ART-04-2016 - Safety and end-user acceptance aspects of road automation in the transition period

H2020-ART-2016-2017

Improved Trustworthiness and Weather-Independence of Conditionally Automated Vehicles in Mixed Traffic Scenarios

Deliverable D4.4

Validation and Evaluation of HMI Concept

This report is part of a project that has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement No 723324.

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Content

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Executive Summary

Human Machine Interface is one of the most critical parts of L3 autonomous driving. The successful operation between driver and autonomous vehicle is supported by this interface. Main topics for a successful HMI can be summarized as follows:

- Provide required data for understanding autonomous drive capabilities.
- Warn driver in appropriate level.
- Minimize surprises
- Accomplish comfort and relaxed driving

This deliverable consists of validation and evaluation of the HMI concept within the use cases. The results of the evaluation will be shown in detail. Additionally, Time-of-Flight based driver monitoring is technically evaluated.

Evaluation of the HMI prototype was done by interviewing professional drivers and receiving their feedback related to the HMI prototype. Participants filled in questionnaire forms after seeing a slideshow and the HMI prototype along with its functionalities from a tablet computer. Questions in the questionnaire were compiled in order to collect data for selected KPIs. The KPIs were set in WP2.

Key Words

Level 3 Automated Driving, HMI, User Acceptance, Questionnaire, Validation, Evaluation, Data pool

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1 Introduction

TrustVehicle project aims at developing trustable and robust controllers for automated driving along with adaptive Human-Machine Interfaces (HMI), which can safely operate in complex and real-world traffic situations. The designed systems will be later experimentally assessed on the consortium vehicle platforms. One of the objectives of the TrustVehicle project is to develop and demonstrate intuitive Human-Machine Interfaces for the safe management of the transition phases between automated driving and manual driving. Work Package 4 (WP4) is focusing on the HMI development for Level 3 Automated driving (L3AD).

One critical aspect for Automated Driving development especially in L3AD is represented by the required Human Machine Interfaces for the safe transition phase between automated and manual driving especially in the situations not manageable by the automated driving systems (system-initiated hand over situations).

TrustVehicle project has adopted a user-centric approach in developing solutions that will increase reliability and trustworthiness of L3AD vehicles including the HMIs. The first task in WP4 has been the development of the general HMI concept and the generation of the requirements for it. The main features of HMI for OEM demonstrations are harmonised to create bases for the TrustVehicle generic HMI concept. The final HMI in the automotive industry is a strongly competitive factor and always an OEM specific solution. Therefore, the generic HMI concept developed in WP4 will be modular and high-level concept, which allows OEM specific HMI designs and implementations later in the project.

1.1 Structure of the report

This report is the deliverable D4.4 from the WP4. D4.4 describes validation and evaluation of the HMI concept that has been developed in earlier phases of the WP4. It includes HMI concept evaluation with real professional drivers and considers their opinions about possible safety impacts and both advantages and disadvantages related to vehicle operation. Also, technical verification of the HMI prototypes is included in the report.

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2 Evaluation of HMI concept

Evaluation of the TrustVehicle HMI concept was done with the Linkker and Ford Otosan HMI prototypes, which were the bus and truck implementations based on the general HMI concept. The HMI prototype was running on a tablet computer, which enabled HMI prototype presentation and evaluation with the several drivers easily. Although, evaluation of fully vehicle integrated system would have provided more valuable information. However, HMI prototype evaluation on a tablet computer before finalising it and integration to the vehicles enables the implementation of possible changes if the feedback from the drivers would require it.

2.1 Evaluated HMI prototypes

2.1.1 Linkker HMI prototype

Evaluation of the Linkker HMI prototype was held for the potential users (the bus drivers) in a classroom setting in Tampere, Finland. The Linkker use case (Automated Driving to the charging station) and the HMI prototype was introduced to the bus drivers in the following way:

- Linkker use case was presented as a slide show, covering
    - goal of the system in development (see TrustVehicle D2.4 Linkker Automatic Charging scenario description)
    - description of the target area (see Figure 1)
    - driver HMI
    - interaction with the system (switching Automated Driving ON/OFF)
    - basic elements of the system
- Linkker driver HMI prototype introduction with a fully functioning mock-up demonstration with graphics, animations, and audio and speech warnings running on a tablet computer. The introduction included
    - HMI functionalities in normal operation (see Figure 2)
    - Event report and driver feedback example
    - Possible warnings in different levels in Manual and Automated driving modes (see Figure 3)

The Linkker use case and HMI introduction took roughly about 20 minutes.

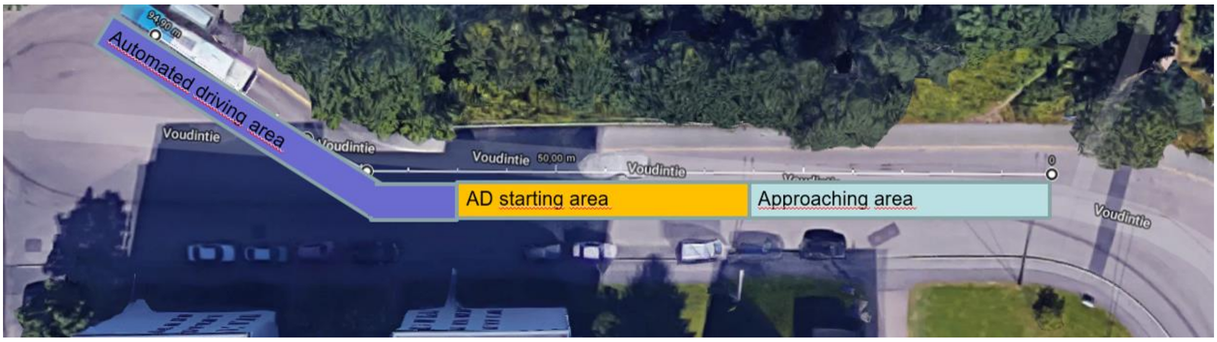

Figure 1. Linkker automated driving target area (map data: Google Earth).

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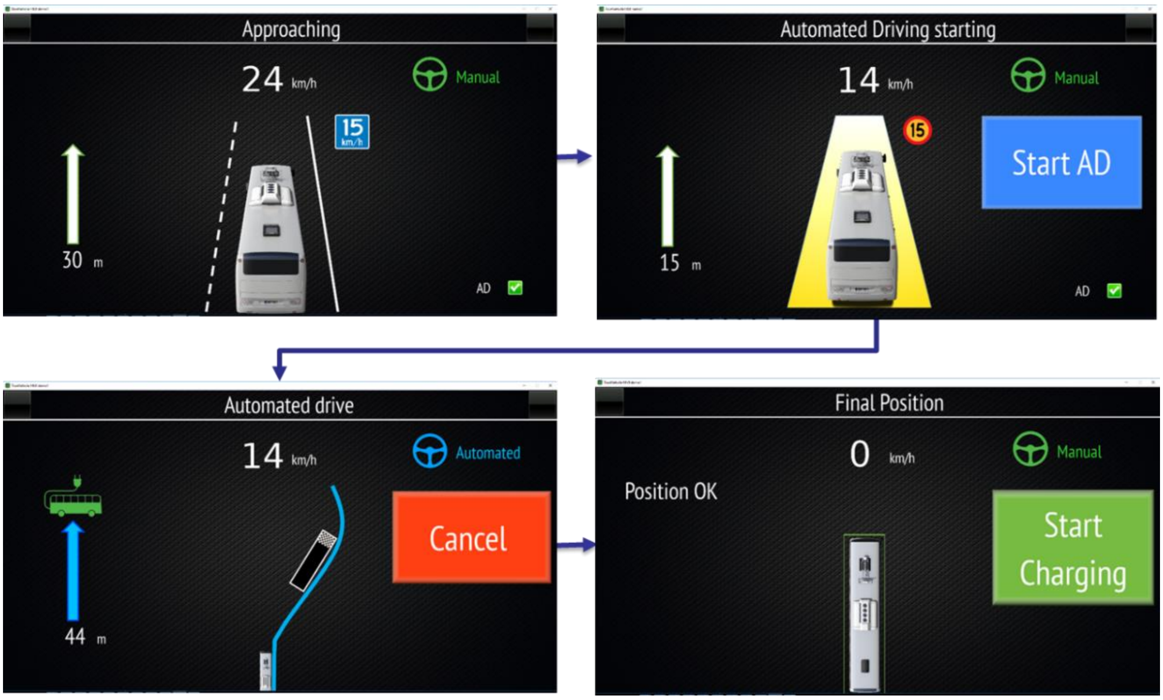

Figure 2. Linkker prototype HMI: approaching, starting AD, AD and final position.

Figure 3. Examples of warnings.

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2.1.2 Ford Otosan HMI prototype

Ford Otosan HMI prototype was evaluated by the test truck drivers of the Ford Otosan R&D Department, in Ford Eskisehir test track, in Turkey. Ford Otosan use case is the Automated reverse back parking of a truck and trailer combination and the HMI prototype was introduced to the truck drivers in following way:

- Ford Otosan use case was presented from WP2 documents, PowerPoint slides and on the test field itself.
- System capabilities, current status of the project and the expected performance levels were explained.
- R&D test drivers were familiar with Ford Otosan's platooning development project. The TrustVehicle Ford Otosan HMI was phrased as "Similar to platooning" tablet application, there will be a similar application for reverse back-parking."

