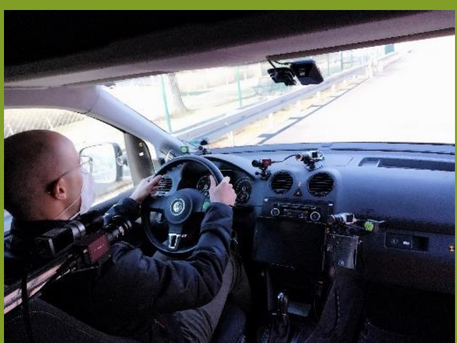
HADRIAN

Holistic Approach for Driver Role Integration and Automation Allocation for European Mobility Needs

HADRIAN Newsletter March 2022

NEWSLETTER CONTENT



In year two of the project the partners in the HADRIAN consortium focused on developing the prerequisites for "**Fluid Human Computer Interactions" (HCI)** to offer drivers tailored information for safe and acceptable managing of the automated driving (AD) vehicle. Specifically, partners investigated different **fluid HCI modalities** in several exploratory studies using driving simulators. In these studies, the partners investigated a variety of HCI innovations using head-up displays, ambient lighting, haptic feedback via the steering-wheel, seat rotation, preview of automated driving duration, driver tutoring, as well acoustic and visual AD signalling characteristics. These studies are described in detail in this newsletter.

Beside the HCI innovation studies, activities in year two centered around the development of a **Driver Monitoring System** for the fluid HCI innovations. Therefore, the partners UGR (University of Granada, Spain) and CEA (Commissariat à l'énergie atomique et aux énergies alternatives, France) collected and analyzed human driver state data from more than 140 drivers using driving simulator studies. More than 160 hours of driving data were collected with state-of-the-art sensors including a thermographic camera, an RGB camera, a depth camera, an eye-tracker and physiological sensors to record the drivers' heart activity, the respiration rate, and electrodermal activity. Also, a sensitive steering wheel was designed to detect whether and where the drivers' hands are positioned on the steering wheel to record the driver's gripping force as indicator of the driver's stress level.

Finally, the preparations for **field demonstrations** have started by identifying the specific innovations that the partners will demonstrate in three real vehicles at three sites: Austria, Spain, and Turkey. The demonstrations will be realized with a large and a small passenger vehicle as well as a commercial truck including integration with road infrastructure using C-ITS.

What else will happen in **year 3**? The partners are going to complete their evaluations of the HADRIAN innovation using simulation studies and calculate a final assessment of the safety and acceptance of HADRIAN innovations. Also **ethical and legal compliance** of the HADRIAN innovations will be investigated and practical design guidelines will be developed. Finally, the HADRIAN consortium intensifies its **exploitation activities** across Europe and beyond to bring the innovations into reality.

ACHIEVEMENTS IN YEAR TWO

An important objective of the HADRIAN project is to investigate the impact of fluid Human Computer Interactions to facilitate safe and acceptable interactions with automated driving vehicles.

Standardization of Alerts for Automated Driving

Have you ever rented a car and were confused about how to engage or disengage the wind-shield wiper, open the gas tank, or enable some advanced driving feature? In the case of automated driving, such confusion could get even safety critical when drivers have to interact quite differently with these functions in different vehicle brands. Especially when in time-critical situations, getting consistent and reliable alert information could be of high importance. The HADRIAN consortium has applied an alerting taxonomy framework from the aviation domain (CFR / CS § 25.1322) and applied it to automated driving. Specifically, three types of alerts are differentiated: warnings are displayed when drivers should become aware immediately of an event or change and act immediately and cautions Caution are displayed when a subsequent (but not immediate) action is necessary. Defining alerts based on required driver responses may represent a framework that different manufacturers may be able to adapt while still allowing design differentiations between brands and models. The framework was presented at the INCOSE Human-Systems Integration conference in November 2021.

