Ko-HAF
KOOPERATIVES HOCHAUTOMATISIERTES FAHREN

# Focusing on the driver: A Human Factors Approach to Automated Driving

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aufgrund eines Beschlusses des Deutschen Bundestages

# Content

- Goals and objectives
  - Finding a common understanding
  - Automation effects
  - Optimizing the HMI
  - Recommendations
- Focusing on the driver? – Conclusion

# Human factors of automated driving – A paradigm shift

- What is the driver's role?
- How does the driver state change and affect human performance?
- Integration and Validation of non-driving related tasks activities
- Concept and design of transitions

# Central questions

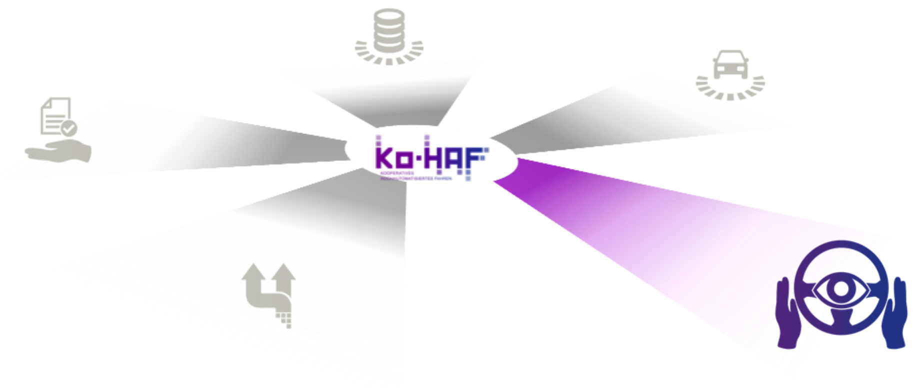
- For how long may the driver attend to non driving related activities?
- How long does it take until the driver can take over the driving task in case of a sudden disturbance?
- How long can the driver be attentive?
- The heterogeneity of the transitions is increasing – Does the system remain operable?

**Ironies of automation**

"Automated systems still are man-machine systems, for which both technical and human factors are important."
(Bainbridge, 1983)

"… the irony that the more advanced a control system is, so the more crucial may be the contribution of the human operator."

# Objectives



**Cooperative driving and controllable automation**

- Specifications of the test scenarios and aspects of the man-machine interaction
- Modelling the driver availability and vigilance
- Investigation of automation effects
- Transition concepts optimised for HAD
- Recommendations for methods and interaction concepts

# Scope

- 33 empirical studies
- Total of 1723 participants
- More than 1750 hours of experiments
- More than 30 publications

# Specifications of the test scenarios and aspects of the human-machine interaction

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**Transition model for take-overs**

