Usability Assessment of a Smart Cognitive Assistant for Automated Driving

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Abstract: The Automated Vehicles (AV) are becoming increasingly important in the industrial and mobility domains. The Human Machine Interface and Interaction are two of the main aspects in the AV design, and as such, the consideration of the user is critical to the design process. The European Project SUaaVE (SUpporting acceptance of automated Vehicle) acknowledges that human-centric design is necessary to help AV in becoming accepted and trusted by road users (drivers, passengers, pedestrians) when it is introduced into the market.

In the first phase of the project, partners, collaborating on the HMI design, performed different tests.

C.R.F. S.C.p.A. performed a user test, which had different objectives. In this paper, the objective of the usability evaluation of the SUaaVE first cognitive HMI prototype is described. The test was performed by showing users a video of automated driving in an AV using the first iteration of the HMI. The findings were then used during the subsequent redesign phase to improve upon the HMI, according to the Human-Centred Design process.

This study allowed identifying advantages and limits of the methodology and of the HMI prototype and to identify and share redesign suggestions (for the following phase of the project) with partners.

1 INTRODUCTION

The deployment of automated vehicles is going to become a reality in the near future and this technological innovation will bring a lot of advantages, for example in terms of higher road safety, better mobility, enhanced inclusiveness, and CO^2 reduction.

Consumer preference for riding in self-driving cars is set to double by 2024 (Capgemini, 2019), yet the idea of being in a self-driven vehicle has not being completely accepted. The different theories on acceptance (Tétard & Collan, 2009; Venkatesh & Bala, 2008; Venkatesh, 2012) show several salient dimensions which could be considered to improve the users' attitudes towards AV usage (e.g., hedonistic aspects, social impact, usefulness, usability).

In order to avoid the creation of gaps between technological feasibility and possible societal concerns (e.g., acceptance, trust), and losing or diminishing the positive impact of this innovation, it is of paramount importance to include road users into the AV design process.

The European Project SUaaVE (SUpporting acceptance of automated Vehicle) acknowledges the risk of such a gap and aims to lean on a Human - Centred Design approach, where the user is at the centre of the process and actively contributes to the new archetype of automation in SUaaVE: ALFRED (Automation Level Four+ Reliable Empathic Driver). ALFRED aims to understand the user's state, and from this information, if needed, to manage corrective in-vehicle actions for enhancing the automated driving road user experience.

In the SUaaVE project, following important dimensions of the acceptance models, three axes of research (Kyriakidis et al., 2019) were considered to

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design the Cognitive, Emotional, and Adaptive interfaces:

1) The cognitive needs of users, which is the information users must receive to increase their knowledge of the situation and to manage it appropriately. For example, taking into account the users' degree of involvement in the driving task (e.g., active road monitoring, non-driving related tasks, drowsiness etc.), and their situational awareness (Kyriakidis et al., 2019).

2) The emotional response of users, possible thanks to the development of an empathic module for monitoring users' emotional and behavioural reactions, able to guide driving decision and comfort choices.

3) The optimisation of users' comfort, which is a dimension of well-being, and an important aspect of the acceptance. The SUaaVE comfort management will ensure a pleasant use of the automated vehicle.

In order to test hypotheses formulated on ALFRED models, a variety of tests are performed by partners of the project, to evaluate the HMI solutions being designed.

This paper concentrates on the first of the three axes of research, mentioned above and, in particular, on the usability evaluation of the first interface prototype of a smart cognitive assistant. The aim was to understand what refinements could be made to iteratively improve the interface from a user point of view, in the following steps of the project.

In this project, innovative features are developed and tested. These tests must be conducted in different countries to control regional disparities. In the early stages of the design, it is difficult to reproduce a prototype in the various regions of all the partners for testing, especially in a health crisis situation. We therefore chose to explore the possibility of testing its usability from a video. This article describes this initiative and concludes on its benefits and limitations.

2 METHOD

2.1 Participants

Participants were recruited among C.R.F. S.C.p.A. (CRF) employees (not externally as originally planned) due to COVID 19 restrictions.

