Ko-HAF
KOOPERATIVES HOCHAUTOMATISIERTES FAHREN

Non-driving Related Tasks in Automated Driving – Implications for Driver's Take-over Performance and HMI Design

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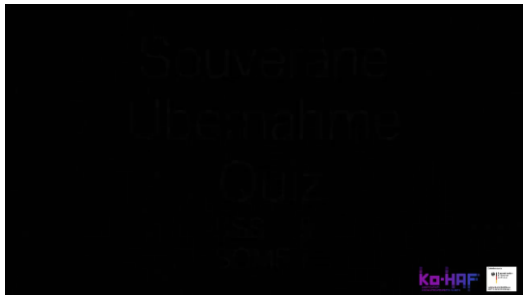
„Please take over vehicle control!“

- In Conditional Automated Driving (CAD, SAE Type 3) the system performs longitudinal and lateral vehicle control.
- The human driver can engage in non-driving related tasks (NDRTs) as she/he is not required to monitor the system/environment.

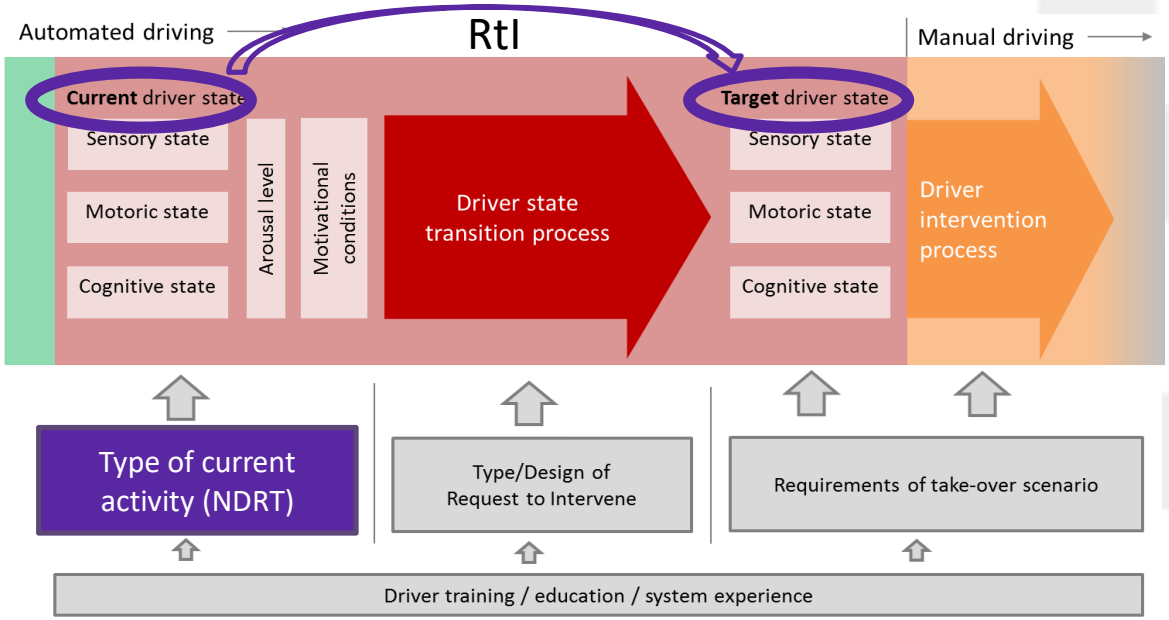
- However, if the system detects a situation it can not handle, the human driver receives a Request to Intervene (RtI).

➢ Example video of short-term take-over situation:



Driver Availability Model

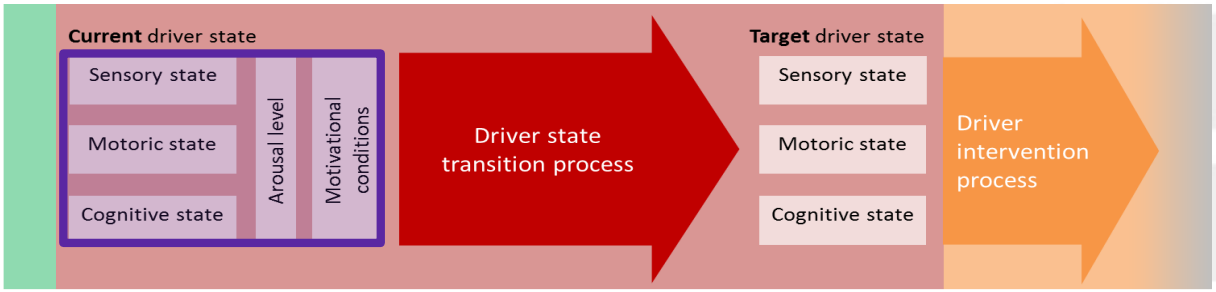
- An adequate driver state is the prerequisite for a successful take-over reaction of the driver:



Marberger et al., 2017

➢ Different NDRTs can affect different aspects of the driver state and thus take-over performance when it comes to an RtI.

Aspects of the driver state



- **Sensory:** what can currently be perceived with the sensory system; what information is required in a take-over situation?
- **Motoric:** position in the vehicle (turned around, lying, sitting) or the availability of the hands for steering (occupied or not?)
- **Cognitive:** reconfiguration of mental task sets or response rules
- **Arousal:** emergence of passive task related fatigue in automated driving
- **Motivation:** reduced willingness to instantly interrupt the NDRT

➢ **In Ko-HAF these aspects were examined in several studies by different project-partners.**

Effects of NDRTs: Sensory and motoric transition (1)

BOSCH

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Method

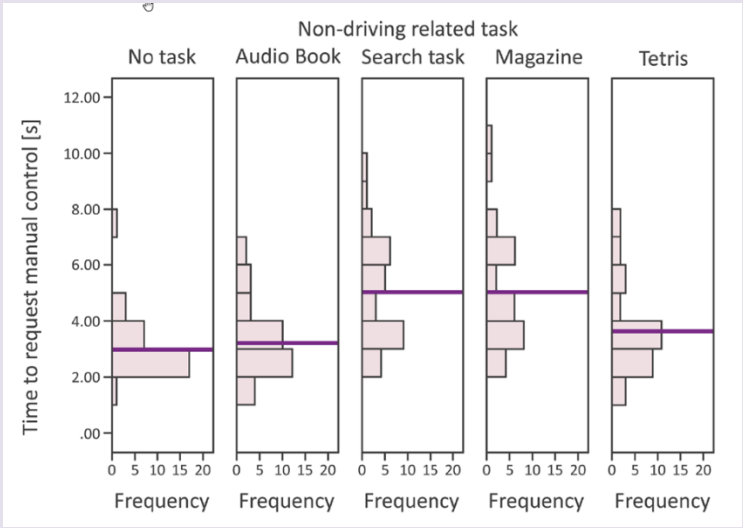
- Wizard-of-Oz-Approach
- *N* = 34 participants
- RtI due to sensor failure on open road
- 5 vs. 15 minutes automation period




Non-driving related tasks (NDRTs)

- Baseline (no task)
- Listen to Audiobook
- Playing Tetris (mounted Tablet)
- Reading magazine (handheld)
- Search task (requieres rotation of torso)

Main results: Take-over reaction



Conclusion

- ➢ Increased take-over times due to motoric unavailability
- ➢ Large inter-individual differences

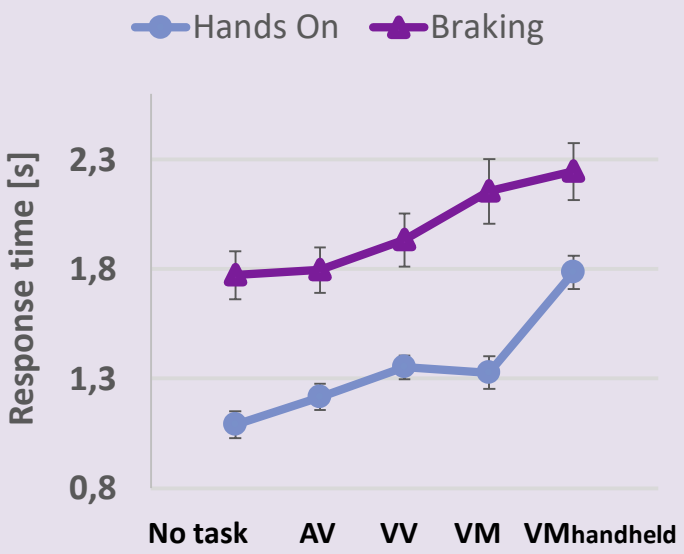
Effects of NDRTs: Sensory and motoric transition (2)

Method: Driving simulator study (*N* = 30)

NDRT	Resource demands
Conversation	Auditory-vocal (**AV**)
Reading out text	Visual-vocal (**VV**)
Texting (Tablet mounted)	Visual-manual (**VM**)
Texting (Tablet handheld)	Visual-manual (**VMh**)

Take-over scenario: Obstacle with TTC = 6 sec.