HMI prototype introduction was made with a presentation, demonstrating the idea, screen layouts, animations and such. For evaluation, the HMI presentation included:

- Sunny day scenario, without any problems, HMI states changes as following:
    - Approach
    - Transition
    - AD Parking
    - Parking Complete Screen
- Warning Screens for any system error, events out of scenarios or driver mistakes.

During introduction, since prototype displays screens and animations in current state, buttons, switches and other tablet screen interactions were explained verbally.

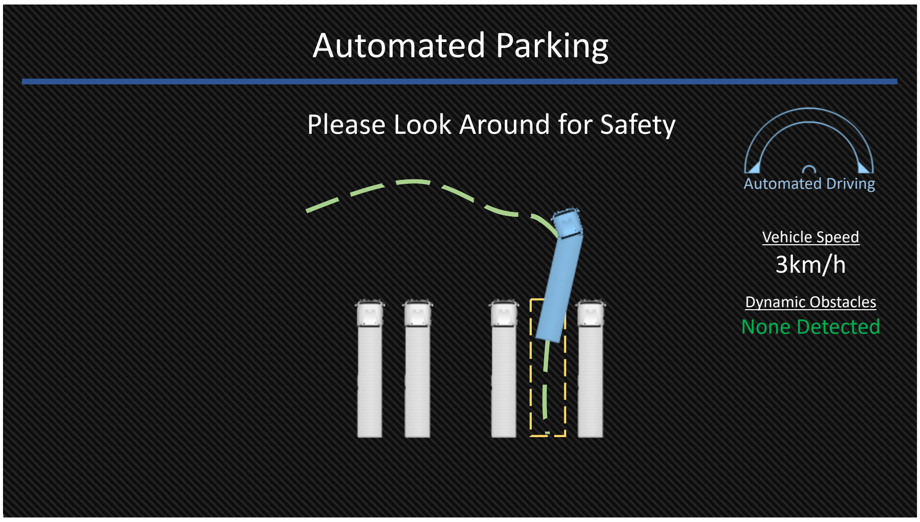

Figure 4. Example Screen from FO HMI Screen with normal AD parking scenario

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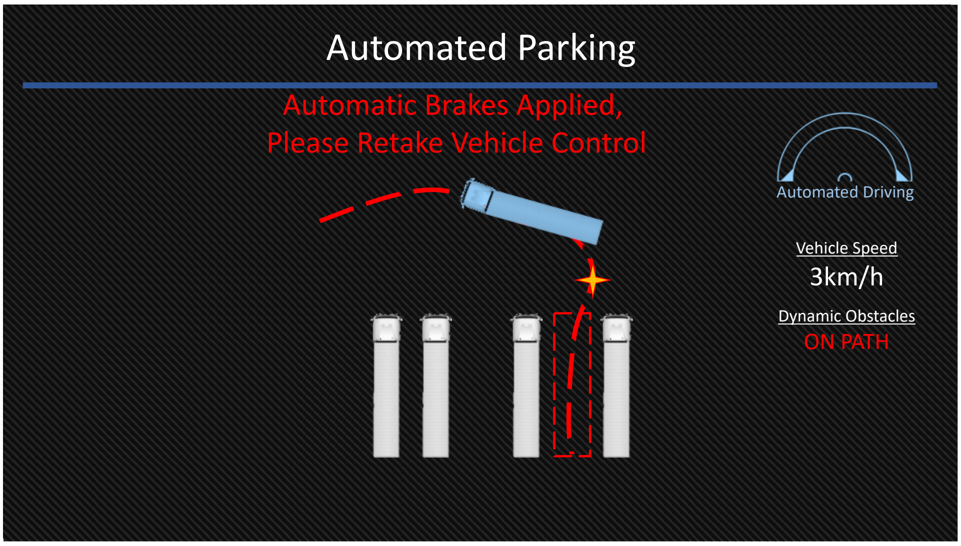

Figure 5. A L3AD Warning for Retake

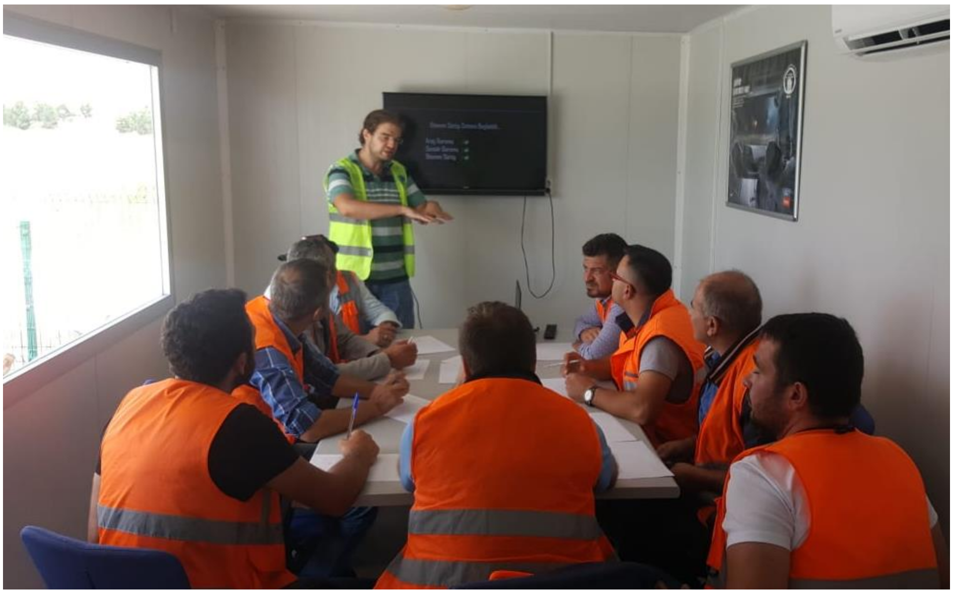

Figure 6. During HMI survey, FO test drivers were introduced with the L3AD trailer parking

2.2 Evaluation method

2.2.1 HMI prototype evaluation

Before demonstrating the HMI prototype to the potential users (the professional drivers), the participants were informed about the study according to the TrustVehicle informed consent procedure (defined in TrustVehicle D8.2). Information about the study was be given orally and afterwards the participants received the information sheet (see Annex 2) where all the consent procedure information

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were written and explained. The data was collected anonymously (no personal or sensitive data). Participants was made aware that participation was fully voluntary and that the respondents were free to withdraw at any time or to refuse to answer any question, without penalty or loss of benefits. Participant had enough time to ask question if something was not clear.

Then the HMI prototype was presented to the drivers. After the presentation the participants were informed that by filling the questionnaire and returning it, they give their consent to participate in the study. The information sheet about the study was left to the participants and it included an explanation of whom to contact for answers to pertinent question about the research and research subject's rights.

The HMI evaluation was done after demonstrating the HMI prototype to the potential users (the bus / truck drivers). The participants filled in a questionnaire form including background questions of their age (group) and gender. In addition, several statements concerning the HMI were stated for them, with the 7-point likert-scale for rating (-3 = totally disagree,…, 3 = totally agree). Moreover, the participants were given an opportunity to give free text feedback on the demonstrated system and the HMI prototype. The questionnaire form can be found in Annex 1.

The questions were designed to collect data for the selected KPIs (from WP2 where KPIs were listed).

- The demonstrated user interface is easy to use (KPI: Ease of use)
- It is easy to understand what the user interface is showing in different phases (KPI: Comprehensibility of user interface)
- It is easy to understand when automated driving can be activated (KPI: Ease of use and KPI: Comprehensibility of user interface)
- It is easy to understand why the automated driving is not available (KPI: Ease of use and KPI: Comprehensibility of user interface)
- It is easy to understand when I need to take back the control of the vehicle (KPI: Take over request understanding)
- It is easy to understand what I need to do to take over the control of the vehicle (KPI: Take over request understanding)
- I accept the system to monitor me as a driver, and adjust the user interface accordingly (KPI: User satisfaction)

2.2.2 Traffic safety impact evaluation

The original work plan included the new HMI solution evaluation of impacts for traffic safety. However, as the HMI was not yet integrated to the vehicle but running on a tablet computer, it was decided to post-pone this evaluation work. The traffic safety impact evaluation can provide more realistic results when it is done with HMI integrated to the test vehicles, and the end users (drivers) can get more realistic view of the HMI in action. Therefore, the traffic safety impact evaluation will be done in WP6 during the final user acceptance tests in the end of the project. The results of this evaluation will be included in the WP6 deliverable D6.7 User Acceptance Test Results.

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2.3 Results

2.3.1 Linkker HMI prototype

Participants

In total 16 professional bus drivers participated the demonstration and filled in the questionnaire form in August 2019 in Finland. Two drivers (13%) were female, and the rest 14 male. The age of the drivers varied a lot, and the largest age groups were 60 - 69 years old and 30 - 39 years old bus drivers (Figure 7). Large variation of the different age groups represented the target population of the bus drivers very well.