A request was sent through CRF Intranet to CRF employees with the kind request to attend this test. Recruitment criteria were as follows: all participants must have a driver licence, must not work in related technical departments (e.g., Advanced Driver Assistance System, Automated Driving) and must not be involved in the SUaaVE project.

The main aim of this first loop test was the in-depth usability evaluation (Rubin, 1994) of the first version of the SUaaVE cognitive interface prototype, and so a sample size of twelve participants (N=12; 75% male, 25% female) was chosen. They had an average age of 46.42 years (*SD*=9.91, range 29-61 years). Thirty-three percent of the participants had a high school diploma, while 67% of them had a university degree.

Participants drove an average of 16000 kilometres per year (km/y) (*SD* = 8034, range 5000-30000 km/y) on mixed types of roads.

Forty-two percent of participants owned small segment cars, 33% mid-size cars, 16% large-size cars, and 8% small sport utility vehicles.

From the socio-demographic questionnaire emerged also that:

- the frequency of use of a navigation app on a smartphone was rarely (42%), often (33%) or sometimes (25%);
- Half of the sample did not use Advanced Driving Assistance Systems, while 33% use them often, and the remaining 17% reported they only sometimes use them.

2.2 Apparatus

The original plan was to use the first version of the Virtual Human Centred Design platform (V-HCD) designed by ESI. This first version is a simplified software that includes an ego-car immersed in a dynamic virtual road environment connected to a driving simulator (ego-car cabin), to allow participants to experience the automated driving, through the interaction with the ego-car cabin, piloted by the V-HCD ego-car model.

Due to the pandemic emergency, this type of apparatus could not be used due to unexpected constraints, like long periods of remote working, which made necessary to find a workaround in case remote tests should have been executed. For this reason, it was determined that it would be reasonable to use a video if remote tests were required. Ultimately, the first loop test was able to take place in person, notwithstanding the COVID 19 emergency period. The test was performed in the CRF Usability Laboratory, using a mixed (real & virtual) apparatus, made of a physical vehicle mock up, and a screen, which was used to display a video, simulating automated driving scenarios, shown to the participants. The participants were not requested to drive while watching the video.

The static vehicle mock-up was built reproducing a vehicle interior with steering wheel, pedals and an automotive seat. An 85” curved TV screen was selected as the most appropriate dimension, and type, to be used and collocated at 1m from the mock-up.

All apparatus parts were mounted in order to reach a realistic participant posture, taking into account comfort as well as visibility needs.

The large screen displayed the videos of the automated driving scene (corresponding to project use cases) including a driving simulator (SCANeR studio 1.9) and the SUaaVE first cognitive interface (HMI) on a tablet (Fig.1). The videos were made and kindly shared by CATIE and Bordeaux IBNP, partners of the project.

The complete apparatus was optimized to reach as much as possible a realistic visual interaction during the test among the participant seated in the mock-up, the physical components of the mock-up and the frontal screen. This required optimization of the screen distance from the mock-up as well as the physical ergonomics adjustments of the mock-up itself.

Once the apparatus was in its optimal configuration, an iterative optimization activity was done with CATIE colleagues, in order to reach the best visibility of the automated driving scenes and of the SUaaVE first cognitive interface (HMI) both displayed on the frontal screen video.

2.3 Scenario

Different situations were presented in the videos, prepared to show simulated manual (driver-in-control) and automated driving sessions.

In the videos, the vehicle usually started the journey in an urban scenario.

Many changes in the driving mode (manual / automated) and viceversa (automated / manual) were visualised, with specific feedback to the driver to show the participant multiple handover, and takeover events.

In urban scenarios, typical uses cases were shown: crossroads, pedestrians on the sidewalk, traffic in which other vehicles performed driving manoeuvres, traffic lights, and roundabouts.

The displayed scenario then followed a rural road to reach a highway. In this condition, the traffic situation changed, together with traffic signs, vehicle speed and other vehicles overtaking.

Figure 1: User test apparatus.