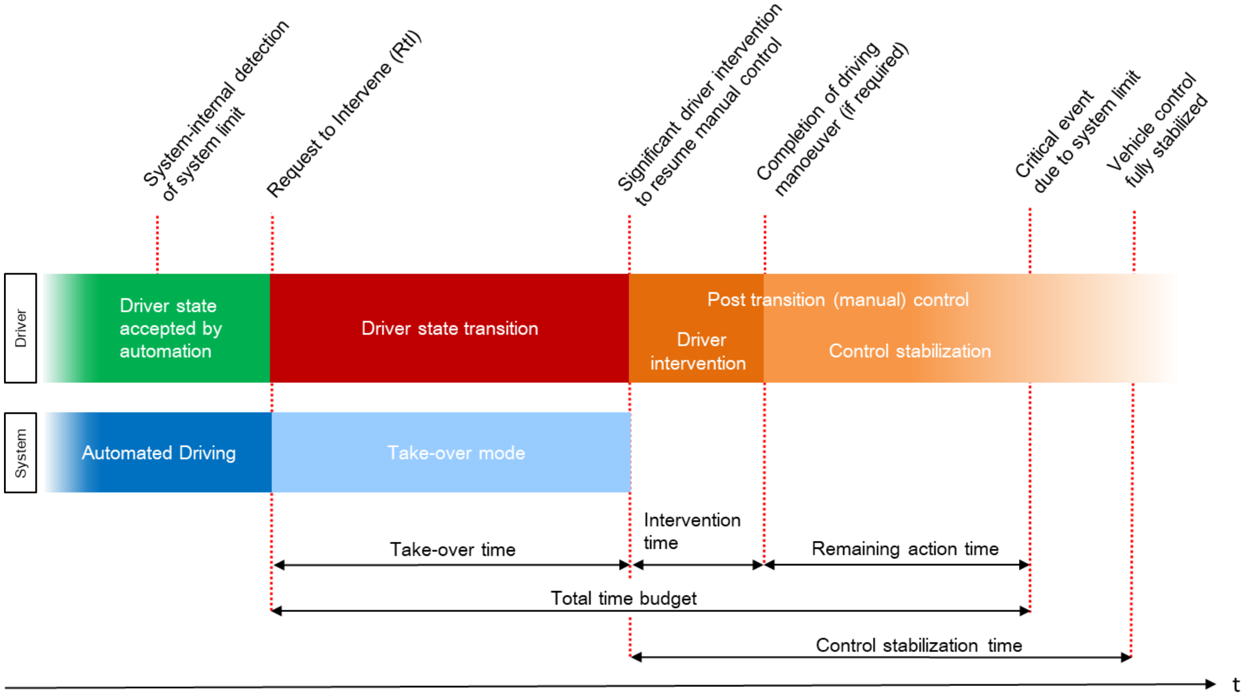
**Definition of take-over situations**

**Generic HMI requirements**

**Catalogue of NDRTs**

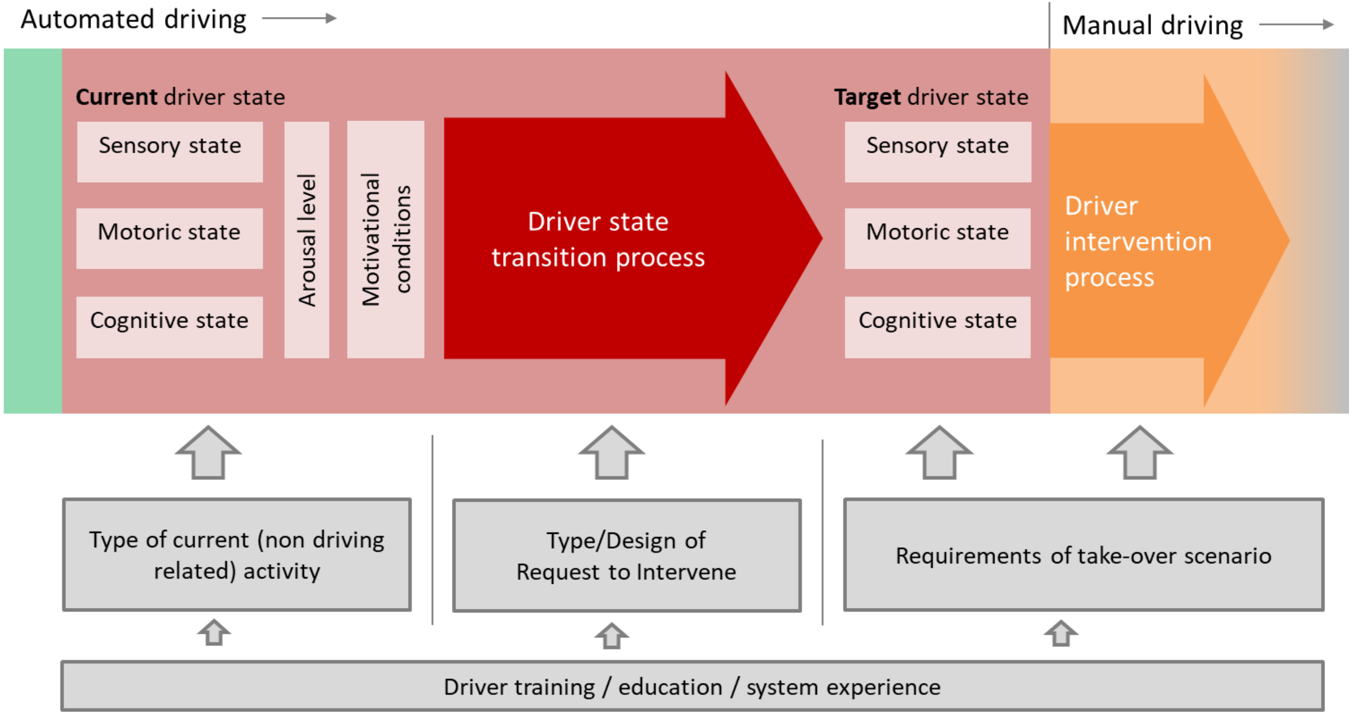
**Common methodology to allow comparison of experiments and results.**