Making Automated Driving Predictable

Could drivers of automated vehicles benefit from knowing the remaining duration of their automated drive? Would they be able to take back control safer and maybe experience a more comfortable automated drive? The Virtual Vehicle Research GmbH (ViF) evaluated these questions in HADRIAN in depth. Whereas current visions for automated driving do not commonly include such information, any passenger on a train probably appreciates the schedule information of the next train stop for getting off the train comfortably. Therefore, in a driving simulator study, 40 participants were either informed about the duration of their automated drive (SAE Level 3) before they had to take back control or were not informed. The results indicate that participants found such predictive information highly useful and that it eventually led to safer driver gaze behavior during the transition. Detailed results from this study will be published in 2022.

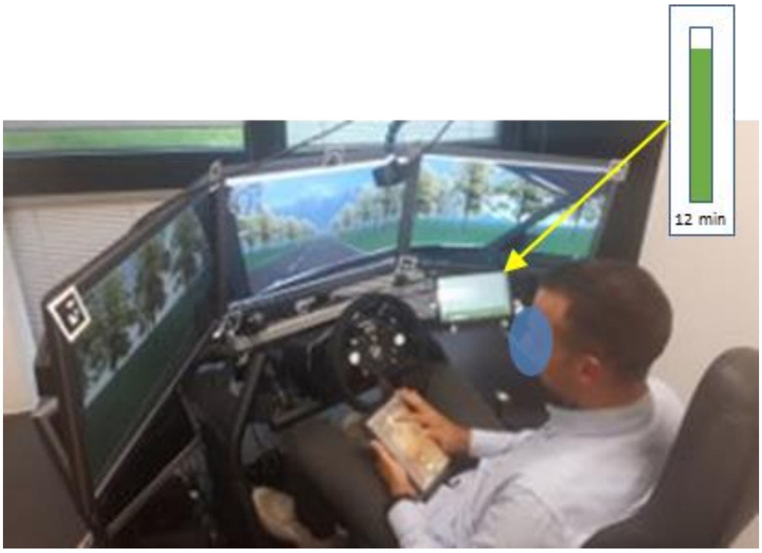


Figure 1 Experimental Set-up to Evaluate the Benefits of Displaying the Driver the Duration of the Automated Drive

Ambient Lights Reveal the Automated Driving Modality

The in-vehicle ambient lighting developed by the Paris Lodron University of Salzburg (PLUS) is a supportive interface that provides the driver with high-abstraction information about (1) current ADL, (2) permitted and/or prohibited tasks per ADL, and (3) requests to intervene. It facilitates the driver's role in an automated vehicle by providing a baseline of control-relevant information, thereby reducing the cognitive effort when observing, or reacting to, the other displays and indicators in the vehicle. The initial prototype consists of LEDs below the windshield, in the steering wheel, and lights illuminating the footwell. Different colors signal different ADLs, whereas different lighting patterns in combination with standard warning color coding communicate urgency.

Initial results suggest the lights adequately prime the driver in terms of ADL and control transitions without increasing cognitive workload. Properly informing the driver about non-driving related tasks (NDRTs) per ADL is still subject to improvement. For follow-up research, an additional indicator for NDRTs is considered and an integration and joint setup with the haptic steering wheel from project partner Tecnalia (potentially others as well) is planned.