In the last part of the videos, the ego-vehicle came back to the town in an urban scenario and ended by parking the vehicle.

2.4 Stimuli

The first SUaaVE HMI prototype, displayed in the central part of the dashboard (Fig. 2), can be divided into four different areas (A, B, C and D) with different information.

Figure 2: SUaaVE first cognitive Human Machine Interface prototype.

Area A is a sort of travel diary, containing contextual information on the trip.

Area B shows some basic information like autonomy and distance to arrival (i2), speed (i3); moreover, this area contains feedback about the technical status of the automated vehicle (i4), the vehicle dynamic e.g., slow, normal, fast (i5), the user's status detection capability (i6) and the driver activity (i7).

Area C shows a schematic "radar" area (s1) with the presence of road users (both vehicles and pedestrians) around the ego-vehicle. Moreover, it shows the vehicle position (s4).

Area D contains information about road conditions (s2) and road signs (s3).

The interface received information from simulator about the driving situation, which was transposed graphically in order to inform the user continuously about the driving data processed by the vehicle.

On this first version of the interface, some functions were not functional and therefore their display stayed static (zones i1, i4, i5, i6, i7, s4 presented in Figure 2).

In front of the driver, beyond the traditional cluster information, additional feedback was displayed to show the automated driving modes:

- a pop-up message to explain that the automated driving mode was available or, when in the scenario the takeover request was necessary, to explain the reason for this request (e.g., GPS interruption, road works);
- a blue coloured band (on each side of the instrument cluster) while the automated driving mode was active, which disappeared once the vehicle was again on manual mode.

This feedback was consistent whether or not the first SUaaVE HMI prototype was displayed on the tablet, included in the video shown to participants (Fig. 3).

2.5 Test Conditions and Experimental Design

This study had two test conditions, one in which the HMI was not displayed on the tablet (Figure 3: a.-b.) and the other in which the participants experienced the HMI prototype (Figure 3: c.-d.).

The test had a within-subject design, in which all participants experienced, through the videos, all scenarios in both test conditions.

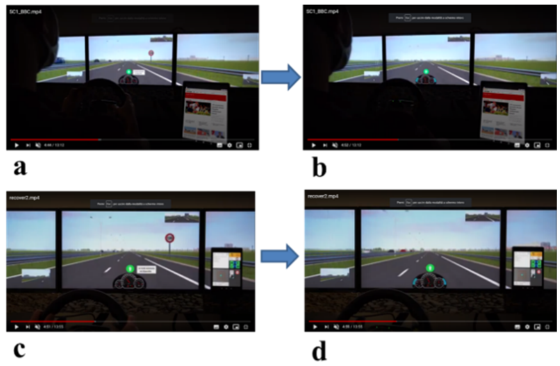

Figure 3: a. Video without HMI / AD availability mode - b. Video without HMI / AD active mode - c. Video with HMI AD availability mode - d. Video with HMI / AD active mode.

2.6 Procedure

Participants were welcomed by an experimenter and hosted at the CRF Usability Laboratory, thanked for taking part in the study, and the anti COVID 19 protocol measures to be followed by everyone involved in the test were explained.

Participants were introduced to the test protocol through written instructions and were informed about privacy aspects according to the EU General Data Protection Regulation, followed in the CRF procedure.

Prior to testing sessions, participants completed a socio-demographic and driving habits questionnaire.

The participants sat in the physical vehicle mock-up and observed the videos on the automated driving without and with (in this order) the first HMI prototype developed in SUaaVE.

After the scenarios were completed, without any explanation from the experimenter, participants were asked to give their explanation of the HMI from their point of view. In a second step, the interviewer explained the HMI using printed images of the interface.

Participants were then administered a questionnaire to evaluate the HMI. They were asked to rate their experience, and provide comments.

Last question was about their preference toward the automated vehicle experience with or without the HMI.

At the very end, participants were thanked for having attended the test session.

The test had a duration of one hour and a half.

2.7 Subjective Measures

Different type of data were collected during the test.