Results: Take-over reaction



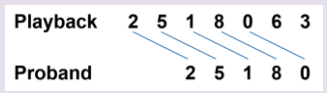
Conclusion

- Significant effects of modalities.
- The handheld texting task degraded performance the most.

Effects of NDRTs: Cognitive transition

Method: Driving simulator study (N=53, age = 32 years, SD=16y)

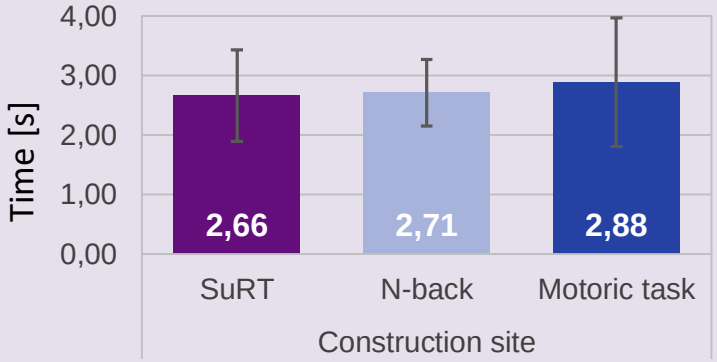
Between subject factor: NDRTs

Visual-motoric	Cognitive	Motoric
Surrogate Reference Task	N-back Task (N = 2)	Shape-sorter ball
		

Within subject factors: take-over situation and instruction (free vs. instructed)

Crash site	Construction site
	

Example Results: Take-over Time



Conclusion:

- NDRTs (different modalities) influence the driver state and can be detected using eye-tracking and seat pressure mats
- However, no significant differences were found regarding drivers‘ take-over performance.

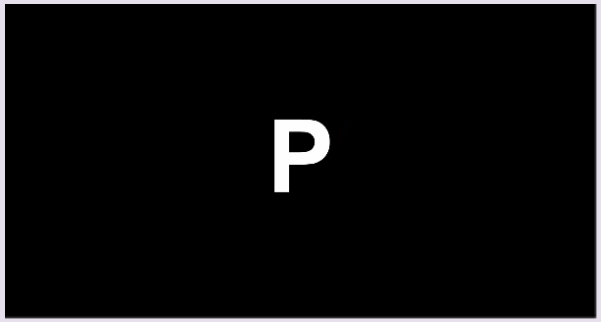
Effects of NDRTs: Arousal Level

Method:

- Motion Based Driving simulator study (N = 66)
- Between-subjects factor: NDRTs to affect fatigue
- Prolonged automated ride: 60 min
- A take-over situation with ttc = 7 s occured after 50 min

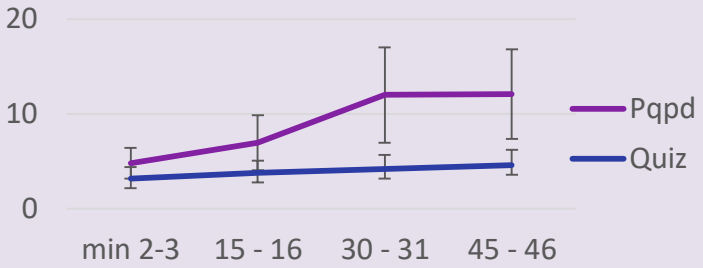
Activating Quiz

vs.

