



RealCarSIM

A NEW APPROACH FOR THE USER TESTING OF IN-VEHICLE APPLICATIONS

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APPROACH



WHY?

Combination of two Approaches



HUMAN FACTORS STUDIES

- ▶ Often in driving simulators with different degrees of fidelity for human in the loop testing.
- ▶ Safe and highly controlled tests environment with repeated testing also in complex driving scenarios.
- ▶ Mostly generic design of HMI / in-vehicle systems.
- ▶ Ordinary drivers as test persons.

Basic principles of driver behaviour.



VEHICLE TESTING

- ▶ On-road testing on test track or public roads.
- ▶ Evaluation of specific, changing vehicle models.
- ▶ Focus on technical tests of vehicle components, specific implementations.
- ▶ Mostly expert tests.

Evaluation of vehicles.



WHY?

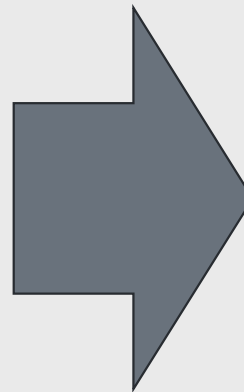
Combination of two Approaches



HUMAN FACTORS STUDIES



VEHICLE TESTING



RealCarSIM

- ▶ Growing complexity of in-cabin functions and infotainment.
- ▶ Growing importance of human factors in vehicle development and testing.
- ▶ Mandatory user studies during vehicle homologation (e.g. ADDW, DDAW, DCAS)





HOW?

RealCarSIM – Basic Idea



- ▶ Physically integration of a real vehicle into the environment of the driving simulation.
 - ▶ Vehicle should be easily exchangeable.
 - ▶ Setup can be adapted to different vehicles.
- ▶ Control of the simulated vehicle in the simulated environment via cockpit of integrated car (pedals, steering wheel, buttons, etc).



HOW?

RealCarSIM – Basic setup

Basic components

- ▶ Vehicle under test (exchangeable) with interface for CAN bus.
- ▶ Turn tables and mats to position the vehicle on, tables allow turning of the steering wheel in standstill.
- ▶ Projection system for front view, e.g. projector and projection screen, TV screen, LED wall.
- ▶ Displays for mirrors and cluster display.
- ▶ Sound system to be positioned on the backseat.
- ▶ PC-rack & operator laptop to control the simulation

Integration in simulated environment

- ▶ Simulation software SILAB
- ▶ The vehicle is connected to the driving simulation via CAN interface
→ information from the vehicle is used in the simulation to control the simulated vehicle







WHAT FOR?

Advantages of the RealCarSIM approach



TEST OF SPECIFIC VEHICLE MODELS

- ▶ Test of different vehicle models, integration of new, also prototypical models.
- ▶ UX studies for market-ready, series production HMIs with their corresponding hardware.
- ▶ In-cabin functionalities (air condition, sound system, seat, ambient light) can be tested.



SIMULATOR-BASED TESTING

- ▶ Safe & controlled environment.
- ▶ Option to repeatedly create also complex driving scenarios.
- ▶ Option to create a multitude of different scenarios also with changing environmental conditions.
- ▶ Safe investigation of adverse driver states (fatigue, distraction) during complex driving tasks.



APPLICATION



STUDY 1 – VEHICLE SOUNDS

GOAL

Evaluation of different sound concepts for in-vehicle sounds from UX-perspective.

