REQUIREMENTS AND CONDITIONS – Booth No. 06

THE HUMAN DRIVER - DRIVER TAKEOVER CAPABILITY IN REAL TRAFFIC

PEGASUS

Research focus, procedure, results, observations and further research

Research focus and procedure

- holistic view on safeguarding of AD requires consideration of the transition to manual
- human performance in different takeover situations is a safety relevant parameter
- testing of driver performance with a conditionally automated (L3) driving function in real traffic. Effects of different traffic densities (normal traffic vs. rush hour) were assessed

Results and observations

takeover time	*n*	*M (SD)*	Min	Max
study 1	237	3.58 (1.19)	2.02	8.24
study 2	108	3.32 (0.77)	2.04	6.29

There are no significant differences between the takeover times from study 1 and study 2.
The normal traffic group shows significantly longer takeover times than the rush-hour group.

- short takeover times
- partly insufficient or no safeguarding of the surrounding traffic during takeover
- takeover quality analysis is in progress (lateral and longitudinal vehicle control)

Further research & exploitation

- influence of long term experience with conditionally automated vehicle
- better understanding of safeguarding behaviour during transition to manual needed
- results on driver performance provide guidance for technical regulations (e.g. type approval)

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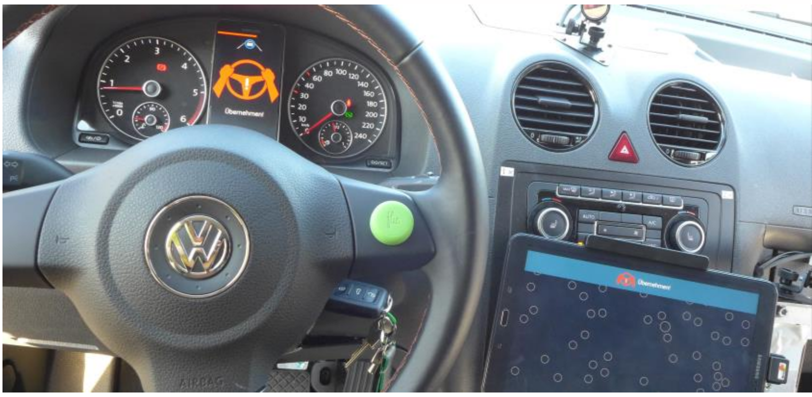
Testing of a highly-automated driving function with a Wizard-of-Oz-vehicle

Impact of surrounding traffic on takeover capability

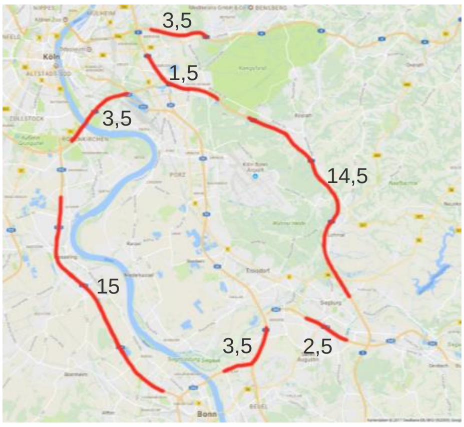
The Federal Highway Research Institute (BASt) conducted on behalf of the Research Association for Automotive Technology (FAT e. V.) a Wizard-of-Oz-test on public roads in order to investigate the human-machine interaction under realistic circumstances.

The testing vehicle is equipped with a second driver seat in the back, which is used to simulate Level-3-automation. Numerous measuring systems captured driving data (such as distances, lane keeping, etc.) and reaction times in order to evaluate the takeover capability of the subjects.

The surrounding traffic was measured as traffic density and varied by the formation of two groups. The takeover time is determined by the time between the transfer request and pressing the button.



A display keeps the subjects informed about the system status and shows a takeover request (TOR) when needed. The TOR is also shown on the tablet PC which is used for the non-driving related task for the subject to perform during the automated drive. With a button on the steering wheel the subjects interact with the system: They can request the completion of the automated drive or confirm to be ready to take over.



On overall 117 kilometers (73 miles), the testing route goes on different sections of motorways in the region of Cologne/Bonn and includes seven planned takeover situations. The test is started with a warm-up phase for the subjects to get familiar with the car. Construction sites and motorway entries and exits are system limits and need to be driven manually by the subject. In order to give the subject enough time to take over the driving task, the TOR is shown approx. 3 km (2 miles) before reaching a system limit.

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Results of study 1 in real traffic on motorways

37 participants (19 female, 18 male)
two groups:
- normal traffic (n = 20)
- rush-hour (n = 17)

The rush-hour group showed significantly higher values in terms of traffic density (U = 3190.50, z = -7.59, p < .001, d = 1.052).