First, data to describe the participants' sample were collected through a socio-demographic and driving habits questionnaire.

While viewing the videos, participants were asked to follow the Thinking Aloud method (Lewis, 1982), expressing their thoughts about what they were experiencing and their comments were collected.

To analyse and quantify the different usability aspects (e.g., comprehensibility, legibility/ readability, preferences) of the different HMI areas and the information they displayed, CRF developed an ad-hoc evaluation grid, agreed with partners, to collect quantitative data through a 7-point scale (very negative, negative, little negative, neither negative nor positive, little positive, positive, very positive). Moreover, qualitative data was collected through comments that participants associated to their scores. These comments, together with the verbatim collected through the Thinking Aloud method, gave a deep insight to their scores.

Then, in order to have a global score of the HMI usability, participants were asked to rate their experience on nine usability dimensions using a 7-point semantic differential scale between polar adjectives (e.g., simple - complex, useful - useless, stressful - relaxing).

3 RESULTS

3.1 HMI Comprehensibility

Average evaluation and confidence interval (with T distribution) were calculated for each HMI area. Then a monovariate ANOVA and a Duncan multi comparison test (using SAS^{TM}) were applied to identify possible statistically significant differences among aspects and areas.

Participants' comprehension evaluation of each area of the HMI (A, B, C, D in Figure 3) is shown in Figure 4 graph ($F(3, 44) = 9.66$, $p < .001$).

3.2 HMI Legibility

Applying the same analysis as for the comprehensibility, results on participants' legibility evaluation of the HMI prototype A, B, C, D areas are shown in Figure 5 graph ($F(3, 44) = 14.80$, $p < .001$).

3.3 HMI Usability Evaluation

Participants' global usability evaluation of the HMI is reported in Table 1:

Table 1: Global usability evaluation mean and standard deviation.

Adjectives	Mean	Standard deviation
Useful	1.25	1.71
Necessary	1.17	1.64
Pleasant	0.42	1.44
Relaxing	0.25	1.48
Friendly	0.08	1.16
Effective	0.00	1.48
Safe	-0.33	1.37
Easy	-0.67	0.98
Simple	-0.83	1.27

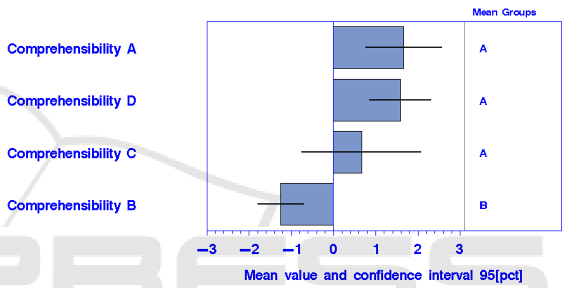

Figure 4: Participants' evaluations comprehensibility of HMI prototype areas.

Applying a monovariate ANOVA using SAS^{TM}, not all adjectives are equivalent ($F(8, 99) = 3.18$, $p = .003$).

With a Duncan, multiple comparison test, with 95% of confidence level, the significance of the different adjectives is shown in the Figure 6: the same letter is attributed to not statistically significantly different adjectives.

For example, no difference there is between Useful and Pleasant ($F(1, 22) = 1.66$, $p = .02$) while significant different there is between Useful and Safe ($F(1, 22) = 5.90$, $p = .002$).

3.4 Preference on Automated Vehicle with or without the HMI

A $\chi 2$ test was applied on the collected subjective data on automated driving preference with or without the HMI.

After this first loop test, there is no statistical difference between participants preferring automated vehicle experience they had with or without the HMI prototype ($\chi 2$ (1, N = 12) =0.33, p = .56).

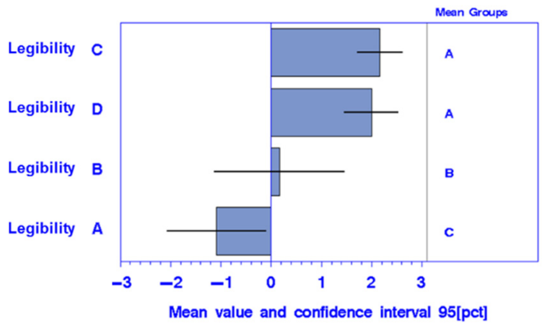

Figure 5: Participants' evaluation of legibility of HMI prototype areas.