METHOD

Evaluation takes place

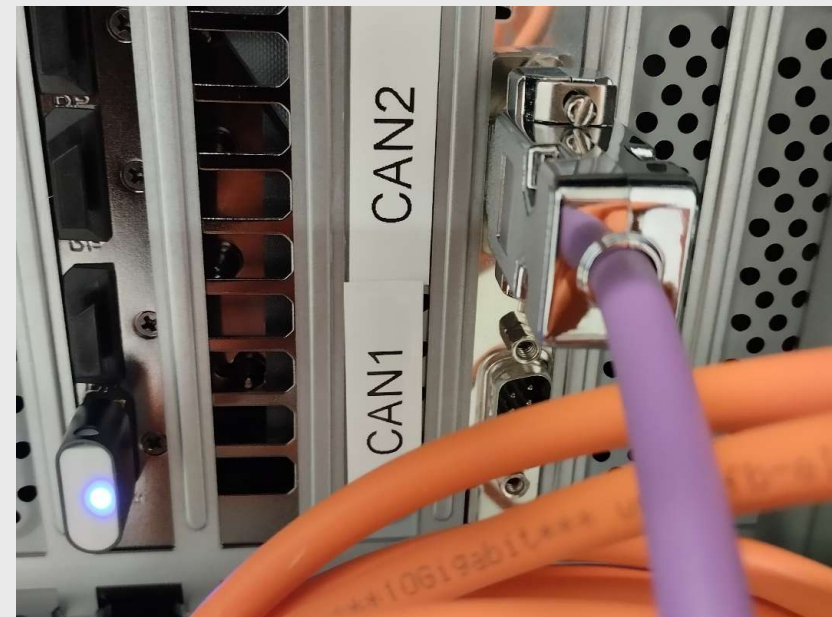
- ▶ in vehicle under test (cockpit design, position of speakers etc.).
- ▶ in relevant traffic or system states (e.g., for FCW or L2-automation).
- ▶ with / without background noise (radio).

N=32 naïve drivers

RESULTS

Results help to understand UX of different sound concepts.

There is an impact of driving situation / environment on the evaluation.





STUDY 2 – ADAPTIVE DIGITAL ASSISTANT

GOAL

Evaluation of driver state dependent adaptations of vehicle functions by a digital voice assistant.

METHOD

Induction of mood via instructions and variation of the simulation environment (weather, time of day).

Digital assistant proposes mood and situation dependent adaption of in-vehicle settings and gives information.

Setup allows to use the full functionality of the tested Audi A6 eTron (AC, seat, ambient light, sound system).

N=40 naïve drivers

RESULTS

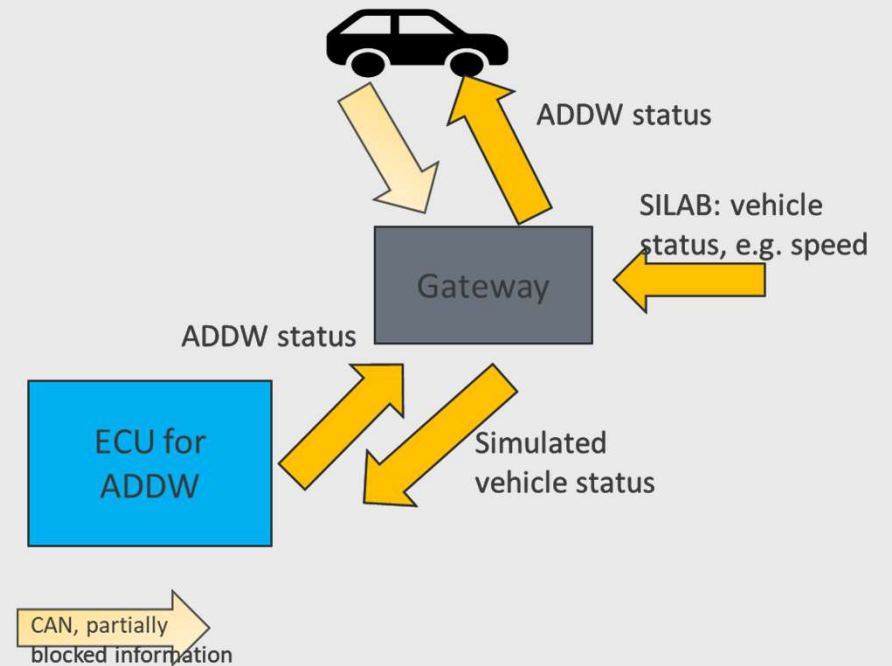
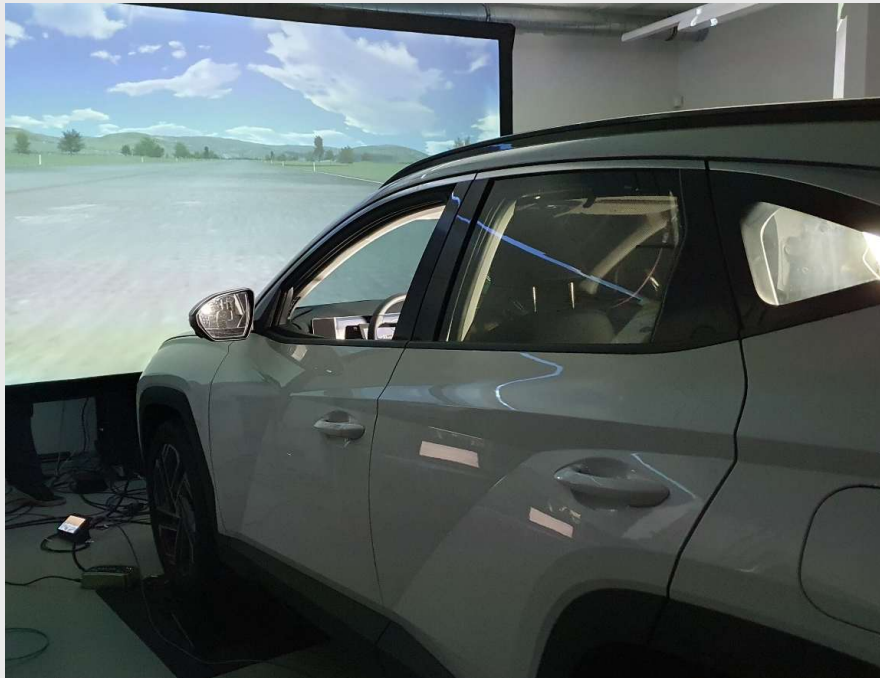
Evaluation of voice assistant depends on driving situation. There is little impact of mood.