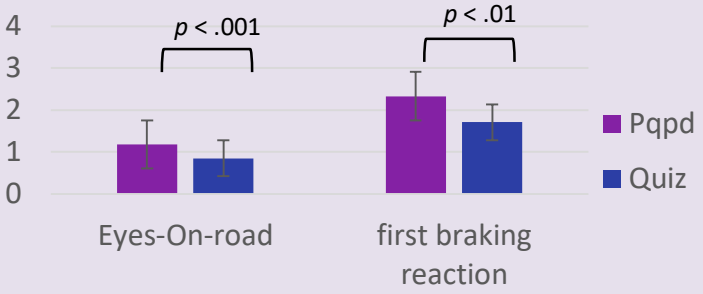


Monitoring task

Results: driver state (PERCLOS)



Results: Take-over time



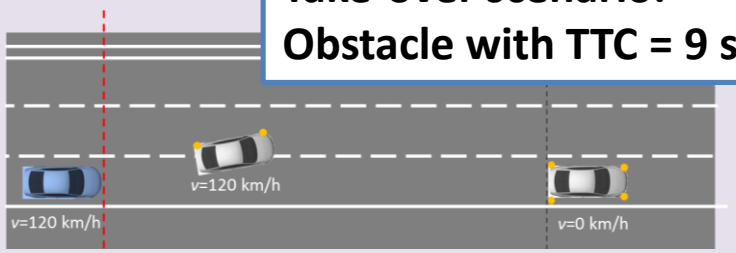
- Significant effect on the driver state (subjective / objective fatigue).
- Significant differences in take-over reaction (reaction times).

Effects of NDRTs: Motivational Aspects (1)

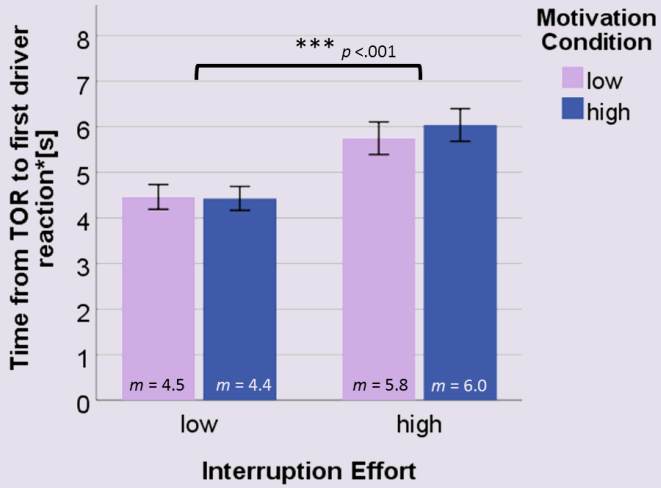
Method: Driving simulator study (N=53)
NDRT: Playing Tetris® on tablet

Manipulation 1: Interruption Effort
→ **Throwing tablet on co-driver's seat vs. storing it in a box**


Manipulation 2: Task Incentive
→ **Playing as a simple pastime vs. playing for points and money**



Results: First driver reaction*



*steering wheel button press, braking or steering wheel angle > 2°

Conclusion:

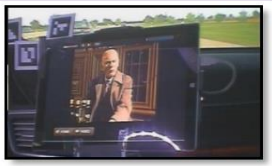
- High interruption effort (storing tablet in box) causes delayed driver reaction times (approx. 1.5 s latency)
- Motivational differences in the study were small and task incentive did not lead to significant differences in reaction times

Effects of NDRTs: Motivational Aspects (2)

DAIMLER Ko-HAF KOOPERATIVES HOCHAUTOMATISIERTES FAHREN

Method

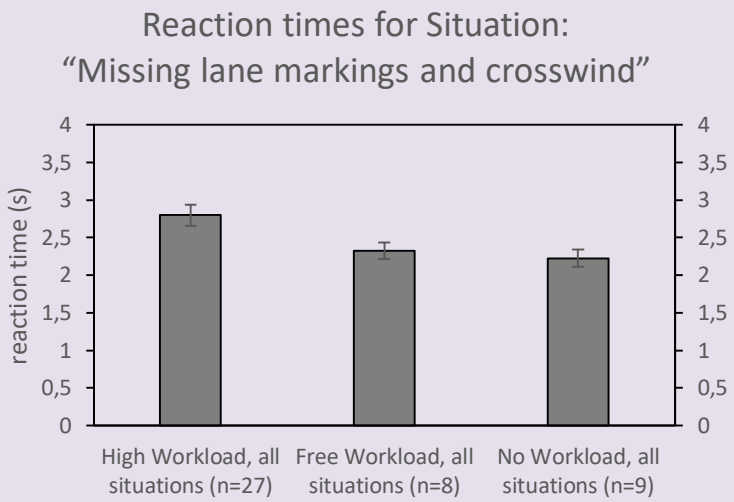
- Study in Daimler Driving Simulator
- *N*(total) = 96, *N*(with all situations) = 44 participants
- NDR-tasks: Reading, Video, Item search
- **Mandatory** vs. **self-regulated** engagement
  Mandatory = High Workload
  Self-regulated = Free Workload