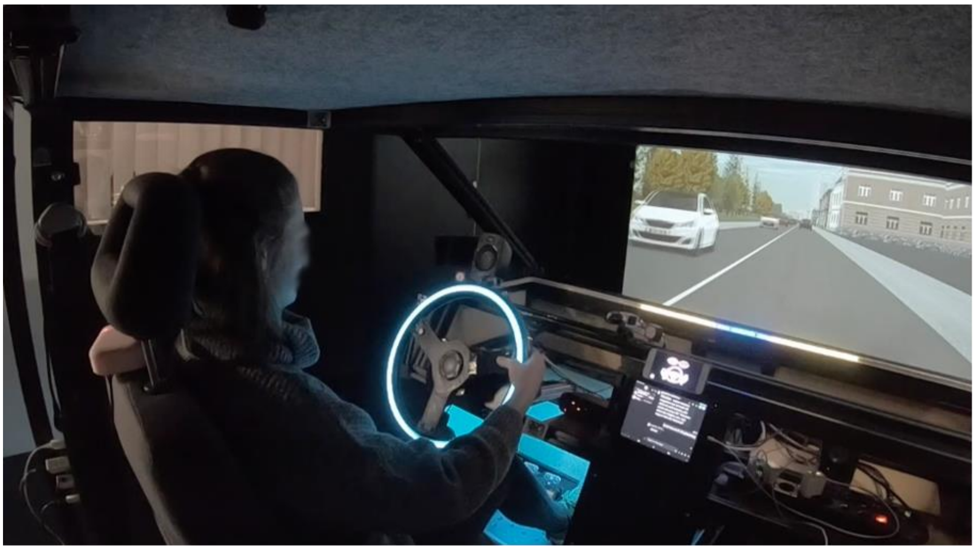


Figure 2: Lights below windshield, in the steering wheel, and in the footwell communicate current ADL (3) as driver is preparing to switch back to manual driving. NDRTs (text chat) can be performed in the center stack display.

Haptic feedback from a Guardian Angel

When we think about information coming from the car, our mind is likely to wander through the dashboard, infotainment, hud, screens of any sort, lights, beeps, bells, or even voice feedback. Regarding the haptic information, the steering wheel gives haptic feedback through the forces it exerts at the touch of our hands. So, within HADRIAN, Tecnalia has set to find ways to actively control the haptic information coming through the steering wheel and exploit this customary channel to convey different sorts of "messages".

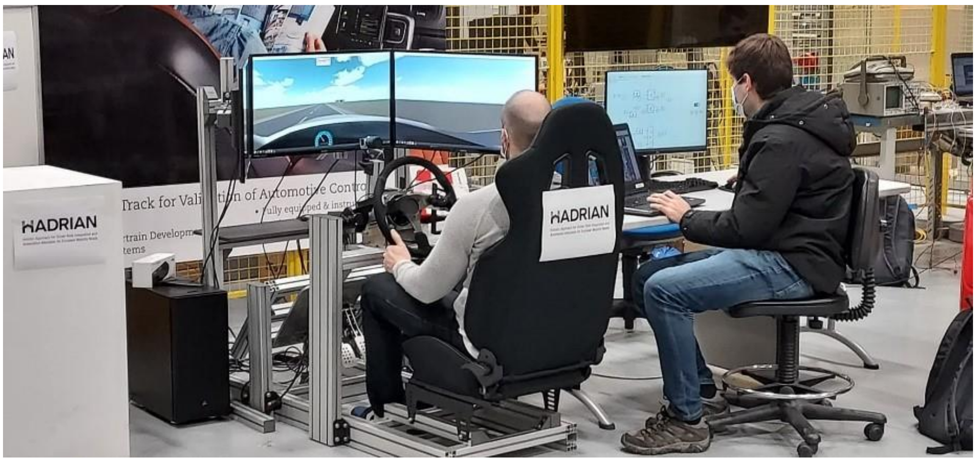


Figure 3: Tecnalia's driving simulator tests

On one hand, a set of haptic icons with particular vibrations has been designed and tested to convey three types of information: non-critical messages, take-over requests, and hand-over transition status. The best icons are now being tested by regular drivers in the simulator, while driving in attentive and distracted conditions, to evaluate the acceptance and help selecting the final set of icons for the haptic steering wheel HMI.

On the other hand, a shared control strategy has been implemented, that in case of an unsafe situation, produces a guiding force that moves the steering wheel towards the desired reference, like a Guardian Angel. Depending on the risk and demanded criticality, this support can go from a gentle “suggestion” to a strong overriding “correction”. Preliminary results show good user acceptance scores and a significant reduction in the number of accidents.