# Transition Process and Model




Marberger, C., Mielenz, H., Naujoks, F., Radlmayr, J., Bengler, K., & Wandtner, B. (2017). Understanding and Applying the Concept of "Driver Availability" in Automated Driving. In N. A. Stanton (Ed.), *Advances in Human Aspects of Transportation: Proceedings of the AHFE 2017 International Conference on Human Factors in Transportation*

# Transition Process and Model

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# Definition of take-over situations

| | | | Prädizier-barkeit | Dringlich-keit | Kritika-lität | Fahrer-reaktion | |
|---|---|---|---|---|---|---|---|
| Normalfahrt | Sensorausfall "Total": alles fällt aus | Sensorausfall vor Kurve | | | | | 2 |
| | | Sensorausfall auf Gerade | | | | | 2 |
| Abfahren von der AB | Spurwechsel auf den Verzögerungsstreifen nicht möglich | Dichter Verkehr | | | | | 3 |
| Durchfahren eines AB-Kreuz | Spurwechsel im AB-Kreuz nicht mgl. | Dichter Verkehr | | | | | 3 |
| Auffahren auf die AB | Spurwechsel beim Auffahren auf die AB nicht möglich | Dichter Verkehr | | | | | |
| Engstelle | Engstelle erst durch Umfeldsensorik erfasst | | | | | | 2 |
| Passieren von Gefahrenstellen | Taktische Gefahrenstelle klassifizierbar, aber nicht umfahrbar (Bsp.: Fußgänger, Tiere…) / nicht klassifizierbar | Objekt auf dem eigenen Fahrstreifen (z.B. Unfall) | | | | | 1 |
| | | Objekt auf einem anderen Fahrstreifen (z.B. Unfall) | | | | | |

1: alles worst case: hoch dringlich, kritisch und komplexe Fahrerreaktion

2: niedrigere Komplexität der Fahrerreaktion, teilweise geringere Kritikalität

3: höhere Prädizierbarkeit, geringere Kritikalität, Komplexität der Fahrerreaktion hoch

In den empirischen Studien zu Einflussvariablen der Fahrerverfügbarkeit auf die Übernahme sollten mind. je eine Situation der Gruppe 1 und 2 enthalten sein, optional eine Situation der Gruppe 3.

Identification of **six** possible and reasonable take-over situations for the workpackage 3 experiments.

| Construction Site | | | |
|---|---|---|---|
| **Urgency** | **Predictability** | **Criticality** | **Complexity** |
| high | low | low – medium | low – medium |

# HMI – Minimal requirements

- Messages concerning the status of the automation
  - System not available and not activated (**Off**)
  - System available but not activated (**Ready**)
  - System available and active (**On**)
  - System soon not available but active (**Request to Intervene**, RtI)

- Modalities of the status of automation
  - Continous system status: **visual**
  - Request to Intervene/Warnings: at least **dual modalities** (e.g. acoustic + visual, visual + haptic)

# Catalogue of NDRTs

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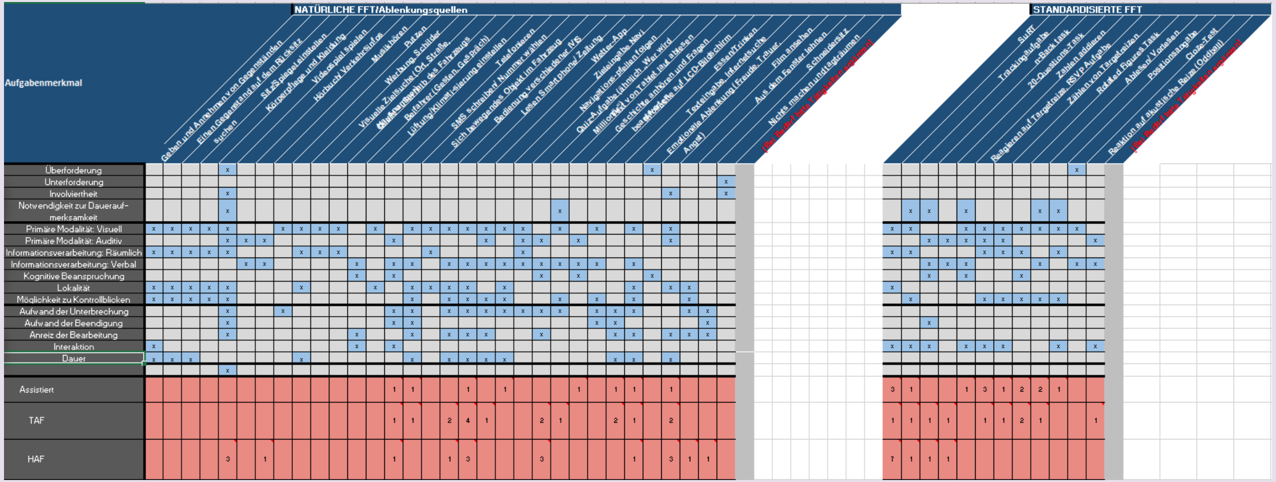
Depending on step of the task switching process