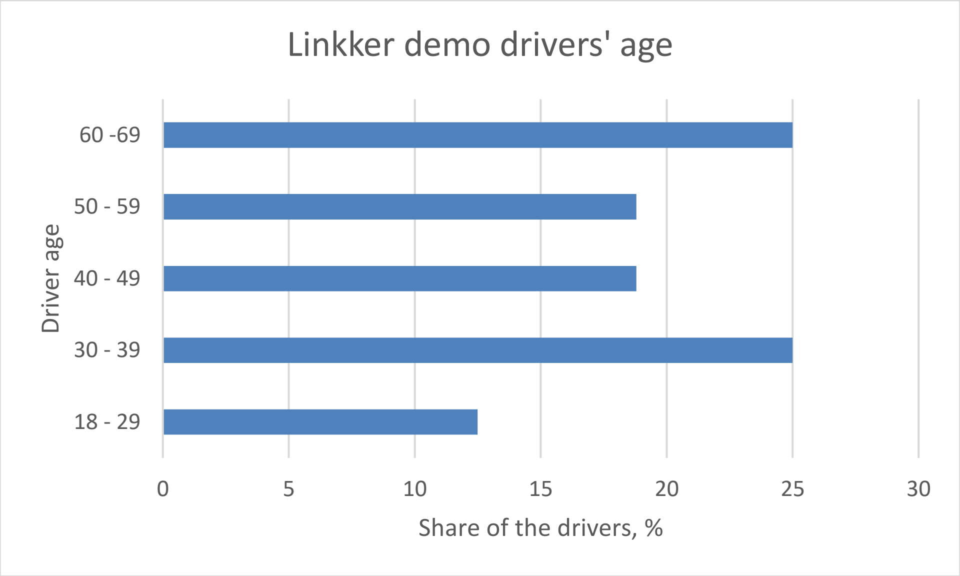

Figure 7. Age range of the Linkker HMI evaluation 16 participants

HMI statement

The drivers were presented a set of statements, which they needed to agree or disagree with, based on the HMI prototype introduction.

The full list of statements in Linkker-case was the following (the same statements were used also for Ford Otosan case):

- The demonstrated user interface is easy to use
- It is easy to understand what the user interface is showing in different phases
- It is easy to understand when automated driving can be activated
- It is easy to understand why the automated driving is not be available
- It is easy to understand when I need to take back the control of the vehicle
- It is easy to understand what I need to do to take over the control of the vehicle
- I accept the system to monitor me as a driver, and adjust the user interface accordingly

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- Additional spoken information and warnings are useful
- Additional event information provided after the drive is useful
- I'm willing to comment on the system performance and events after the drive

Overall, the professional bus drivers were quite positive on the HMI prototype and the system under development. They agreed most with the statement "It is easy to understand when I need to take back the control of the vehicle". The least agreed statement concerned additional spoken information provided with the Linkker HMI demo. It was actually the only statement scoring less than +1 on average in scale -3 = totally disagree…, +3 = totally agree (Figure 8).

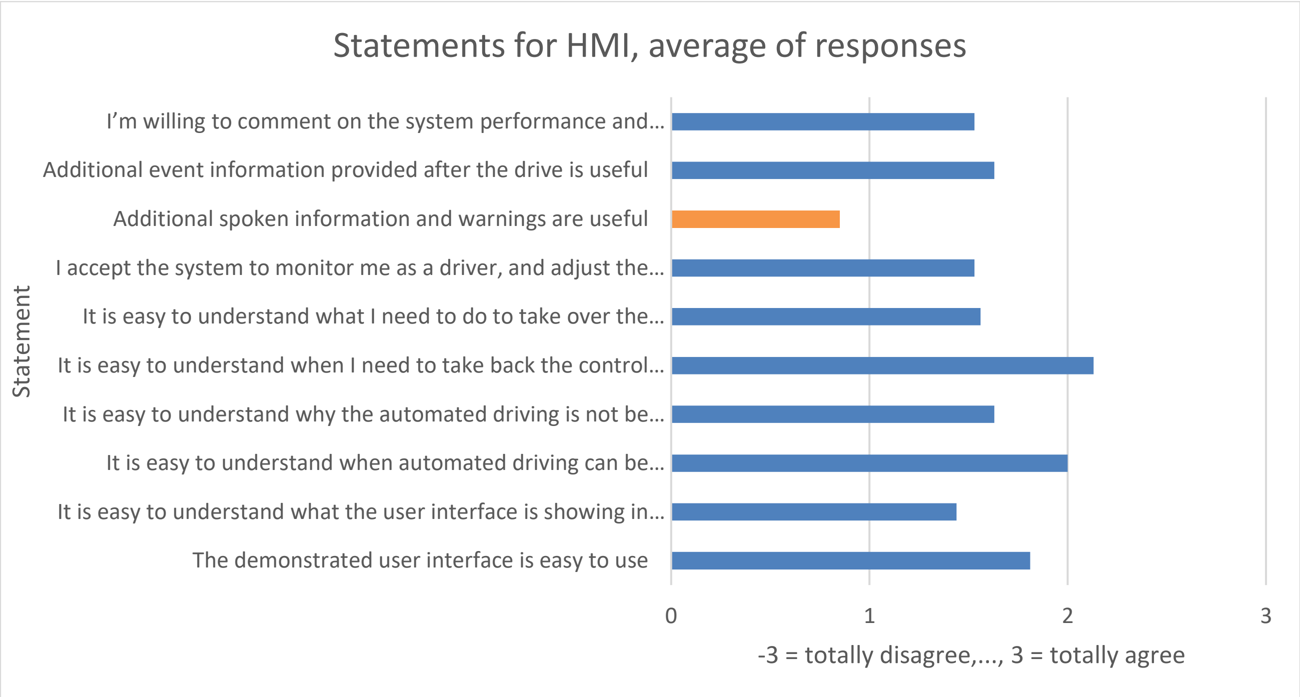

Figure 8. Agreement of the statements concerning Linkker HMI

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The share of drivers agreeing (at least 1 in scale -3… +3) are shown in Figure 9. The additional spoken information had least positive responses, but still 50 % of the bus drivers agreed with that statement, too. This feature seems to divide bus drivers with opposite opinions.

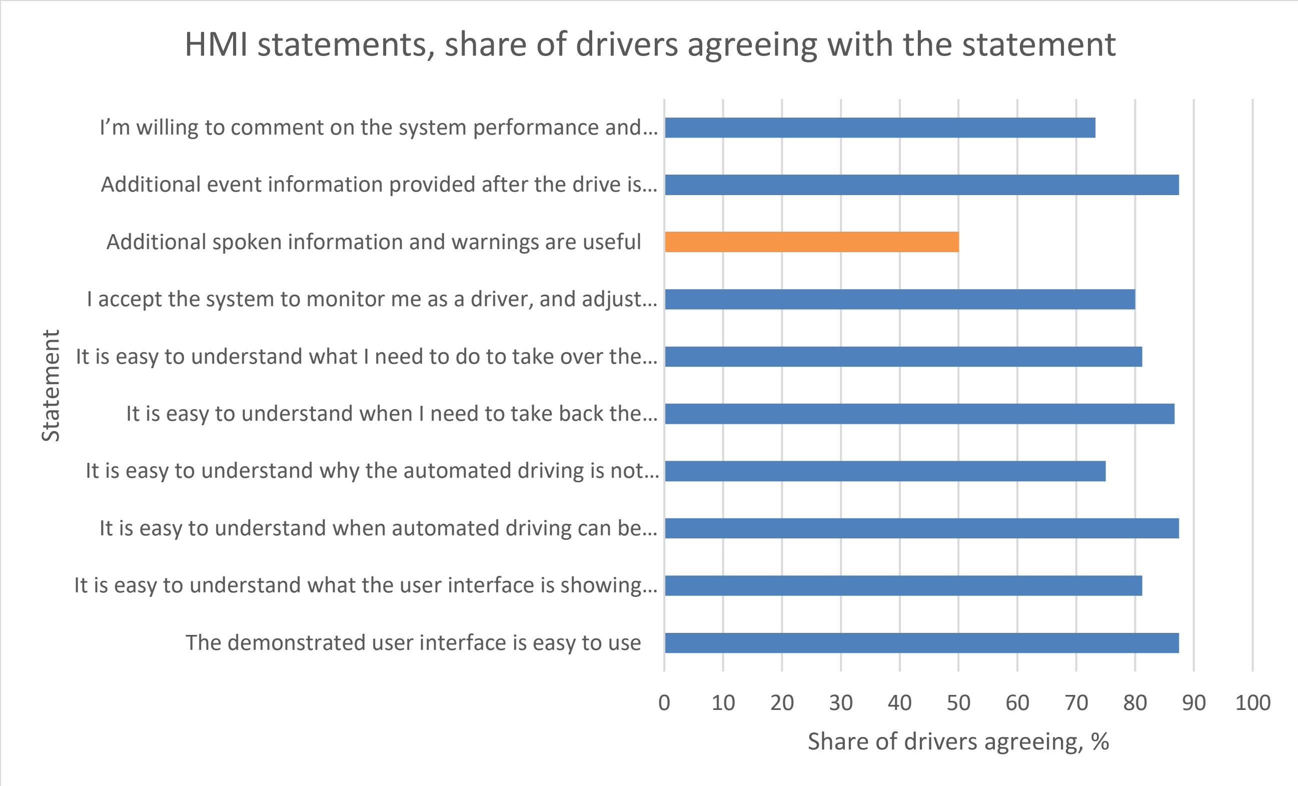

Figure 9. Agreement of the statements concerning Linkker HMI. Share of drivers agreeing (in some extend) with the statement

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Benefits of demonstrated system/HMI

The drivers were slightly less positive on the potential benefits of demonstrated AD HMI. Overall, 2/3 of drivers agreed with the statements, and there were no big differences between the estimated benefits. Safety benefits were rated a bit higher than benefits in making driving easier or reducing stress (Figure 10). The stress factors could be related to concerns, which were stated in the free comments, about system functionality in adverse conditions or possible additional time that automated driving may require.