Optimizing Head-up Displays for Automated Driving

Automated vehicles with higher levels of automation have numerous sensors that are used to help the driver with the monitoring of the environment. In-vehicle information systems use the signals from these sensors and with the display of visual, auditory or tactile ques, try to direct the driver’s attention to where critical information lays in the environment. The project partner University of Ljubljana (UL) has developed four prototypes of the visual HUD. They display different amount of information (MIN vs. MAX) and present in two-dimensional (2D) projection on the windscreen as shown in Figure 4 and use augmented reality (AR) to highlight of information directly in the environment. Each of them was tested with end users to identify which and how should information be displayed to ensure highest level of driving safety, improve the user experience, provide better usability and last, but definitely not least, which information would drivers like to have displayed all times. In the next step, the results from all four prototypes will be compared and used for the development of a unified visual HUD that features the best features from all four prototypes.

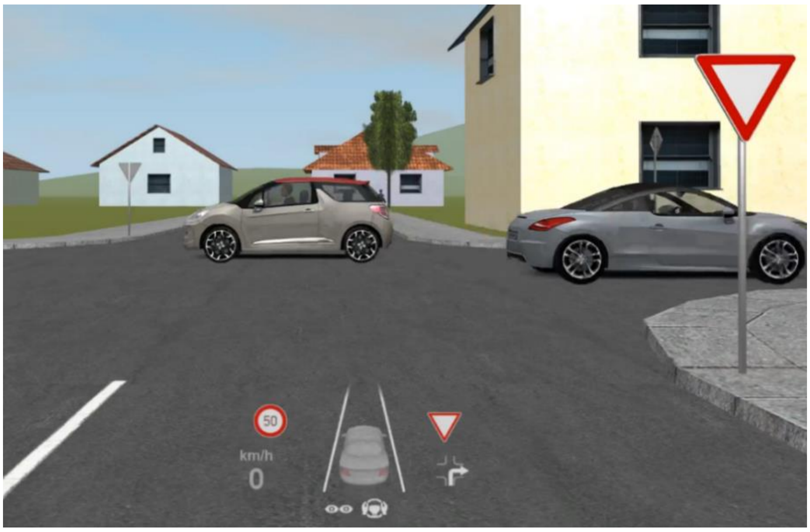


Figure 4: 2D MAX head-up display

Improved Visual and Auditory AD Display Elements

In automated driving it is crucial that the driver's trust is maintained appropriately to use the automated driving function effectively. Project partner Technical University of Delft (TUD) believes that transparency between the driver and the vehicle can enhance driver trust. TUD performed an experimental study in a driving simulator with SAE Level 2 automation where drivers experience interactions with other vehicles which merge, brake or change lanes. Four HMI variants were evaluated aiming to enhance perceived safety and trust. To enhance transparency, automation performance information is provided regarding, 1. detection ("merging vehicle is detected") and 2. action ("we are slowing down"). TUD found that the driver's understanding of the state of automation affects the increase in trust. It means that the interaction between the driver and the vehicle is necessary even if automation is developed. The next step is to separately identify the impact of information type and modality.