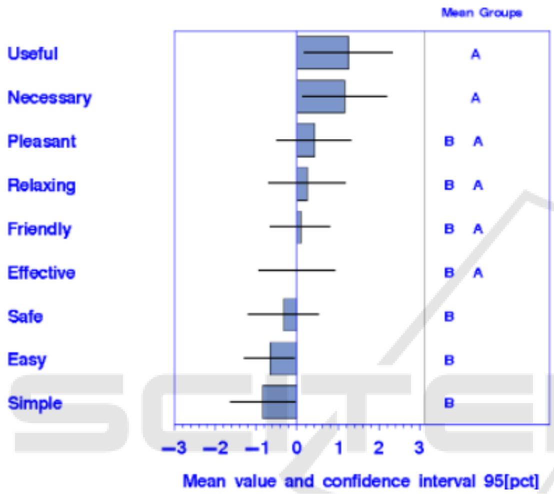

Figure 6: Global usability evaluation results.

4 DISCUSSION OF THE RESULTS

In the first three paragraphs, there is an explanation of the results, which considers both the participants' subjective scores and comments, followed by a summary of suggested ways to improve the interface.

4.1 HMI Comprehensibility

Area A (i1): it was considered comprehendible but there were too many words, to be processed quickly; it would be better to show travel information in a more graphical way.

Area B: the upper sections (i2, i3) were considered comprehendible, but not useful enough to be displayed on the HMI prototype.

The lower section of area B (in particular i5, i6 and i7) was not found to be intuitive by participants; however, following the experimenter's explanation this kind of information was considered interesting by the participants.

Participants always defined the secondary functions i4, i5, i6, and i7 as icons, because participants felt none of these functions looked like buttons they could interact with.

Area C (s1): the meaning of this area was partially understood by the majority of participants, but some have difficulties because of the clutter in this area, the details, colours and shapes. In particular:

- the coloured shapes were not evaluated as represented in a realistic way;
- the shapes had different chromatic code, not always discernible to participants. (e.g., the difference between light grey and the other colours);
- participants didn't realize that each of the shapes represented different road users (e.g., the pedestrian represented by a square was less noticeable);
- the radar modality visualisation was not very familiar to users. Moreover, the radar grid is perceived as cluttered by 40% of participants;
- the latency was considered slow (there was an evident delay between the event on the road and the obstacles visualized on the radar map), but probably this was a video reproduction effect.

Area D: it was fairly well understood but still found to be a slightly confusing, because of the presence of multiple icons.

4.2 HMI Legibility/Readability

Area A legibility/readability was evaluated negatively: there was too much written information, the font was too small and the spacing between lines of text was not sufficient.

Area B evaluation was neither negative nor positive, as some details could be easily read but other could not.

Best evaluations were given to areas C and D to which participants gave a positive score.

4.3 HMI Usability Evaluation

In the usability evaluation, the HMI prototype received the highest rating for the adjectives "necessary" and "useful". All the other evaluations were around the neutral point and or on the negative side of the scale.

In fact, the HMI prototype was considered necessary and useful in general, but participants' comments explained that this HMI should contain more information regarding automated driving, especially feedback about the transition manual - to - automated and automated - to - manual (handover and takeover), currently shown besides the instrument cluster.

Due to some aspects not completely understood (especially in area B), the HMI was evaluated a little enjoyable, but not so relaxing and friendly. Some elements were distracting (so potentially having some level of impact on safety, when displayed during manual driving) or less useful (e.g., Area C was cluttered).

Participants did not find using this HMI prototype to be simple, because the information was not very intuitive and the huge quantity of details.