STUDY 3 – ADDW TESTING

APPROACH



- ▶ Test protocol for evaluation of ADDW systems according to EU-Regulation 2023/2590 is transferred into simulated environment.
- ▶ Expansion of RealCarSIM approach by additional integration of ADDW system into simulation. Connection between simulation software and ECU via CAN gateway.



STUDY 3 – ADDW TESTING

PROOF OF CONCEPT

- ▶ Testing of ADDW system following the experimental protocol
 - ▶ On the test track
 - ▶ In the RealCarSIM
- ▶ Procedure and data logging are comparable in both environments.
- ▶ Testing of full experimental protocol
 - two speeds, 13 fixation point, nighttime vs. daytime conditions.
- ▶ N=3 drivers participate in both environments.
- ▶ Comparable analysis of warning times based on the driver video.

Fahrt 02 - 55 - 1720

Versuchsprotokoll

Datum: 15.03.24 Startzeit: 11:29 Endzeit: 12:10 Fahrer: 12 Beifahrer: M.M. Rücksitz: T.W.

Fahrt Nr.: 2 Wetter: bewölkt Geschwindigkeit: ☐ 20 - 35 (Tempomat 30 km/h) ☒ 50 - 65 (Tempomat 55 km/h)

Alter: 24 Geschlecht: W

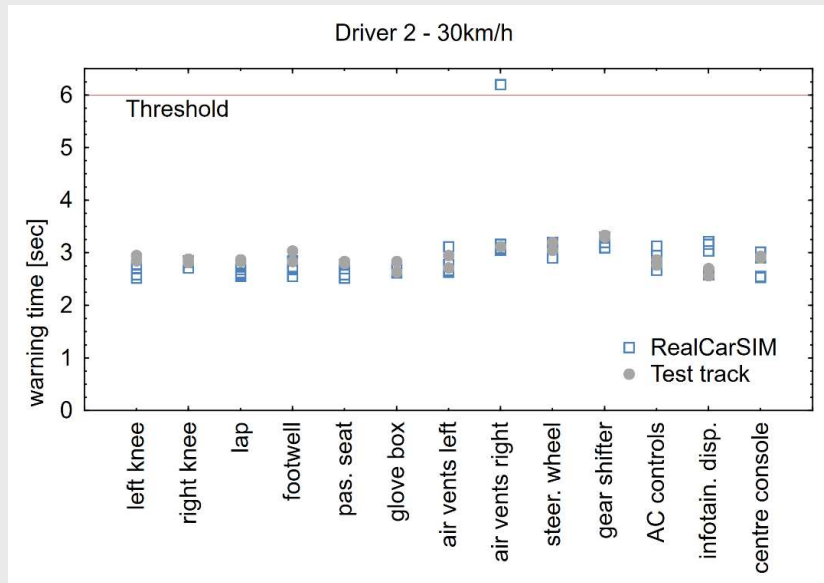
Tests	Blickposition	Durchgang 1			Durchgang 2			Durchgang 3		
		Nr.	Warnung (ja-nein)	Anmerkung	Nr.	Warnung (ja-nein)	Anmerkung	Nr.	Warnung (ja-nein)	Anmerkung
✓ Q	driver's left knee	1	ja		2	ja		3	ja	ja
✓ W	driver's right knee	4	ja		5	ja		6	ja	
✓ E	driver's lap	7	ja		8	ja		9	ja	
✓ R	passenger's footwell	10	ja		11	ja		12	ja	
✓ T	passenger's seat surface	13	ja		14	ja		15	ja	
✓ Z	glove box	16	ja		17	ja		18	ja	
✓ U	air vents (left side)	19	ja		20	ja		21	ja	
✓ I	air vents (right side)	22	ja		23	ja		24	ja	
✓ O	instrument cluster	25	ja		26	ja		27	ja	
✓ P	steering wheel	28	ja		29	ja		30	ja	
✓ A	gear shifter	31	ja		32	ja		33	ja	
✓ S	heating, ventilation, AC	34	ja		35	ja		36	ja	
✓ D	infotainment display	37	ja		38	ja		39	ja	
✓ F	centre console	40	ja		41	ja		42	ja	