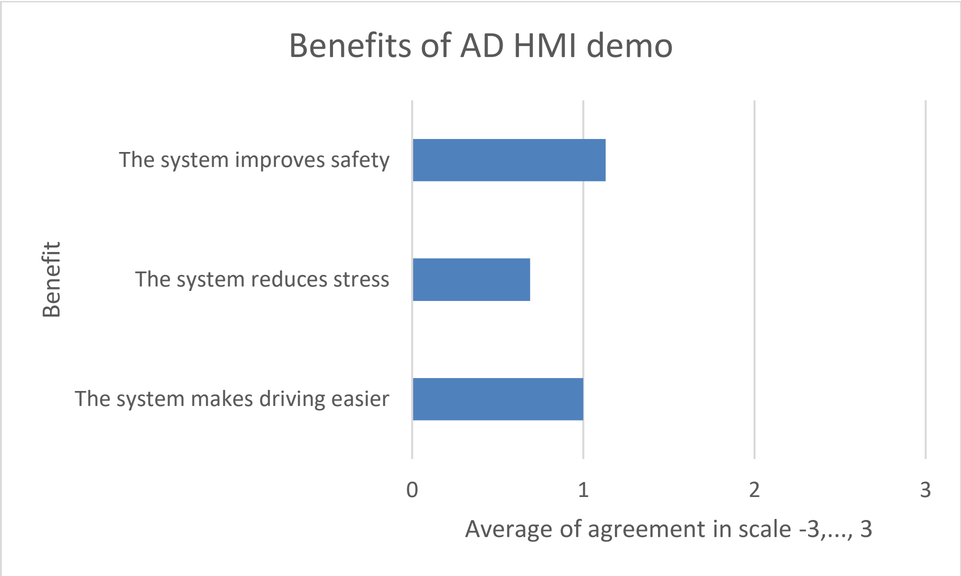

Figure 10. Agreement (average) of the statements concerning the benefits of Linkker HMI.

In the free comments concerning the system, the Linkker drivers were raising a few concerns or comments. In the actual HMI the following were raised:

- Prioritisation of audio warnings is very important. Audio only if something is critical.
- Variety of language versions are needed.
- System needs to be reliable. In addition to the touch screen, physical controls are preferred.

Moreover, the following comments concerned the overall functionality in various situations:

- It is possible that the passengers are running very close to the bus when in rush catching the bus. The system needs to recognize them.
- Concerned about the functionality in adverse Nordic conditions.
- Good that it is possible to send the error report immediately.

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In additional overall comments the following were raised:

- A few concerns about the need for the system or automated driving overall, but also the similar number of positive comments of the potential benefits.
- A slight concern of the additional time needed on the stop due to the system.
- In addition to the few concerns, also many positive comments on the demonstration were given.

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2.3.2 Ford Otosan HMI prototype

Participants

In total 10 professional drivers participated the Ford demo HMI evaluation. Ten of them returned the filled in questionnaire form in August 2019 in Turkey. All drivers were male. Age of the drivers varied much less than in the Linkker study. Eight drivers were 30 - 39 years old, and two 40 - 49 years old, share of these age groups are presented in Figure 11.

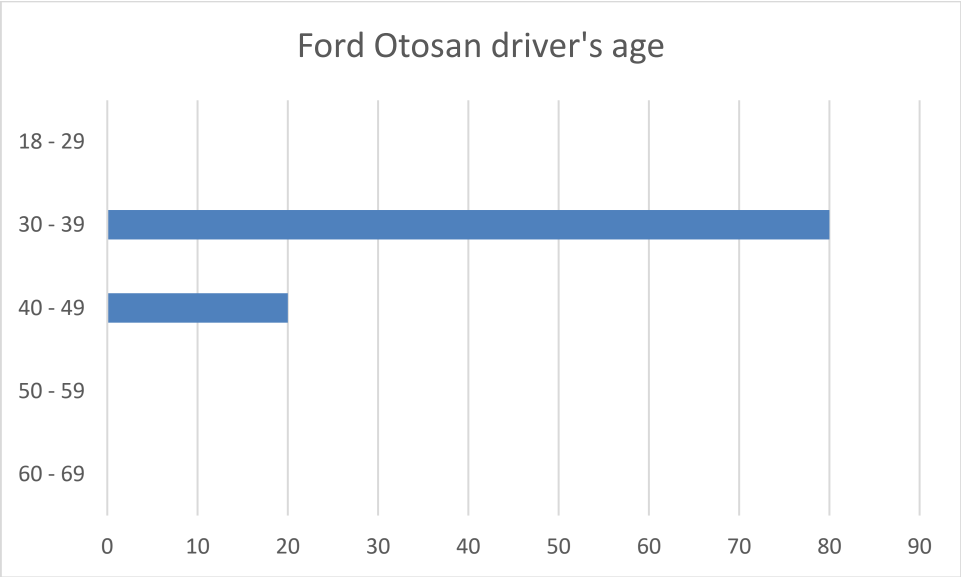

Figure 11. Age of the Ford Otosan HMI evaluation participants.

Statements of HMI

Overall, almost all the drivers in Ford case agreed with high degree with the HMI statements. The share of agreed drivers varied only between 90% and 100%. The average agreement was also very high (Figure 12). The statements were identical with the Linkker case, with one exception. The "additional spoken information" statement was replaced with "Additional chimes similar to cluster or radio warnings are useful" because Ford HMI prototype did not use any spoken output.

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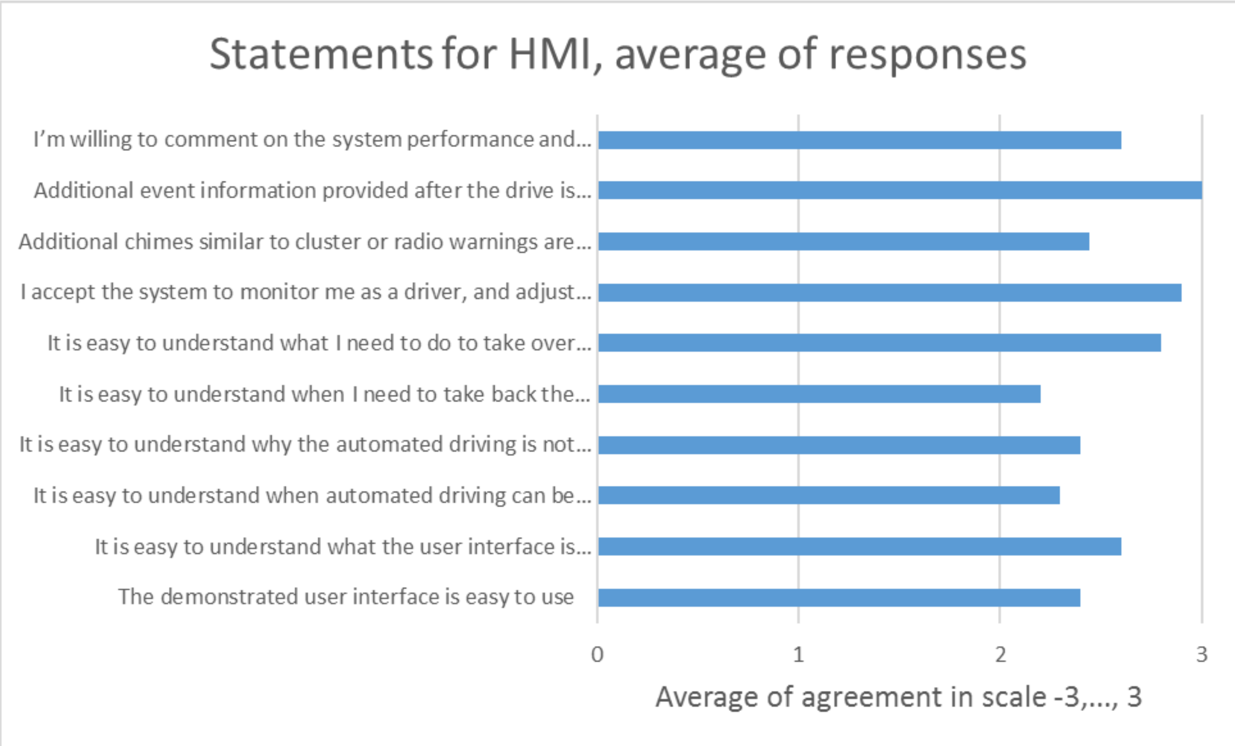

Figure 12. Agreement of the statements concerning Ford HMI. Averages of the responses in scale -3…+3

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Benefits of demonstrated system/HMI

The benefit statements got very high agreement, too. Overall, almost all the drivers (90% +) agreed with all the statements concerning the potential benefits of demonstrated AD HMI. Similar to Linkker demo, also the Ford drivers rated safety benefits highest. The difference between the stated benefits was, however, very small, and the average agreement was above 2 for all the stated benefits (in scale -3…+3). (Figure 13).