In this study, all users' evaluations, and associated verbatim were very useful in redesign the HMI, especially when the evaluations were negative. These evaluations clearly indicated what had to be modified in the next version of the prototype.

4.4 Preference

During this study, based on subjective measures, a preference did not emerge for having or the HMI or not, while driving in the automated mode.

Participants found the task of expressing a preference, which includes hedonistic aspects, was not easy when only experiencing this HMI by watching a video and observing printed images.

Despite the complexity of the task, it is worth noting that participants stated many times that the tested HMI would be very useful to inform the users in an AV, once issues they highlighted had been fixed.

4.5 How to Improve the HMI Prototype

A set of recommendations for the redesign of the HMI were identified and shared with SUaaVE colleagues and, in particular, CATIE partners, for the next version of the cognitive HMI prototype development.

Area A

To convey travel information, in particular during automated driving sessions, it was suggested to:

- use a more graphical layout and less words;
- explore the possibility to add navigation maps that are familiar to drivers;
- display emergency messages (e.g., congestion, incident) if available.

Area B (i2, i3)

Suggested changes were:

- present the information of autonomy, in particular the distance from destination and current speed in the instrument cluster and not in the i2 and i3 sectors;
- present a visual dynamic graphic feedback of the takeover request, instead of having a blue feedback only besides the instrument cluster (Fig. 3);
- add an audible feedback to the visual graphic for a takeover request, to enhance the driver situation awareness, in order to avoid the negative outcomes of a takeover request that is noticed late, or missed altogether;
- add an emergency vehicle takeover request message or messages related to issues with the automated vehicle to indicate when rapid response measures are needed, and explain the on-going situation to the user. These emergency messages could be displayed in redundant locations, such as the instrument cluster as well.

Area B (i4, i5, i6, i7)

The following changes were recommended:

- display any icons or messages related to automated vehicle issues (e.g., failure) on the instrument cluster as well as in area i4 (technical status of the AV), to follow familiar messaging strategies;
- to enhance the intelligibility of the icons in i5 (AV dynamic style), i6 (user monitoring status), and i7 (driver activity), users could be involved in the icons definition (ISO 9186-1:2014; Campbell et al., 2004);
- use 3D visualisation to differentiate the icons of i4, i5, i6, i7 (if they will be virtual buttons), to indicate to the user that they can be pushed to select among different options.

Area C (s1):

Some changes to the graphical elements used on the radar area were suggested:

- use more realistic shapes (e.g., 2D or 3D vehicle shapes);
- do more to visually differentiate between the shapes (e.g., square and circle) to make them to be more salient, so the user can distinguish among them and consequently among the different road users (e.g., pedestrian, vehicle) surrounding the ego-vehicle;
- expand the colour codes associated to the graphical elements to enhance the users' ability to detect the difference between them;

- use a more realistic view of the simulated scenario external to the vehicle. For example, instead of the radar grid, consider to use a lanes representation, which is more familiar to drivers' mental model and creates less visual cluttering;
- reduce the latency time in s1 sector of the HMI to avoid the perception of a delay in the system's ability to detect obstacles;
- Avoid flickering in the graphical elements, which can be annoying and distracting.

Area C (s4)

Evaluate moving the indication of position into Area A, to be more consistent with the navigator mental model users have

Area D

Regarding this area the following changes were identified:

- do more to differentiate the signs of different domains to minimize issues with signs comprehension, for example road signs, weather conditions, road types;
- associate relevant events occurring in the external scenario with the displayed signs. For example, when there is a crossroad in the external scenario, display the crossroad sign on the SUaaVE HMI prototype in the proper road sign dedicated sector.

5 GENERAL DISCUSSION

The SUaaVE first loop user test was fundamental to understand if the methodology was adequate and could provide sufficient feedback to redesign the HMI for the second loop test.

The mixed (physical and virtual) apparatus used to evaluate the usability of the HMI first version had pros and cons.