→ What is affected by the NDRT?

→ List of **16 features** (e.g. over-/underload, modalities, involvement, effort of disengagement)

Naujoks, Befelein, & Neukum. 2016.



# Conclusion – Methodology

- The developed systematics and metrics were evaluated on the basis of prototype conditionally automated driving systems and generic user-interface-designs.
- The project partners analyzed relevant parameters of the driver state (sensoric state, motoric state, cognitive state, arousal and motivation) and their impact on take-over performance.
- In order to evaluate the influence of these parameters on take-over performance, we focused on average driver reactions. However, if the controllability of take-overs is to be assessed, a wider range of human performance needs to be considered as well.

# Investigation of automation effects

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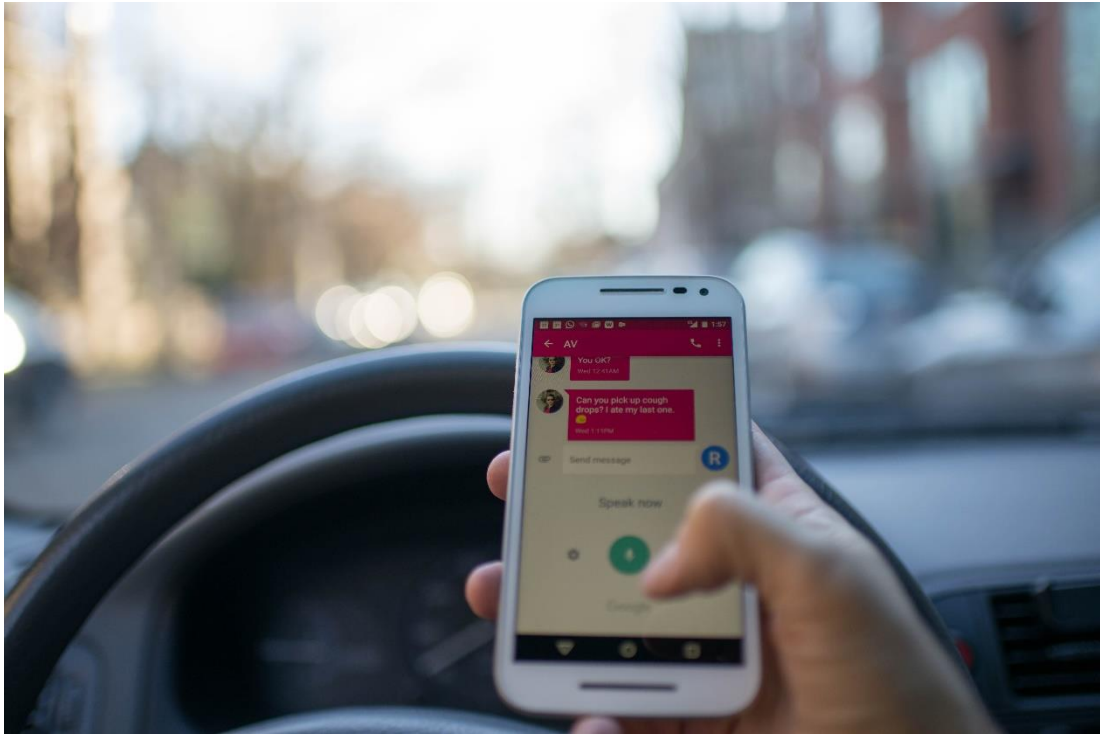

# Drowsiness and fatigue – Questions

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How can these driver states be **induced** and **assessed** (in real traffic)?

