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From Concept to Action - Measuring General and Applied Mental Models in the Context of Automated Driving

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INTRODUCTION AND MOTIVATION

- Conditionally Automated Driving allows drivers to disengage from the driving task and focus on activities, such as reading or texting (SAE International, 2021)
- It also requires the driver to immediately return attention to the driving task and assume full control of the vehicle in the event of a Takeover Request (SAE International, 2021)
- It is only available under certain conditions, so that in other cases only Partially Automated Driving or even no automation can be activated (SAE International, 2021)
- Partially Automated Driving also provides longitudinal and lateral control of the vehicle, with the difference that the driver is responsible for monitoring the system and environment (SAE International, 2021)
- Transitions between these levels not only create out-of-loop problems for the driver, but also mode confusion (Kurpiers et al., 2020).

It is essential for drivers to perceive and comprehend relevant information to ensure safe operation of automated vehicles. Therefore, individuals require a suitable mental model of the automated system. (Endsley, 2017)

MENTAL MODELS IN THE AUTOMATED DRIVING CONTEXT

- Mental Models (MM) are cognitive representations of an external reality and necessary for real-world orientation (Johnson-Laird, 1980)
- They enable the categorization of perceived information, and support the comprehension of goals, processes, as well as performance and limitations of systems (Seppelt & Victor, 2020)
- They evolve with increasing experience and are continuously adjusted (Beggiato & Krems, 2013)

Conceptual Model

is the precise and comprehensive representations of the vehicle, including the interaction of all sensors and actuators installed

(Norman, 1983)

General Mental Model

comprise the theoretically and practically acquired knowledge about the goals, processes, structures, and limitations of the vehicles and reflect the driver's understanding of their functions and limitations

(Seppelt & Victor, 2020)

Applied Mental Model

is represented by the situation awareness, i.e., the perception, understanding, and projection of a situation, and is reflected in the driver's behavior

(Seppelt & Victor, 2020)

MENTAL MODELS
IN THE AUTOMATED DRIVING CONTEXT

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In the field of automated driving, research focuses on investigating

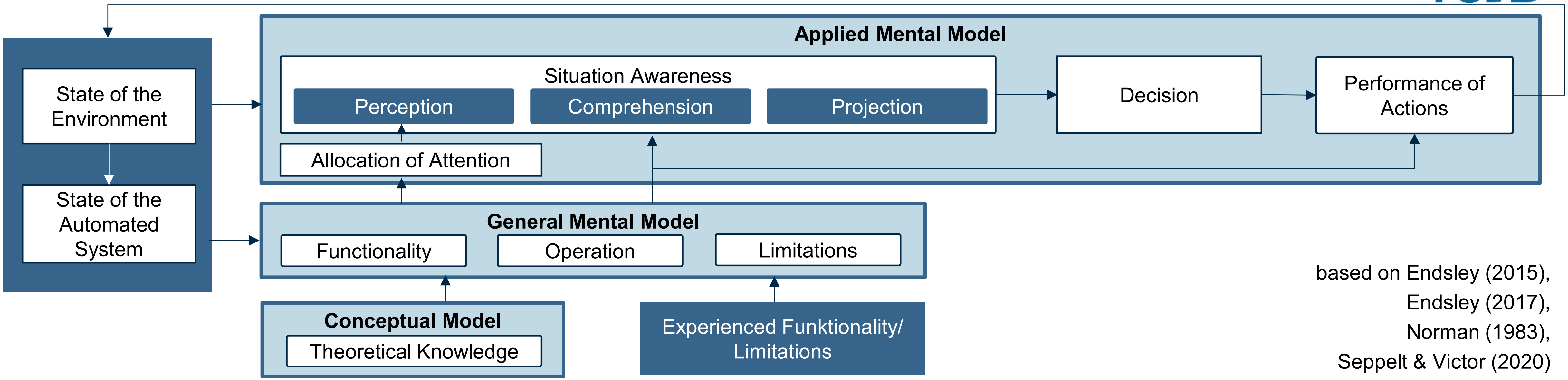
- the evolution of general mental models with increasing practical experience
- depending on the accuracy of the initial system description
- focusing on a single level of automation or a specific driver assistance system
- focusing on the General Mental Model