Take-over Situation with RtI (Request to Intervene)

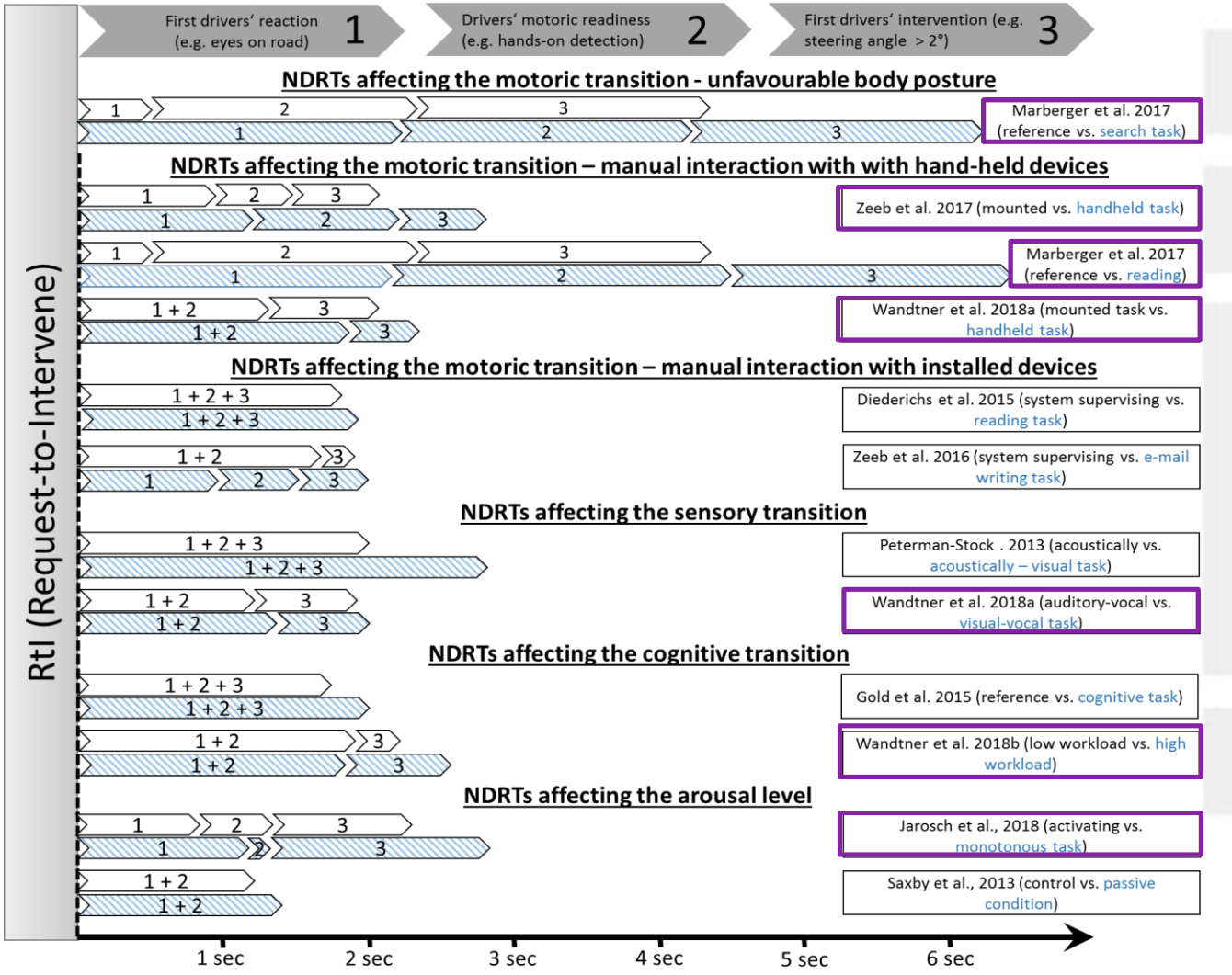
- Missing lane markings & crosswind

Main results



- The differences in drivers' reaction times to RtI for different levels of workload are statistically significant, but practically irrelevant.
- The reaction times to RtI during self initiated NDRT are faster than during instructed NDRT.