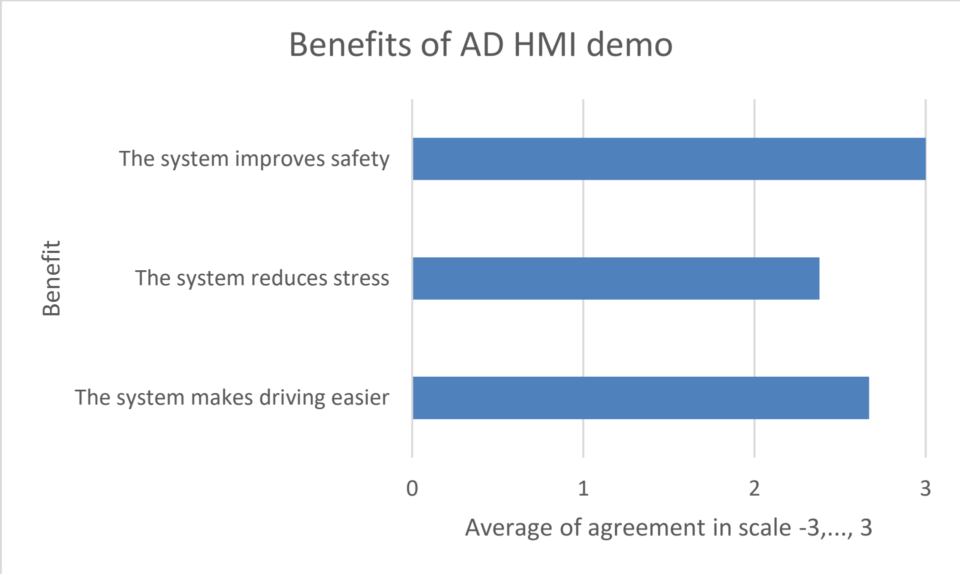

Figure 13. Agreement (average) of the statements concerning the benefits of Ford HMI

In the additional comments concerning the HMI, the drivers wished for different colours for the HMI, hoping especially the available vs. not-available parking slots to be better visible. In addition, a few text notifications, e.g. “Moving object detected” was proposed to be removed. Brake pedal (in the HMI) was wished to be animated, and an indicator for the finished automated driving was wished to be added. In addition, one driver commented that if the system stops or crashes - it should be resumed in the state: stopped.

The additional overall comments concerning the AD were similar to the rating the drivers gave earlier, overall very positive. The drivers commented that the system reduces stress and makes their job easier.

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2.4 Conclusions from HMI evaluation

From HMI prototype evaluations with bus and truck drivers the following conclusions can be drawn:

- Overall feedback to the HMI prototypes was very positive in both cases (as presented in the Figures above).
  - The answers from the female bus driver were slightly more negative compared to answers from men. However, there were only two women in the study and therefore we cannot make any general conclusions from the data for gender differences.
- The main principles of the HMI concept (such as simplified HMI, driver monitoring, driver supervising AD, driver giving feedback after the AD drive) was evaluated also very positively. Overall, the TrustVehicle HMI concept was very well received by the drivers.
- The feedback from the drivers indicated only minor needs to modify the HMI prototypes. The following feedback can be used to finalise the HMI:
  - For Linkker HMI prototype:
    - Spoken information, which had least positive responses, could be modified in the HMI. For example, the spoken information (in addition to audio warnings) could be implemented as an optional feature, which driver could select to use, if she/he wants.
    - Language versions for HMI could be considered.
    - Physical buttons are needed, but this is already planned for final HMI implementation in the bus: flaps behind the steering wheel are used to activate automated driving and steering wheel turning or use of brake pedal cancels the automated drive.
  - For Ford Otosan HMI prototype:
    - The colours in the Ford prototype were given some critique and some specific requests were made for HMI graphics.

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3 Technical verification of the HMI prototypes

Technical verification of the HMI prototypes was done before HMI integration to the vehicles. Therefore, verification was limited to the prototype implementation software testing.

3.1 Linkker HMI prototype testing

HMI prototype technical verification for the Linkker was done by VTT. As the HMI was not integrated to the vehicle, the technical verification could be done only to the SW interface between the driver HMI module and HMI & Mode Transition Manager module (application), see the TrustVehicle HMI concept in Figure 14.

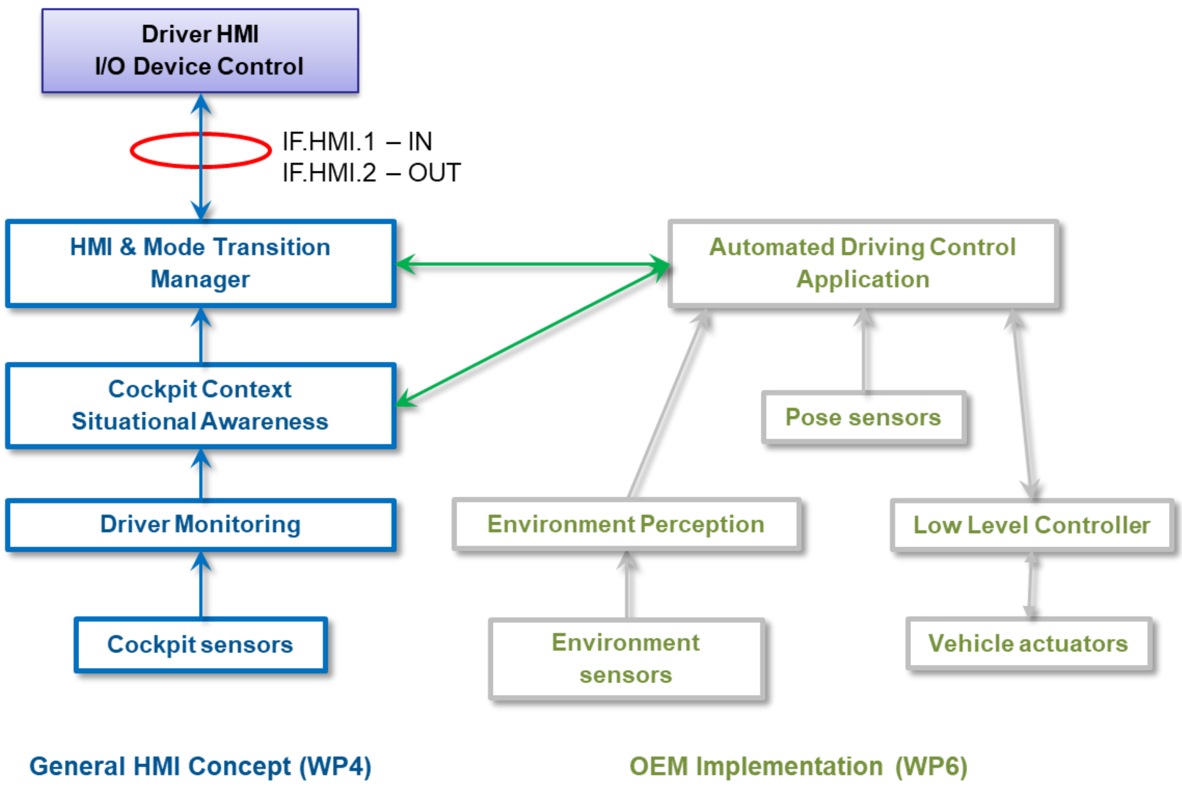

Figure 14. HMI concept high-level architecture.

The Driver (and passenger) HMI prototype was implemented with EB GUIDE tool for the HMI user evaluation with the bus drivers. The software interface between EB GUIDE Graphics Target Framework (GTF)and third-party applications was defined during the prototype implementation. The application and the HMI were decoupled and run independently of one another. The 3rd party applications communicate with HMI prototype via: [1]

- Datapool – Which stores data written by the application and used by the HMI.
- Event system – Which allows the application and the HMI to communicate asynchronously.