  (Beggiato & Krems, 2013; Beggiato et al., 2015; Blömacher et al., 2018, 2020; Forster et al., 2019; Gaspar et al., 2021)

Research gaps exist with regard to

- comparative analysis between general mental models and applied mental models, as well as the resulting driving performance
- consideration of the entire automated vehicle with various automation levels and assistance systems instead of one single level of automation or driver assistance system

RESEARCH OBJECTIVE



based on Endsley (2015),
Endsley (2017),
Norman (1983),
Seppelt & Victor (2020)

- measurement and comparative evaluation of the **general and applied mental model** of the automated driving system and the resulting behavior represented by **gaze movement** and **driving performance**
- insights on how a mental model should be characterized to ensure safe interaction with the automated driving system
- basis for developing training concepts for the education of future users

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STUDY DESIGN - DRIVING SIMULATOR STUDY

Confounding V.

- socio-demographic characteristics, driving experience, experience with automated driving functions
- general trust in technology (subscale - Körber et al., 2017) and affinity for technology (Franke et al., 2019)
- individual reaction times is measured using a stimulus-response test (Matheus & Svegliato, 2013)
- simulator sickness (before and after the test drive) (Kennedy et al., 2009)

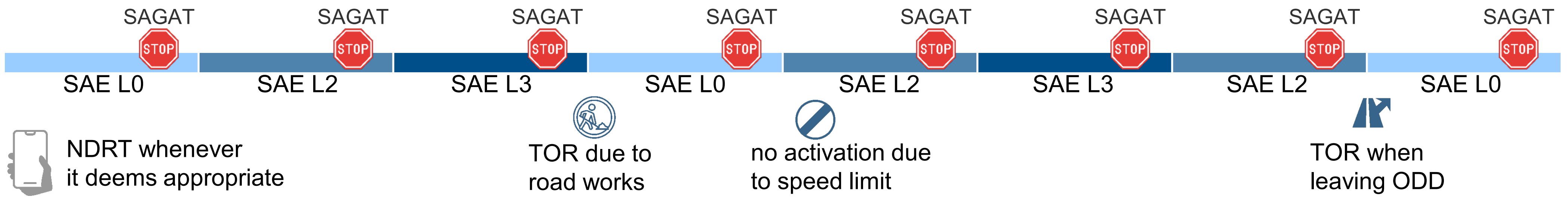
General MM

- General Mental Model is then recorded using the Questionnaire according to Richardson et al. (2019) complemented by a short interview

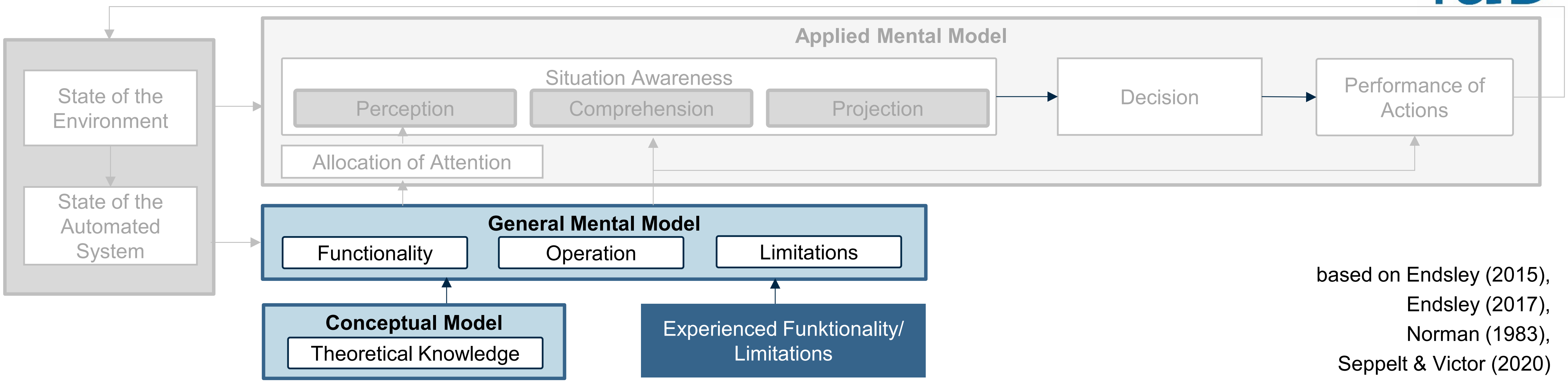
Applied MM

eyetracking (Forster et al., 2019)

reaction times, time to collision, braking and acceleration behavior, steering behavior (Müller, 2020)