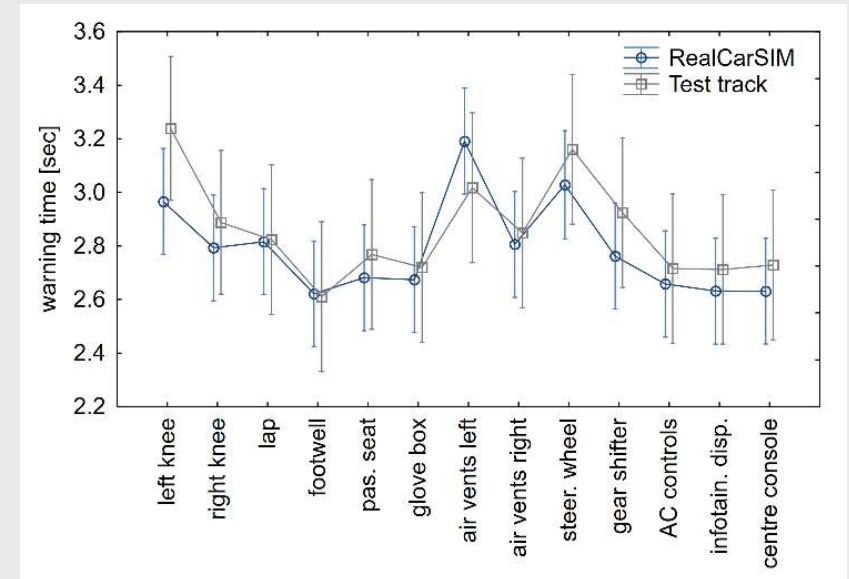


STUDY 3 – ADDW TESTING

RESULTS



- Evaluation according to EU-Regulation 2023/2590 brings comparable results for both environments.



- Fine grained differences in warning times between fixation points can be replicated in the RealCarSIM.
 - Main effect Fixation point $F(12,443)=4.01$, $p<.001$
 - Main Effect Environment $F(1,443)=2.05$, n.s
 - Interaction: $F(12,443)=0.35$, n.s.



SUMMARY

Why the RealCarSIM approach?



POTENTIAL

- ▶ Allows standardized user tests addressing human factors topics in the development / evaluation process for in-cabin applications.
- ▶ The driving simulation allows in-cabin applications to be evaluated systematically during driving e.g. in appropriate driving situations or with varying driver states.



CHALLENGES

- ▶ Requires access to vehicle architecture – CAN interface + dbc-file
- ▶ In addition, extended applications require access and in-depth expert knowledge about tested vehicle functions (e.g. ADDW, DDAW).

OUTLOOK – FUTURE DEVELOPMENT

- ▶ Development of a sensor setup that allows to integrate pedal position / steering angle without access to CAN data.
- ▶ Further development of driving simulation software to include further sensor simulation in the testing.



**THANK YOU
FOR YOUR KIND ATTENTION**

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