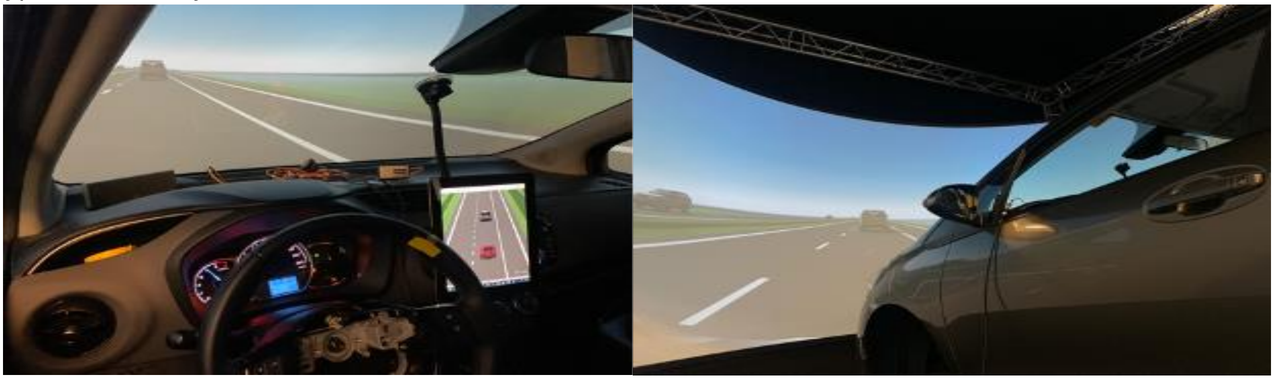


Figure 5: Simulator setup to Evaluate the Visual and Auditory Signals to Support AD Interactions

Capturing omnidirectional attention is an important advantage of the auditory interface. It is not common for sound to be used as a single modality in vehicles. In collaboration with FORD and University of Surrey (USR), TUD designed critical scenario sounds in automated vehicles that support visual UI for truck drivers. The validation results indicated that the sounds evoked the correct function and urgency level. In particular, the sounds of dangerous situations were recognized by clearly separating these from other sounds.

A Fluid HMI for Trucks

With the help of autonomous driving, truck driving will be safer and more fuel-efficient. Human-centred fluid HMI plays a critical role in the acceptance and trustfulness of truck drivers to autonomous driving and increasing engagement and ease of use. FORD and University of Surrey (USR) has developed a comprehensive HMI design based on an iterative approach. HMI design iterations are carried out to evaluate the feedback of professional truck drivers in the experiments to reach a more effective design from the driver's point of view. The critical scenarios for autonomous driving are taken into account and designed.

Regarding that, autonomous driving level transition, low arousal level, and minimum risk manoeuvres are visualized to increase engagement of the drivers with the critical situation. Also, with the collaboration of TUD, the HMI become multimodal by integration of auditory cues.

In the first step, FORD and USR questioned the naturalistic expectation of truck drivers, then based on drivers' experiences, needed modification is conducted. For that purpose, four different sets of questionnaires have been prepared. Questionnaire 1 consisted of 20 participants, 100% identified as male. The age of participants ranged between 18 -59 years old, with the majority of the sample under the age of 40 (45%). The preliminary results have shown that the first two choices of the truck drivers regarding the way the information should be provided to make it easy to understand when automated driving is activated are: Visual Signs (70%) and Unique sound chime (60%), which is in line with the targeted f-HMI design.

Interestingly, based on the results, 75% of truck drivers would like warnings (e.g. Low Tire Pressure Warning.) to be shown on the HMI during the takeover process, which is already included. Findings of the questionnaire will be taken into consideration for the alpha version of the f-HMI design in year 3.

A Turning Seat that Indicates the Automated Driving Mode

With the turning seat concept, project partner RWTH Aachen University (IKA) investigates an option with which the driver's role may be facilitated and an accepted AD level transition may be achieved. When driving in conditionally automated driving mode, driver's visual and acoustic modalities may be occupied by non-driving related tasks. The turning seat actively turns the driver away from the driving task in AD mode. The modified seating position during AD is intended to support the driver's Mode Awareness.

In the case of a Takeover Request (TOR), the driver receives a kinesthetic cue by applying a torque around the vertical axis of his seat, turning him back to the driving task. To investigate the turning seat, a pre-parameterization with potential users was conducted. The goal was to define rotation speed parameters to be as fast and as comfortable as possible. Results show, that potential users prefer a rather quick rotation of about 2.5 seconds from automated driving position to manual driving position.

