designing communication strategies of automated vehicles: Interpretation of implicit driving behavior in Japan and Germany. Paper in Accident Analysis and Prevention
- Jieun Lee, Linda Miller, Martin Baumann, Tatsuru Daimon, Satoshi Kitazaki: Designing Communication between AV and Alien Pedestrian: A Case Study in Japanese Countryside. Transportation Research Part C / IEEE Transaction on Human-Machine Systems

Joint Publications (planned/tentative titles)

Task B: Driver-system interaction

- Luisa Heinrich, Martin Baumann (Ulm University), Yanbin Wu, Kunihiro Hasegawa, Ken Kihara, Toshihisa Sato, and Satoshi Kitazaki: Transition process between automated and manual drives and its effects on
  Driver's condition while using the automated driving system Planned submission: by December 2022
- Burak Karakaya, Klaus Bengler (Technical University of Munich), Yanbin Wu, Kunihiro Hasegawa, Ken Kihara, Toshihisa Sato, and Satoshi Kitazaki: Influence of MRM(Minimum Risk Maneuver) on driver transition behaviors
  Planned submission: by December 2022
- Luisa Heinrich, Linda Miller, Jasmin Leitner, Yanbin Wu, Kunihiro Hasegawa, Ken Kihara, Toshihisa Sato, Satoshi Kitazaki, Martin Baumann: Working title: Monitoring or decision-making? How can safety be improved during transitions in highly automated driving. ICCTP Conference: 7TH International Conference on Traffic and Transport Psychology for a poster presentation
- Luisa Heinrich, Linda Miller, Jasmin Leitner, Yanbin Wu, Kunihiro Hasegawa, Ken Kihara, Toshihisa Sato, Satoshi Kitazaki, Martin Baumann: Transitions in highly automated driving: Increasing safety through appropriate driver task selection. Paper in Human Factors OR Accident Analysis and Prevention
- **Task C: Driver education**
- Makoto Itoh, Huiping Zhou, Yoshiko Goda, Satoshi Kitazaki, Christina Goegel, Tibor Petzoldt, and Klaus Bengler: Advances in education/training for automated driving use Planned submission: June 30, 2022
- Huiping Zhou, Yoshiko Goda, Makoto Itoh,Satoshi Kitazaki, Burak Karakaya and Klaus Bengler: Cross cultural investigation on effects of education/training for safe use of automated drivings systems based on web-based experiment Planned submission: November, 2022