Effects of NDRTs: Summary of Publications



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

Example Concept for Long-term transitions (1)

Method: Driving simulator study (*N* = 36)

Tested HMI versions (selection)

- Basic HMI
- Adaptive HMI (staged pre-alerts)

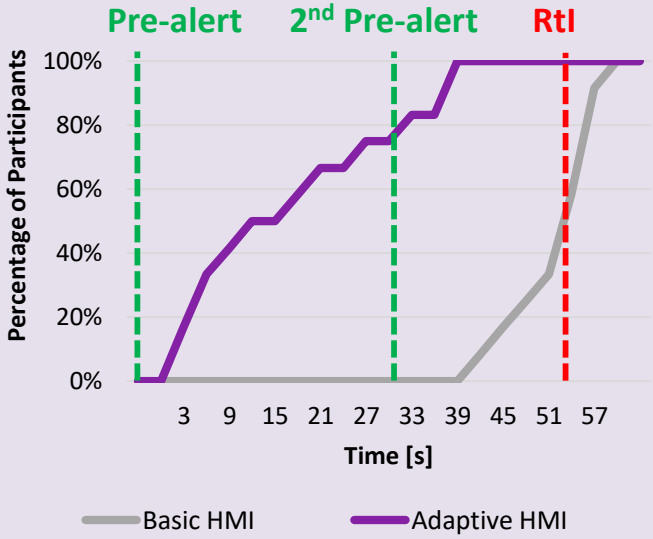
➢ What is the impact on NDRT disengagement and take-over times in predictable transitions?

Instrument Cluster

Center Display

Adaptive HMI

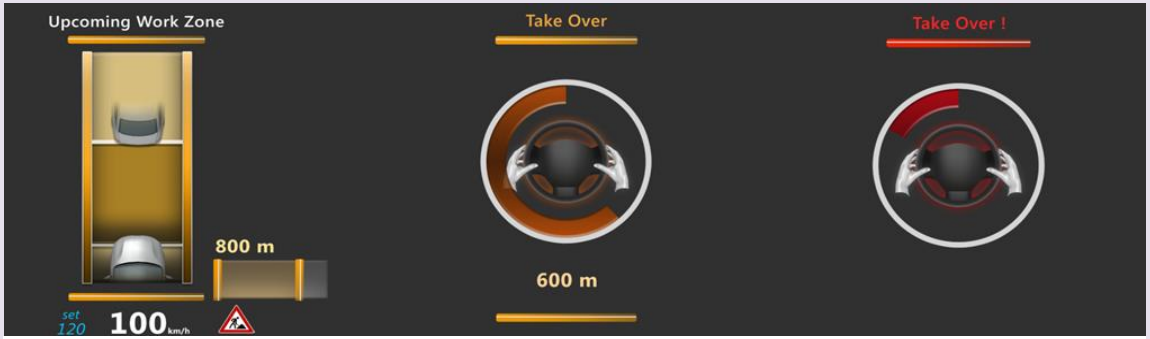
Results: NDRT disengagement



- Pre-alerts facilitated NDRT disengagement and take-over time.
- Very good user experience and acceptance ratings for adaptive HMI.