→

Does drowsiness/ sleepiness or fatigue **influence take-over** performance?

# Assessment of drowsiness and fatigue

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**Duration of the automated driving period**

**Fixed time**

**vs.**

**State dependent**

**Subjective Assessment**

Karolinska-Sleepiness Scale (KSS)

**Objective Metrics**

Heartrate

Galvanic Skin Response

PERCLOS

EEG

COP in the seat

**Expert Ratings**

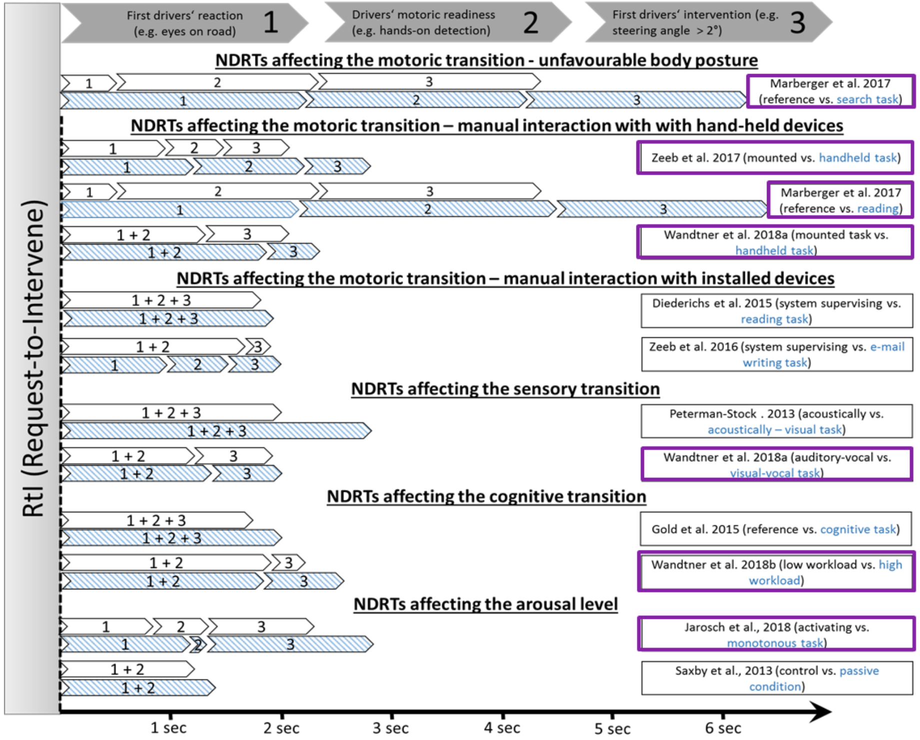
Based on Wierwille

**Methodical challenges: How were these driver states assessed?**

# Conclusion – Drowsiness and fatigue

- It was possible to induce drowsiness and fatigue in test situation (without sleep deprivation). **Driver state changes could be detected** by using several metrics and methods (under experimental conditions).
- While driving with conditional automation, **extreme levels** of drowsiness and fatigue (drivers close to falling asleep) **must be avoided**. Clear and consistent effects on take-over behavior could not be found.
- Based on the detection of high levels of drowsiness and fatigue, **countermeasures (e.g. a specific offer of NDRTs)** can be initiated to avoid or to postpone such extreme driver states.

# Effects of NDRTs – Summary




vs. NDRT 1: see **black** text
NDRT 2: see **blue** text

Overall effects of different NDRTs.
Not only Ko-HAF experiments are represented.

**For a detailed description see:**

Jarosch, O., Wandtner, B., Marberger, C., Naujoks, F., Gold, C., Schrauf, M., Weidl, G. (2018). *The Impact of Non-Driving Related Tasks on Take-over Performance in Conditionally Automated Driving – A Review of the Empirical Evidence.* Manuscript submitted for publication.

# Conclusion – NDRTs

## The Ko-HAF experiments showed increased take-over times for NDRTs including:

- Strong rotations of the torso (> 90°)
- Manual interaction with **handheld objects** (e.g. tablet computer)
- High effort or steps needed to disengage from an NDRT

## No clear / consistent results were found for:

- Visual or visual-manual tasks without occupation of hands
- NDRTs affecting the **cognitive transition**

## Overall: Strong individual differences

➢ Natural behavior, **self regulation** and motivational aspects of NDRTs should be considered in the experimental design.