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The technical verification testing of the driver HMI module prototype implementation was done with EB GUIDE Monitor. EB GUIDE Monitor allowed developer to observe and control the EB GUIDE model during simulation. It included the toolset needed for communication with the datapool, event system, and state machine of the EB GUIDE model. EB GUIDE Monitor is a stand-alone application to EB GUIDE. [1]

The functionality of HMI prototype implementation and the interface between the driver HMI module and HMI & Mode Transition Manager module (application) was tested (technical verification) with EB GUIDE Monitor application. EB GUIDE Monitor was connected to the simulation of the HMI prototype implementation running on the PC. Monitor application was used to read and write datapool values and send events with parameters. The correct functionality of HMI prototype implementation was visually verified, and the different state machines and their states are also checked from the Monitor application. Testing (technical verification) was done to the driver HMI interface (see Table 1).

Table 1. Linkker driver HMI interfaces.

Interface	Description	Technology	Direction
IF.HMI.1	Interface enables vehicle Mode Transition Manager utilize Driver HMI and send output information to Driver HMI	EB-Guide datapool & events	IN
IF.HMI.2	Interface enables Driver HMI to send user interaction to Mode Transition Manager	EB-Guide datapool & events	OUT

3.1.1 Technical evaluation results

Technical functionality testing of the Linkker HMI prototype included testing of the events related to view state changes, events inside a view states, and changes in data pool values in all relevant view states. The prototype implementation of the HMI did not include all data and events, which were not needed for HMI prototype evaluation with the drivers. However, all data and events which are needed for HMI main functionality and logical implementation testing have been implemented and tested.

All implemented data pool items and events were successfully verified in the testing. The technical verification provided consistent and tested solution for final HMI implementation in real target software environment. The results of this testing will be provided as a separate (confidential) Annex.

3.2 Ford Otosan HMI testing

Sequence diagram of the HMI screens were created. Necessary transforms from vehicle and sensor outputs to the user interface was defined. Each class or method is currently under testing with primitive data.

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The connection between HMI tablet and vehicle systems will be based on User Datagram Protocol (UDP)communication.

Selected vehicle states (brake pedal input, throttle input, gear selector position, heading difference between trailer and truck) vehicle position (high accuracy GPS position), environmental information (sensor fusion outputs) and controller algorithm outputs (planned path for the reverse parking manoeuvre) currently under testing on Android studio’s emulator.

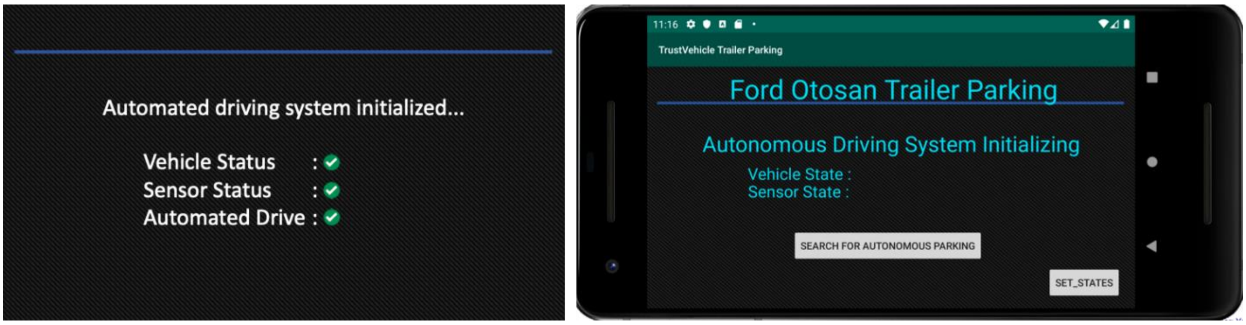

Figure 15. HMI Graphical Prototype (Left) HMI Emulated Prototype (Right)

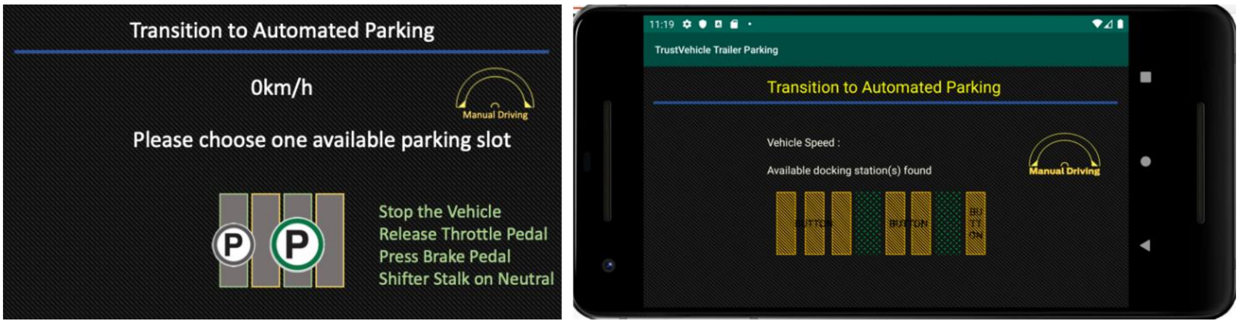

Figure 16. Current emulated prototype has basic styling

3.3 Tofas Use Case

Human Machine Interface is one of the most critical part of L3 autonomous driving, successful operation between driver and autonomous car is done by using this interface. Main topics for a succesfull HMI can be summarize as follows:

- Provide required data for understanding autonomous drive capabilities.
- Warn driver in appropriate level.
- Minimize surprises.
- Accomplish comfort and relaxed driving

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Most of serial application for HMI designs use green, yellow, blue steering wheel colours in order to inform driver when system detects lines, lane edges and road signs. Some of the OEMs use white and grey when autonomous system detects road edges/ lave markings properly. But different type of applications are also available.

In this deliverable, Tofas analysed homologation requirements for L3AD features. For this purpose, several European regulations was investigated, and OEM applications are examined. Due to this examination, there were no significant regulations found as of today for L3 AD and the OEMs are applying various type of solutions on the HMI. On the other hand, there are homologative requirements up to Level 2 on HMI regulations, which can also lead future requirements. There are mainly the requirements about audible and visible signals and shapes expressing the information or warning conditionals in general.

Due to the analysis on the current ADAS UNECE regulations, several requirements are existing. As L3 AD features consist of higher-level integration on base ADAS features, they are likely to be requested in the future as part of the L3 AD HMI.

Below, there are some examples from L1 and L2 ADAS regulations:

a. Intelligent Speed Assistance (Informal document GRSP-65-16 (65th GRSP, 13-17 May 2019 agenda item 28(a))) [[4]

It should be possible to switch off the intelligent speed assistance, for instance, when a driver experiences false warnings or inappropriate feedback as a result of inclement weather conditions, temporary conflicting road markings in construction zones and misleading, defective or missing road signs. Such switch off feature should be under the control of the driver, last as long as necessary and have the option of being easily switched on by the driver. When the system is switched off, information about the speed limit may be provided. The system should be always active when switching the ignition on and the driver should always be made aware whether the system is on or off. It shall be possible to switch off the system. Information about the speed limit may still be provided, and the intelligent speed assistance system shall be in normal operation mode upon each activation of the vehicle master control switch.

b. Emergency Lane Keeping System UNECE REG.79 (7 Nov 2018) [5]

Every Corrective Steering Function (CSF) intervention shall immediately be indicated to the driver by an optical warning signal which is displayed for at least 1 s or as long as the intervention exists, whichever is longer.

Unless otherwise specified, the optical signals identified in paragraph 5.6.4.5. shall be easily distinguishable from each other (e.g. different symbol, colour, blinking, text).

In the case of an intervention longer than: (a) 10 s for vehicles of category M1 and N1, or (b) 30 s for vehicles of category M2, M3 and N2, N3, an acoustic warning signal shall be provided until the end of the intervention.

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Optical warning signals shall be visible, even by daylight and distinguishable from other alerts; the satisfactory condition of the signals shall be easily verifiable by the driver from the driver's seat; the failure of a component of the warning devices shall not entail any loss of the steering system's performance.
Acoustic warning signals shall be by continuous or intermittent sound signal or by vocal information. Where vocal information is employed, the manufacturer shall ensure that the alert uses the language(s) of the market into which the vehicle is sold. Acoustic warning signals shall be easily recognized by the driver.

Where applicable, a yellow warning signal indicating an electrically detected defect within the steering equipment, which is not indicated by the red warning signal.
Whenever the system becomes operational, this shall be indicated to the driver. Any termination of control shall produce a short but distinctive driver warning by an optical warning signal and either an acoustic warning signal or by imposing a haptic warning signal (except for the signal on the steering control in parking manoeuvring). For RCP, the requirements for driver warning shown above shall be fulfilled by the provision of an optical warning signal at least at the remote-control device.
A system failure shall be signalled to the driver by an optical warning signal. However, when the system is manually deactivated by the driver, the indication of the failure may be suppressed.