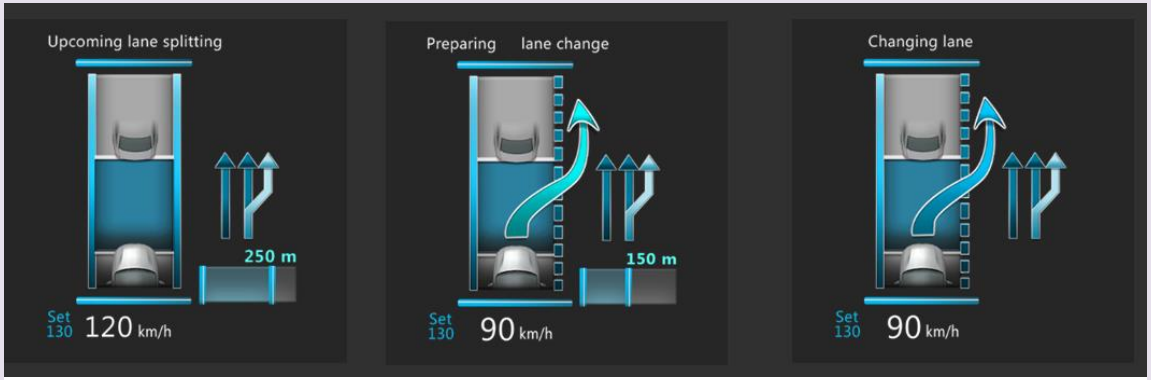
Example Concept for Long-term transitions (2)

HMI for take-over requests



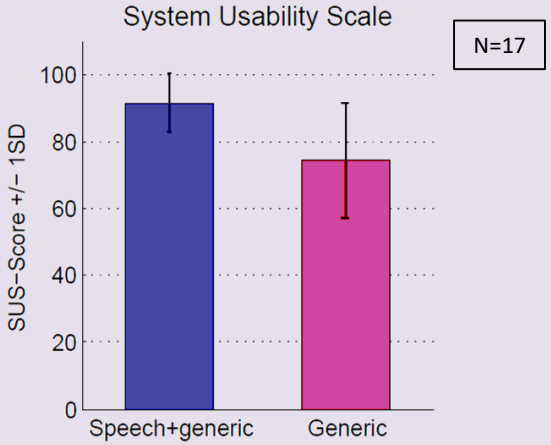
„Upcoming work zone – please take over soon“ *„Please take over“* *„Take over!“*

HMI for system maneuvers (no driver intervention required)



„Upcoming lane splitting“ *„Preparing lane change…“* *„Changing lane…”*

Results: Usability

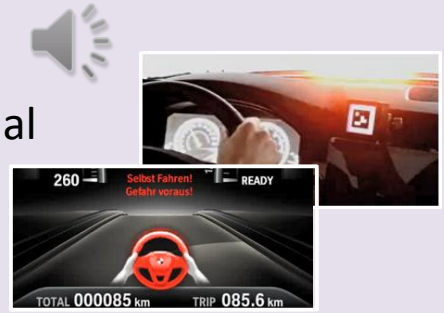


- Take-over requests followed a multi-step escalation scheme
- Take-over requests and system maneuvers displayed different HMIs
- Additional speech output increased overall system usability

Example Concept for Short-term transitions

Method: Driving simulator study (N = 64)
3x2 between-within design

- Three different HMI concepts for RtI
  - Speech output
  - LED – light signal
  - Baseline: Text



- Take-over scenarios

Scenario 1:

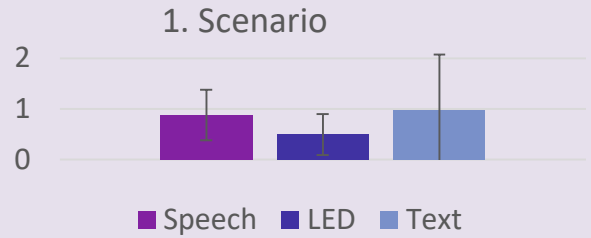
required reaction of driver: Lane change maneuver

Scenario 2:

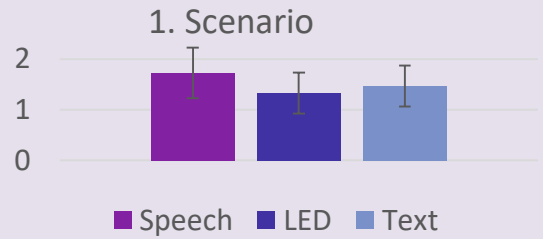
required reaction of driver: Braking maneuver

Results: Take-over reaction

Gaze-reaction time (in s)



Hands-on times (in s)



- Eyes-on road time was lowest in the LED group.
- In the LED group reaction times were faster compared to the other HMI concepts (hands-on time, braking reaction).

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 control of the vehicle.
- An „NDRT lockout“ simultaneously with the request to intervene (RtI) can accelerate the driver response.





Thank you
for your attention!

Gefördert durch:
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