# HMI Implications:
## How to support the driver?

Different **types of take-over situations** considered in Ko-HAF:

- Long-term transitions (based on Safety-Server)
  - Known from maps / card material / online updates
  - Safety-Server (Ko-HAF)
  - The human driver can be requested long time before he has to regain control

- Short-term transitions (based on Onboard Sensors)
  - Detected by onboard sensors
  - Short period of time – the human driver has to regain control within seconds

# Conclusion – HMI

## Long-term transitions

- **Multi-stage transition concepts** have been shown to accelerate the disengagement from NDRTs and take-over time.
- A preview of planned requests to intervene along the route (based on safety server information) helps **drivers to self-regulate their engagement** in NDRTs.

## Short-term transitions

- The **request to intervene (RtI)** should be designed to be **multi-modal** and needs to explicitly convey the necessity for taking over vehicle control.
- An „NDRT lockout" simultaneously with the request to intervene (RtI) can accelerate the driver response.

# Wizard-of-Oz (exemplary BASt)

- Second seat in the back, used to simulate automated driving by a human (wizard)
- Concealed and unrecognizable for participants
- Can be used on **public roads**
- Specific HMI concept to allow transitions between manual driving and automated driving
- Data acquisition of driving data, eye-tracking, physiological data, reaction times

→ Other Wizard-of-Oz-Approaches at Audi, BMW and Bosch


# Recommendations for methods and interaction concepts

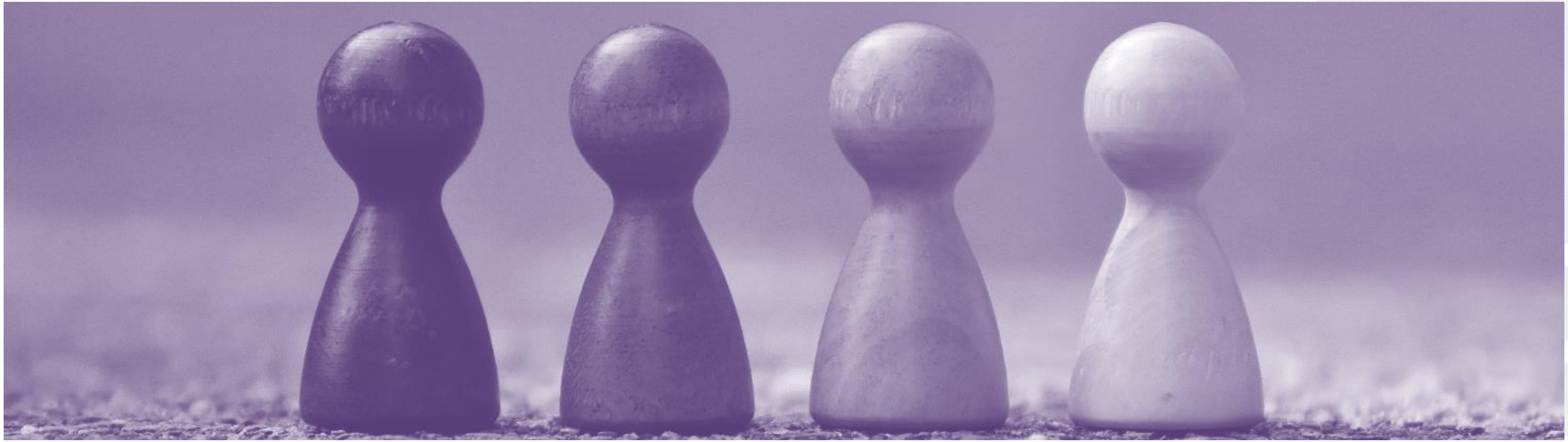
- Key messages on definitions and results from experiments.
- **See the rollups for more details**!

# Conclusion

- In our experiments, the take-over time is influenced by
  - Attributes of the take-over scenario (e.g. time budget, complexity of the required driver intervention)
  - Individual driver characteristics
  - Attributes of non-driving related tasks (NDRTs)
  - The design of the human-machine interface
- By adopting the so-called Wizard-of-Oz approach, we further developed a method for conducting automated driving experiments in real traffic.

# Human factors of automated driving

- Results, nomenclature and understanding were integrated into the **ISO discussion** and **standardization**.



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# Thank you

## for your attention!



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