Figure 17 Steering control

If, after a period of no longer than 15 seconds the driver is not holding the steering control, an optical warning signal shall be provided. This signal may be the same as the signal specified below in this paragraph. The optical warning signal shall indicate to the driver to place their hands on the steering control. It shall consist of pictorial information showing hands and the steering control and may be accompanied by additional explanatory text or warning symbols - see examples below:

If, after a period of no longer than 30 seconds the driver is not holding the steering control, at least the hands or steering control in the pictorial information provided as optical warning signal shall be shown in red and an acoustic warning signal shall be provided. The warning signals shall be active until the driver is holding the steering control, or until the system is deactivated, either manually or automatically. The system shall be automatically deactivated at the latest 30 seconds after the acoustic warning signal has started. After deactivation, the system shall clearly inform the driver about the

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system status by an acoustic emergency signal which is different from the previous acoustic warning signal, for at least five seconds or until the driver holds the steering control again.

c. Lane Departure Warning System (LDWS).UNECE REG.130) [6]

The lane departure warning shall be noticeable by the driver and be provided by: (1) at least two warning means out of optical, acoustic and haptic; or (2) one warning means out of haptic and acoustic, with spatial indication about the direction of unintended drift of the vehicle.

The optical warning signals shall be visible even by daylight; the satisfactory condition of the signals must be easily verifiable by the driver from the driver's seat.

When the driver is provided with an optical warning signal to indicate that the LDWS is temporarily not available, for example due to inclement weather conditions, the signal shall be constant.

d. Advanced Emergency Breaking System [7]

A collision warning when the AEBS has detected the possibility of a collision with a preceding vehicle of category M, N or O in the same lane which is travelling at a slower speed, has slowed to a halt or is stationary having not being identified as moving.

A constant optical warning signal shall inform the driver that the AEBS function has been deactivated. The yellow warning signal specified in below may be used for this purpose.

The optical warning signals shall be visible even by daylight; the satisfactory condition of the signals must be easily verifiable by the driver from the driver's seat.

For Tofas use case scenarios such as narrow street passing and backward autonomous parking, the following specific HMI requirements can be considered:

- More informative about the objects surrounding the vehicle
- Audible and visible warning during a potential crash detection
- Current driving mode representation and handover requests visibility
- Empty parking slot availability (it can be more advanced with best parking place recommend ations)
- Trajectory representation of the vehicle movement
- Informative about upcoming steering or braking commands
- Images from sorrunding of the vehicle (in case of surround view availability)

Tofas has not performed any HMI design in WP4. The demonstration vehicle will be used only for real traffic data collection and sensor fusion. Since it has been no vehicle control expected, the interface can be based on the point cloud and object detections on the camera images.

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3.4 IFAT: Technical Evaluation of the Time-of-Flight based Driver Monitoring Functionality

The Time-of-Flight (ToF) based Driver Monitoring Unit (DMU) will offer the functionality to record, detect and identify the driver. Applications of the driver identification include, driver base customization, support and security. Figure 1 shows the prototype of the ToF camera based DMU demonstrator. For the technical evaluation of the DMU demonstrator functionality, we tested the driver detection and identification functionality in a laboratory set-up. No structured vehicle interior tests

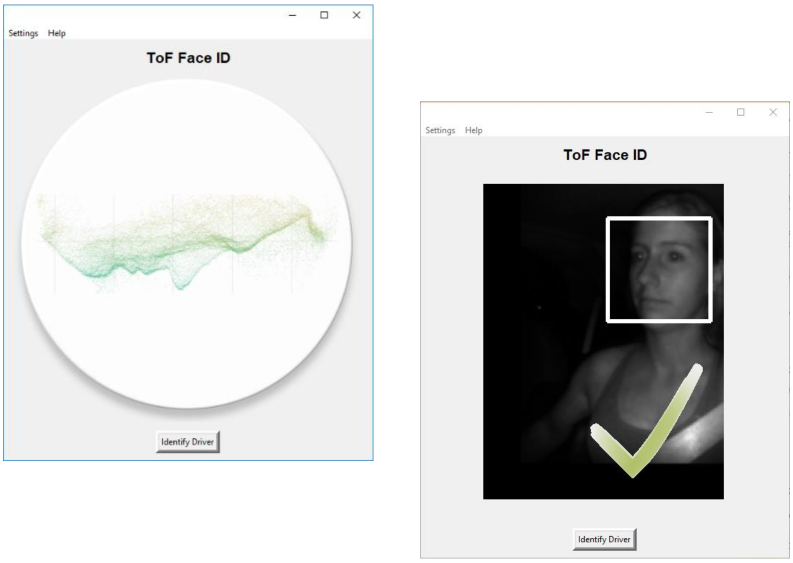

Figure 18. HMI prototype of the DMU demonstrator. Left the initial view of the HMI. Right the HMI with activated ToF camera and identified driver.

have been performed in this technical evaluation.

The basic driver detection and identification functionality operates in several steps. First, we identify a face in the field of view (FoV) of the ToF camera. For the initial face detection step, we decided to apply a pre-trained Haar-Cascade identifier on the amplitude data of the ToF camera. Once we successfully detected a face inside the FoV we utilize a facial landmark detection algorithm to identify basic facial features such as the forehead, the eyes and the nose. Based on the detected landmarks in combination with the depth value, we are able to remove the foreground and the background of the ToF camera data. Once the data is cleaned from unnecessary information, we apply normalization transformations before handing it to the convolutional neural network (CNN) for driver identification. The CNN was custom trained on the ToF camera data for face identification. It operates by learning a transformation that should provide a unique identifier for every person, which is provided as input. Once the CNN provides this identifier, a comparison with previously stored face identifiers can be used to find the matching identity for the provided face.

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We conducted a technical evaluation of the performance for each of these steps. In the preprocessing step two steps are possible to fail. First the initial face detection based on the Haar-Cascade identifier and second the facial landmark detection. If any of these steps fail, the CNN is likely to result in a failed identifier. If the Haar-Cascade identifier fails, either wrong parts of the image or only partially detected parts of the face may be used in further processing.

In the preprocessing step most of the problems occurred due to a failed facial landmark detection. As briefly described before, the landmark detection is used for normalization transformations. This includes the rotation of the face to align the axis between the eyes with the horizontal image axis. If the facial landmark detection fails, one of the side effects can be a misalignment of the eye-axes. This issue has been addressed by training the CNN to handle slightly rotated faces.

We evaluated several CNN architectures for the use in our driver identification demonstrator. The selected CNN architecture is based on the NIRFaceNet architecture presented by Peng [3]. The architecture was adapted to our use case. To evaluate the performance of the tested CNN architectures, we used a test set of eight people and a validation set of six. To ensure that the results are not influenced by a person being already known to the network, we could not separate the train, test and validation set based on the number of images but had to separate it by person. With the selected architecture, we were able to reach an accuracy of 93.66%, a precision of 99.12% and a recall of 62.52%.

To evaluate the real-world performance of the driver identification system we conducted test on the final pipeline with nine participants, previously unseen to the CNN. The participants consisted of seven males and two females. On average, the participants had an identification success rate of about 70% and no false positive tries. The pipeline was configured to be less susceptible to false positive identification attempts, resulting in a lower identification success rate than with a more relaxed setting.

We further conducted preliminary spoofing test on the final pipeline. We tried to fool the system with printed RGB and grayscale images, as well as images shown to the pipeline on a Samsung LCD display. The images selected to be presented, were recordings of previously accepted identification attempts. We attempted to fool the system with one RGB image in 32 identification attempts and three printed grayscale images in 48 identification attempts. None of the described attempts was successful. The tests on the LCD display too were unsuccessful, because the active illumination unite was reflected too strongly by the display.

We conclude that we have an expected identification success rate of 70% while the system rejects all identification attempt of unauthorized drivers.

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4 Conclusions

This deliverable sums up validation and evaluation activities of developed HMI concept. Focus within this evaluation was to monitor how professional drivers are reacting to HMI concept when they had possibility to get familiarized with it. Generally speaking, feedback was mostly positive for both Linkker and Ford Otosan HMI prototypes.

The main principles of the HMI concept were evaluated very positively. TrustVehicle HMI concept was well accepted by the professional drivers. They had some minor modification needs and ideas. The comments from the drivers as well as the existing L1 and L2 ADAS regulations (including guidelines for in-vehicle warnings) will be taken into account when the HMI will be implemented to the demonstration vehicles.

Technical functionality testing of the Linkker HMI prototype included testing of the events related to view state changes, events inside a view states, and changes in data pool values in all relevant view states. All implemented data pool items and events were successfully verified in the testing. The technical verification provided consistent and tested solution for final HMI implementation.

The Time-of-Flight (ToF) based Driver Monitoring Unit (DMU) offers the functionality to record, detect and identify the driver. Applications of the driver identification include driver base customization, support and security. For the technical evaluation of the DMU demonstrator functionality, the driver detection and identification functionality were tested in a laboratory set-up.