In fact, it allowed participants to experience the sensation of the automated driving of an AV and the HMI, even if on a video basis. The displayed scenario (e.g., urban, highway) and the relative use cases (e.g., crossroads, pedestrians, other vehicles manoeuvres, traffic lights, roundabouts, road signs, vehicle overtaking) were adequate for participants to project themselves in the use of an automated vehicle, and to collect very interesting data on the usability interface issues.

On the other side though, it was not easy for participants to fully experience the role of HMI in the automated vehicle and express a preference without interacting with a real HMI prototype.

In the second test loop, the HMI will be integrated on the vehicle physical mock-up, positioning the tablet (visualising the HMI) in the central upper part of the dashboard, where a real central head-unit typically is. This way participants will have the opportunity to interact with the HMI.

Moreover, to enhance the fidelity of the simulation, the second loop test will be performed with the low level VHCD, and the participants will be able to interact with the simulator, instead of watching a video only and three 55" screens will be used to create an immersive external environment.

This testing method (video based) remains interesting at the beginning of the design process, as in this instance for the SUaavE project and in such situations where there is a need to conduct tests with users remotely (e.g., working on international projects, or realized by remote teams, or to test with users who stay at home). In fact, although participants were exposed to a video, from their subjective comments, it was derived they felt immersed in this low-fidelity virtual environment. They felt they were able to appreciate the driving style of the reproduced automated vehicle or to experience anxiety while testing this AV and appreciate with the usage the novelty of the automated driving.

The psychometric instruments and the Thinking Aloud method were easily understood by participants and did not cause any issues during testing or data analysis. These instruments will be used again in the next experiments.

The duration of the test was found to be long enough to collect the data and not annoying participants, so the next experiment will be designed taking into account this duration as a reference.

6 CONCLUSIONS

Using a mixed-reality method, valuable insights on participants' evaluation of the usability of the first cognitive SUaaVE HMI prototype were obtained.

The first loop test allowed highlighting pros and cons of the HMI prototype.

Thanks to the identification of aspects considered 'not intuitive' or 'less useful', etc., recommendations to enhance the usability of the HMI, were suggested.

The results will be useful to the redesign of the SUaaVE HMI, as stated in the Human-Centered Design process (ISO 9241-210:2010).

Moreover, the interesting lesson learned on the methodological side on the video-based experiment will be useful for possible next usability remote evaluation needs it might occur in the future.

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REFERENCES

Campbell, J. L., Richman, J. B., Carney, C., and Lee, J. D. (2004). *In-vehicle display icons and other information elements*. Volume 1: Guidelines (Report No. FHWA-RD-03-065). McLean, VA: Federal Highway Administration.

Capgemini Research Institute (2019, May 9). The autonomous car. A consumer perspective.

Retrieved July 30, 2021, from https://www.capgemini.com/news/the-autonomous-car-report/

Kyriakidis, M., de Winter, J. C. F., Stanton, N., Bellet, T., van Arem, B., Brookhuis, K., Martens, M. H. Bengler, K., Andersson, J., Merat, N.; Reed, N., Flament, M., Hagenzieker, M. & Happee, R. (2019). A human factors perspective on automated driving. *Theoretical Issues in Ergonomics Science*, 20, 223-249.

International Organization for Standardization (2014). *Graphical symbols - Test methods - Part 1: Method for testing comprehensibility*. Genève: ISO (ISO 9186-1:2014).

International Organization for Standardization (2010). *Ergonomics of human-system interaction Part 210: Human-centered design for interactive systems.* Genève: ISO. (ISO 9241-210:2010).

Lewis, C. H. (1982). *Using the "Thinking Aloud" Method. In Cognitive Interface Design* (Technical report). IBM. RC-9265.

Rubin, J., & Chisnell, D. (2008). *Handbook of usability testing: How to plan, design, and conduct effective tests*. Indianapolis, IN: Wiley Pub.

Tétard, F., & Collan, M. (2009). Lazy User Theory: A Dynamic Model to Understand User Selection of Products and Services. *2009 42nd Hawaii International Conference on System Sciences*, 1-9.

Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision Sciences, 39, 273–315.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. MIS Quarterly, 36, 157-178.