PRE-STUDY - REAL TRAFFIC ENVIRONMENT



based on Endsley (2015), Endsley (2017), Norman (1983), Seppelt & Victor (2020)

- What influence does theoretical knowledge in form of a short Video prior to first contact have on the General Mental Model of drivers?
- What influence does first contact in real traffic environment have on the General Mental Model of drivers?

PRE-STUDY - REAL TRAFFIC ENVIRONMENT PROCEDURE

- socio-demographic characteristics, driving experience, experience with automated driving functions
- general trust in technology (subscale - Körber et al., 2017) and affinity for technology (Franke et al., 2019)
- General Mental Modell (Richardson et al., 2019)

- video on functionality, activation conditions and operation of the system
  https://www.dom.daimler.com/V297/MC000.010.091.847-digital-high-de_de.mp4

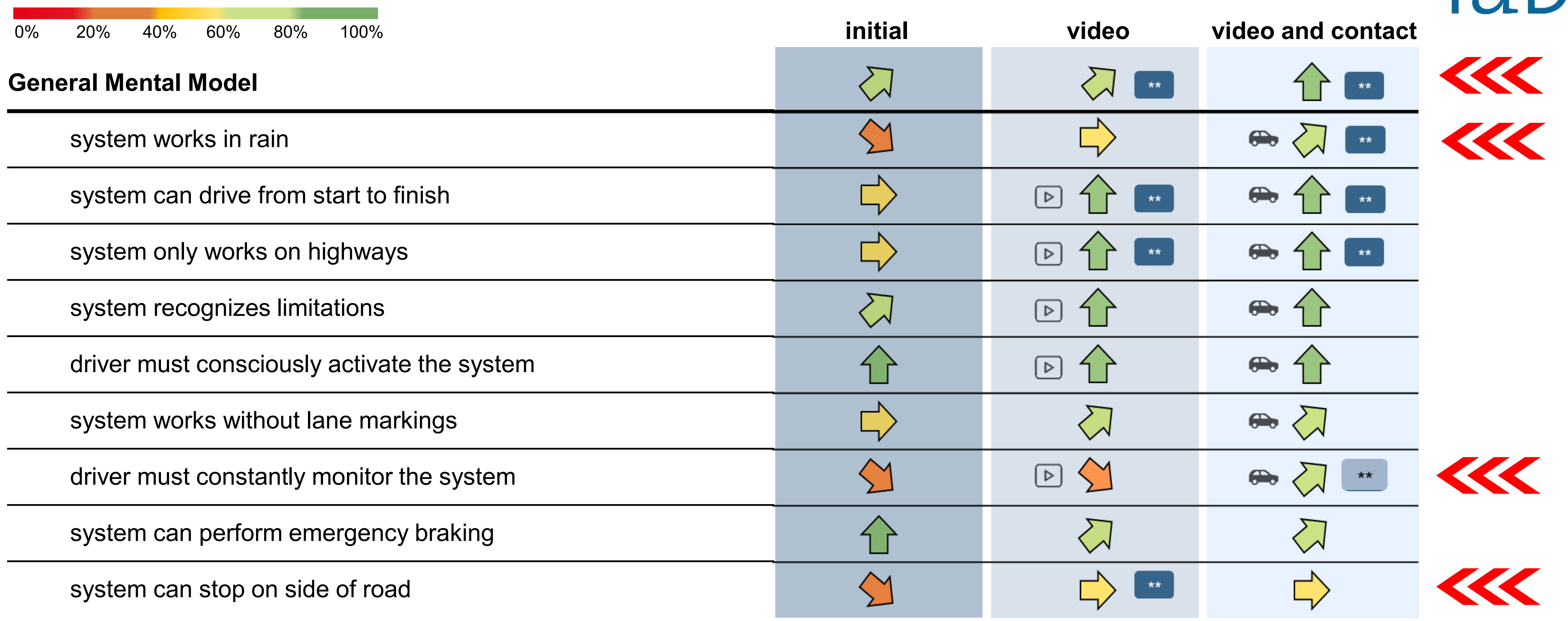
- General Mental Modell (Richardson et al., 2019)