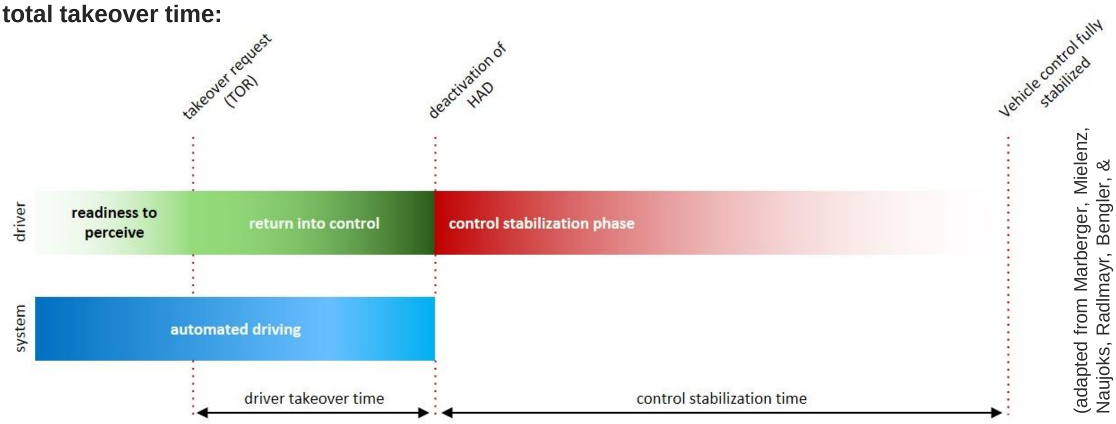
N = 37

	M	*SD*
age	51.32	11.49
driver licence	33.43	11.12
km per year	17.57	6.96

takeover time	*n*	*M (SD)*	Min	Max	10^{th} percentile	90^{th} percentile
normal traffic	130	3.87 (1.35)	2.02	8.24	2.48	5.87
rush-hour traffic	107	3.21 (0.83)	2.05	6.69	2.46	4.11

The normal traffic group shows significantly longer takeover times than the rush-hour group (U= 4817.00, z = -4.07, p < .001, d = 0.55).

total takeover time:



(adapted from Marberger, Mielenz, Naujoks, Radlmayr, Bengler, & Wandtner, 2017)

N = 237 takeover times
M = **3.58 s** (*SD* = 1.19 s)
Min = **2.02 s** *Max* = **8.24 s**
90th Percentil = **5.46**

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Analysis of study 1 and derivation of research needs for study 2

Analysis being currently performed:
- analysis of lateral vehicle control
- analysis of the gaze movement of specific subjects (under 5th and over 95th percentile of the takeover time)

The analysis of the takeover times show an unexpectedly fast takeover. It should be noted, however, that the TOR were only issued in **non-critical situations**.

Nevertheless, the question arises as to what effect a preceding automated journey has on handling an unexpected event in the immediate aftermath of a successfully completed takeover:

- Do the subjects actually have control over the traffic situation after approx. four seconds?

Handling an unexpected event

Due to a possible risk to other road users, the study was carried out on a test site in Pferdsfeld, Germany.

The unexpected event was simulated by the collision-free trailer "EVITA" of Technische Universität Darmstadt, which suddenly decelerates at 8 m/s².

Experimental vehicle for unexpected target approach (EVITA 2.0) of the TU Darmstadt

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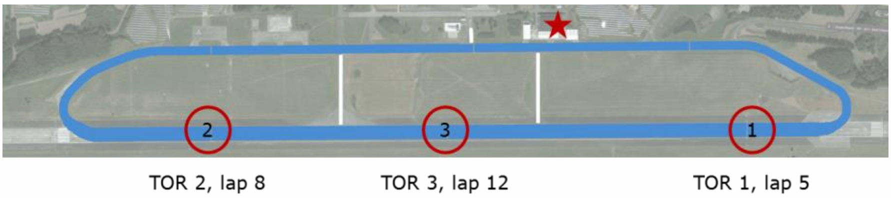
Procedure and Results of study 2 on test site



Testing area Pferdsfeld with the position of TOR

To test the subjects' handling of the unexpected event, 12 laps (approx. 5 km each) on a test site were driven. The subjects received a TOR three times. Immediately after the 3rd TOR, the unexpected harsh braking of the EVITA-trailer occured. During the drive, another vehicle escorted the Wizard of Oz vehicle in order to simulate surrounding traffic.

➡ 36 participants (12 female, 24 male)

(relevant data on takeover capability after the unexpected event in 20 cases)

N = 36

	M	*SD*
age	44.67	12.18
driver licence	25.47	11.58
km per year	18.92	9.66

➡ takeover time	*n*	*M (SD)*	Min	Max	10th percentile	90th percentile
study 1	237	3.58 (1.19)	2.02	8.24	2.48	5.46
study 2	108	3.32 (0.77)	2.04	6.29	2.49	4.27

There are no significant differences between the takeover times from study 1 and study 2 (U= 12150.00, z = -0.75, p = .451, d = 0.08).

➡ **Handling the unexpected event:**
A first evaluation of the remaining 20 participants shows that all were able to avoid a collision. 16 participants achieved this by braking and 4 by braking and changing lanes.
These results initially indicate that the human driver is able to handle an unexpected event after a completed takeover. However, it should be noted that there was no surrounding traffic, so that it was not absolutely necessary to secure the manoeuvre.

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