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

Prof. Dr. phil. Klaus Bengler, Jonas Radlmayr
TU Munich, Chair of Ergonomics
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

- 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

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

Transition Process and Model

Automated driving →

Current driver state
- Sensory state
- Motoric state
- Cognitive state

Arousal level

Motivational conditions

Driver state transition process

Target driver state
- Sensory state
- Motoric state
- Cognitive state

Manual driving →

Driver intervention process

Type of current (non driving related) activity

Type/Design of Request to Intervene

Requirements of take-over scenario

Driver training / education / system experience

Definition of take-over situations

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

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)
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
Drowsiness and fatigue – Questions

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

<table>
<thead>
<tr>
<th>Duration of the automated driving period</th>
<th>Subjective Assessment</th>
<th>Objective Metrics</th>
<th>Expert Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed time vs. State dependent</td>
<td>Karolinska-Sleepiness Scale (KSS)</td>
<td>Heartrate, Galvanic Skin Response, PERCLOS, EEG, COP in the seat</td>
<td>Based on Wierwille</td>
</tr>
</tbody>
</table>

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

For a detailed description see:

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.
Results, nomenclature and understanding were integrated into the ISO discussion and standardization.
Thank you for your attention!

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