- test drive with multiple activation of the DrivePilot and Takeover Requests

- General Mental Modell (Richardson et al., 2019)
- short interview on usefulness, comfort, safety, use of NDRT

DrivePilot - Mercedes EQS

PRE-STUDY - REAL TRAFFIC ENVIRONMENT RESULTS



MM accuracy | described in Video | experienced while driving | significant difference (** p < 0.001 ANOVA, Bonferroni correction) ** to initial MM ** to MM after Video

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PRE-STUDY - REAL TRAFFIC ENVIRONMENT RESULTS

	initial	video	video and contact
system can overtake slower vehicles	↗	→	↘ **
system operates between 0 and 60 km/h	↗	▷ ↑	🚗 ↑
system adapts speed of vehicle in front	↑	▷ ↑	🚗 ↑
system steers automatically	↑	▷ ↑	🚗 ↑
system can handle traffic jams	↑	▷ ↑	🚗 ↑
system observes all traffic signs on highways	↑	↑	🚗 ↑
system works in complex road works	→	↑ **	🚗 ↑ **
system works with yellow lane markings	↗	↘ **	🚗 ↘ **
driver must take over within seconds	↗	▷ ↑ **	🚗 ↑
system maintains set speed	↑	↑	🚗 ↑

↗ MM accuracy ▷ described in Video 🚗 experienced while driving | significant difference (** $p < 0.001$ ANOVA, Bonferroni correction) ** to initial MM ** to MM after Video

PRE-STUDY - REAL TRAFFIC ENVIRONMENT RESULTS

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General Mental Model before the video and first contact with automated vehicles (SAE L3)

- the General Mental Model before the first contact tends to be correct (M = 68.3 %, SD = 8.6 %)
- the functionalities that are similar to those of the ACC are rated correctly
- the system tends to be overestimated with regard to the limitations of the operational design domain
- the system tends to be underestimated, particularly with regard to the need for constant monitoring

Influence of the short video before first contact on the General Mental Model

- the General Mental Model improved significantly after the video (M = 76.5 %, SD = 6.5 %, $p < .001$)
- mostly constant or improved General Mental Model regardless of whether the functionality was explained in the video
- consistent belief that the system must be constantly monitored, despite explicit description in the video

Influence of first contact on the General Mental Model

- the General Mental Model continues to improve after the initial contact (M = 80.3 %, SD = 5.2 %), but there is no significant difference to the General Mental Model after the video
- significant reduction in the belief that the system needs to be constantly monitored
- partial impairment of the assessment of functionalities that were neither described nor experienced

- N = 29
- 21 to 68 years (M = 37.7; SD = 14.9)
- 20 male, 9 female
- generally high affinity and trust in technology
- no prior experience with SAE L3 systems

CONCLUSIONS AND FUTURE WORK

Based on the pre-study, the following conclusions can be drawn:

- videos are an effective tool for the formation of a correct General Mental Model
- the first contact can further improve the General Mental Model
- spillover effects occurred, which resulted in a change in the correct classification of the system's capabilities, despite the absence of any description or experience of the functions in question.

- as it was not possible to quantify the applied mental model in terms of situation awareness and driving behavior in real traffic, the subsequent phase of the study will entail conducting the previously described simulator study.
- this will allow for an investigation into the interrelationship between the General and Applied Mental Models, as well as the identification of a comprehensive General Mental Model that can facilitate safe operation during the initial contact.
- based on this, appropriate training concepts can be developed

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THANK YOU!

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