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5 References

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6 Annex 1 - TrustVehicle - WP4.4 HMI prototype user (driver) questionnaire (08/2019)

1. What is your age?

    □ 18 to 29
    □ 30 to 39
    □ 40 to 49
    □ 50 to 59
    □ 60 to 69

2. Gender:

    a) male: ☐
    b) female: ☐
    c) N/A: ☐

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3. Based on the HMI demo, please indicate how much you agree with the following statements:

	totally disagree (-3)	(-2)	(-1)	neither disagree nor agree (0)	(1)	(2)	totally agree (3)	Don't know (-)
a) The demonstrated user interface is easy to use								
b) It is easy to understand what the user interface is showing in different phases								
c) It is easy to understand when automated driving can be activated								
d) It is easy to understand why the automated driving is not be available								
e) It is easy to understand when I need to take back the control of the vehicle								
f) It is easy to understand what I need to do to take over the control of the vehicle								
g) I accept the system to monitor me as a driver, and adjust the user interface accordingly								
h) (Linkker only): Additional spoken information and warnings are useful								
i) (Linkker only/FO pending): Additional event information provided after the drive is useful								
j) (Linkker only/FO pending): I'm willing to comment on the system performance and events after the drive								

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4. Any suggestions for improving the demonstrated user interface?

____

____

____

Next, think about the usage situation for which the system is designed *(in your test site)*

5. How much you agree with the following potential benefits of the demonstrated system

	totally disagree (-3)	(-2)	(-1)	neither disagree nor agree (0)	(1)	(2)	totally agree (3)	Don't know (-)
a) The system makes driving easier								
b) The system reduces stress								
c) The system improves safety								

6. Overall comments on the idea of automated driving as demonstrated:

____

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7 Annex 2 - Participant Information Sheet

PARTCIPANT INFORMATION SHEET

Trust Vehicle: HMI prototype evaluation

You are being invited to take part in Trust Vehicle research carried out by VTT Technical Research Centre of Finland.

Before you decide whether to join, it is important that you understand what Trust Vehicles project aims. Please, take the time to read the following information carefully. If anything is not clear or if you would like more information, please talk with a member of the project team.

Thank you for taking the time to consider being involved in TrustVehicle Research.

What is the purpose of Trust Vehicle?

Trust Vehicle is a European research project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723324. The responsible persons of this program will finally assess the project and thus this study. The purpose of Trust Vehicle is to enhance the safety and user-friendliness of level 3 automated driving systems during the transition period from human driving to fully automated driving by emphasizing a user-centric approach. The main objectives of Trust Vehicle project are:

- The systematic identification of critical road scenarios for the currently available automated driving systems, with special focus on the uncertainty associated with the behaviour of the other road users and the sensor fusion system of the ego vehicle.
- The development of controllers and sensor fusion systems capable of dealing with complex, uncertain and variable road scenarios, for enhanced road safety.
- The development and the demonstration of intuitive human-machine interfaces for the safe management of the transition phases between purely automated driving and human driving, considering user acceptance.
- The development and the demonstration of new tools for the cost- and time-effective assessment of vehicle and driver behaviour in complex mixed-traffic scenarios.
- The assessment and the tailoring of selected level 3 functions on real vehicles from four different road transport markets relying on the framework developed in Trust Vehicle objectives.

Why were you chosen?

You have been invited to take part in this study because you are a professional driver.

Do you have to attend?

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Participation is completely voluntary; you do not have to participate in the study. This information sheet is intended to inform you about the whole study and your participation. If you have any questions, please contact the research team.

What does your participation in this research involve?

As participant you will be involved in this activity: Questionnaire

If you agree to take part, you will fill out a questionnaire about a HMI prototype.

What are the possible benefits or disadvantages of taking part?

Your participation is valuable, you will help us in increasing our knowledge. No other benefits or disadvantages are tied to taking part in this research.

Why do we need your consent?

Your permission is requested to use the received data for research purposes. By filling the questionnaire and returning it, you acknowledge that your participation in the study is voluntary, you give permission for your responses to be collected, anonymized and analysed with the aim to publish research or reports, you are 18 years of age.

What happens to my data?

Your data will be anonymized and then analysed with the aim to lead to research publications and reports. All project data related to the administration of the project will be kept for at least 6 years and all research data for at least 10 years in accordance with the law.

What happens to the results?

There will be a final report with a summary of the main findings, which will be sent to the EU as part of the project. The project also aims to disseminate the research results through publications and conferences.

Will your data be used in future research?

If you agree to participate in a research study, the anonymous information we collect can be shared with researchers who are conducting other research studies in that organisation. Your data will only be used by researchers to conduct research and process it on the basis of public interest.

This information does not identify you and is not combined with other information in any way that could identify you. The information is used for research purposes only and cannot be used to contact or influence you.

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What if I want to complain about data handling?

If you wish to file a complaint about the handling of your data, you can contact the University of Surrey Data Protection Officer, who will investigate the matter. The contact details of the University of Surrey Data Protection Officer can be found at: https://www.surrey.ac.uk/information-management/data-protection

If you are not satisfied with our response or believe that we are processing your information in a way that is not lawful, you can contact the Information Commissioner's Office (ICO) (https://ico.org.uk/).

Who should you contact for further information?

If a participant wants any further information concerning the project or if the participant has any problems which may be related to the involvement in the project, please contact one of the following people:

Investigator: VTT Technical Research Centre of Finland, Mikko Tarkiainen, mikko.tarkiainen@vtt.fi

Ethics and data protection: Dr Micaela Troglia, m.troglia@cisc.at

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8 Annex 3 – Ethics Self-Assessment Form

SAFE_MAR2019

Response ID	Completion date
428470-428461-50561524	3 Oct 2019, 16:45 (BST)

1	**Project title**	TrustVehicle

2	**Principal Investigator**	Dr. Karci
2.a	**Email address**	a.hartavikarci@surrey.ac.uk

3	**Level of research**	Staff
3.a	**Co-investigators- if you don't have any co-investigators please enter NA.**	Dr. Sorniotti

4	**School/ Department. External applicants should list their affiliated body or institution.**	MES

5	**Proposed start date for data collection**	02/09/2019

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6	**End date for data collection**	03/10/2019

7	**Does the study fall into any of the following categories?**	f. None of the above

8	**Are there any procedures involving more than minimal risk to a participant's health or well-being?**	No

9	**Does the study involve the use of surveys, questionnaires and any research, the nature of which might be offensive, distressing or deeply personal for the particular target group, where the participants will be identifiable to the researchers e.g. interviews, focus groups?**	No

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10	**Does the study involve children under the age of 16 or other vulnerable groups, or those who may feel under pressure to take part due to their connection with the researcher?**	No

11	**Does the study involve prisoners or young offenders?**	No

12	**Does the study involve the new collection or donation of human tissue, as defined by the Human Tissue Act, from a living person or the recently deceased according to the Human Tissue Authority?**	No

13	**Does the research require participants to take part in the study without their knowledge and/or consent at the time?**	No

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14	**Does the study involve deception other than withholding information about the aims of the research until the debriefing?**	No

15	**Do you think that any other significant ethical concerns may arise, or does your external funding body or sponsor require full ethical review to be undertaken?**	No

16	**Have you answered Yes to any of the questions on this page?**	No- I don't need to apply for full review

33	**Does the study involve the use of surveys, questionnaires and any research, the nature of which might be offensive, distressing or deeply personal for the particular target group, where the participants will not be identifiable to the researchers e.g. online surveys, anonymous questionnaires?**	No

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34	**Are you planning to access records of and/or collect personal identifiable data, concerning identifiable individuals as defined by data protection legislation?**	No

35	**Are you linking or sharing personal data, special category data (sensitive personal data) or confidential information beyond the initial consent given (including linked data gathered outside of the UK)?**	No

36	**Will you collect or access audio recordings, video recordings, photographs or quotations within which participants may be identifiable and with the intention to disseminate them beyond the research team?**	No

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37	**Do you plan to offer incentives which may unduly influence participants' decision to participate?**	No

38	**Does the study involve activities where the safety/wellbeing of the researcher may be in question?**	No

39	**Could the behavioural/physiological intervention possibly lead to discovery of ill health or concerns about wellbeing in a participant incidentally, even if the intervention in itself causes no more than minimal stress is to the research participant?**	No

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40	**Are you investigating existing working or professional practices among participants, identifiable to yourself as the researcher at your own place of work (this may be the University of Surrey or another organisation where you, your supervisor or co-investigator works)?**	No

41	**Have you answered Yes to any of the questions on this page?**	No- I don't need to apply for proportionate review

53	**According to the answers you have submitted your research project does not require review by the UEC.**	I confirm that I have answered No to all questions. I understand that my completed form may be audited.

54	**I, the undersigned, confirm that I have read and will comply with the Ethics Handbook for Teaching and Research and the Code on Good Research Practice. I understand that the project may be monitored and audited by the University of Surrey to ensure that it is carried out in**	I agree

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	accordance with good practice, legal and ethical requirements and any other guidelines. I understand that the protocol and any associated documents such as information sheets and consent forms should have version numbers and dates. If I make any significant changes to my protocol I understand that I should complete the self-assessment again. I am also aware that any knowingly wrong answer to any of the questions below and any research misconduct reported may lead to disciplinary measures after investigation. In case of dissertation projects or theses, the provision of knowingly incorrect information or proven research misconduct may affect academic progression.	
54.a	**Name**	Dr.Karci

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