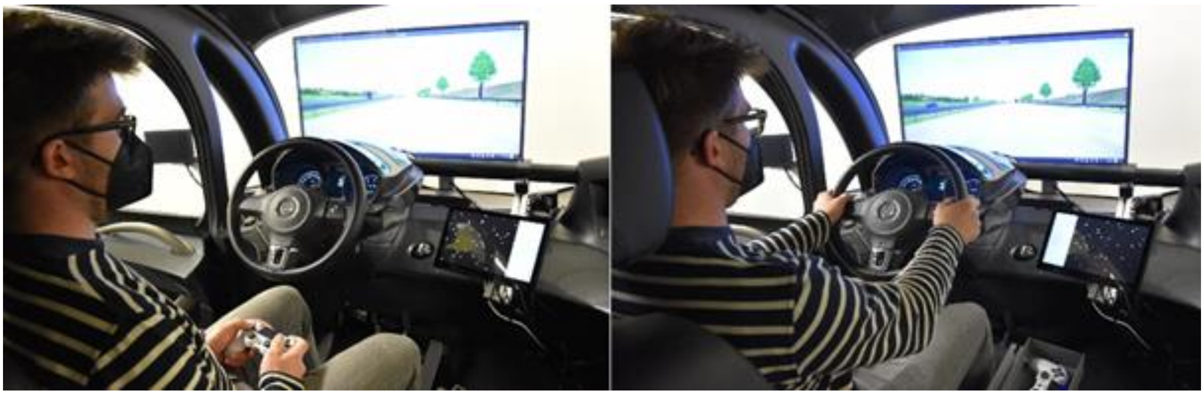


Figure 6: (left) seating position for automated driving; (right) seating position for manual driving

Driver Reengagement Times for ADL 2 and ADL 3

An important consideration for the ability of human drivers to manage automated driving is the amount of time they have available to reengage in the driving task. Therefore, the HADRIAN partner Federal Highway Research Institute (BASt) performed a literature review to approximate how much time drivers need to actively exercise vehicle motion control after having engaged in a secondary task during an active SAE Level 2 phase (so called re-engagement time). Based on 33 mean re-engagement times obtained from 16 publications, a time budget of 5 seconds for re-engagement was found to be sufficient to cover most of the mean re-engagement time values found in the literature.

BASt also performed a Wizard-of-Oz study in a real driving setting with ADL 3 functionality on a test track to measure takeover times from natural non-driving related activities (playing Tetris, reading & typing, watching a documentary film). Half of the participants experienced rides in the dark, the other half at daytime. The study indicates that takeover times both at daytime and in the dark, and after engagement in natural non-driving related activities during SAE Level 3 automated driving were below 15 sec. Therefore, these times are used in the HADRIAN project as threshold for the maximum take-over times from automated driving at Level 2 and 3. The studies are also being described in detail in a forthcoming publication.

What else happened in the project?

The consortium was very active in **disseminating the project** at various events with conference papers, workshops or project presentations as well as a publication:

- ACM CHI Conference on Human Factors in Computing Systems, 8-13 May, 2021, Yokohama, Japan
- Annual INCOSE International Workshop, 29-31 January 2021, virtual
- TRB Human Factors in Road Vehicle Automation ACH30 Subcommittee, 01 June 2021, online
- Connected Automated Driving - EUCAD2021, 20-22 April 2021, online
- 10th International Congress on Transportation Research – ICTR, 1-3 September 2021, Rhodes, Greece
- American Human Factors and Ergonomics Conference (AHFE), 25-29 July 2021, New York; USA
- CAR.HMI Europe, 28-29 June 2021, Berlin, Germany
- 13th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, 09-14 September 2021, online
- NEXT ITS Workshop, 01 December 2021, online
- 28th FuSaComm Workshop: Safety Concepts, SOTIF and Standardization, 31 January 2022, online
- IEEE 30th International Electrotechnical and Computer Science Conference (ERK 2021), 20-21 September, Portorož, Slovenia
- Effects of User Interfaces on Take-Over Performance: A Review of the Empirical Evidence in MDPI, 2021

HADRIAN PROJECT INFORMATION

More information on HADRIAN is available on our website: https://hadrianproject.eu/

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