Exploring a Cognitive Interface to Support Trust and Acceptability of Future Users of Autonomous Vehicles

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Abstract. The lack of acceptability of future autonomous vehicles (AVs) is a challenge for investing in their design. Driving simulators offer opportunities to imagine and test possible solutions to achieve acceptability. The solution studied here is a cognitive interface based on theories of mental representation, under the assumption that they are the basis of acceptability and trust. A first interface was designed and then tested by users on board a simulator. The interviews carried out at the end of the tests allowed characterization of user fears regarding self-driving vehicles and identification of ways of improving the initial concept. In particular, there is a need for information on the functioning and decisions of the AV. This information is essential for the construction of a mental representation that is sufficiently rich to establish a satisfactory level of confidence. However, information about AV functioning is not an end in itself, but a necessity to help in decision making processes according to the situation. For this reason, the second version of the interface will be connected to an empathic function in order to inform and reassure the user when his cognitive and emotional states require it.

Keywords: Autonomous vehicle · Acceptability · Trust · Situational awareness · Empathetic interface · Mental representation

1 Theorical Background

1.1 Context of the Study

Most car manufacturers have started to integrate self-driving functions into their vehicles. Some have already reached a fairly high level, where the vehicle is able to drive autonomously under the active supervision of the driver [1]. Some countries have already paved the way for this practice. In Europe, road users (motorists, pedestrians, cyclists, etc.) are increasingly open to autonomous vehicles, but there is still a long way to go to completely convince the population [2]. European countries are focusing on autonomous vehicules through various research projects [3, 4] to build a transition adapted to their territories. These projects focus on the opportunities and impacts of autonomous vehicles and explore different levers to promote their acceptability. The acceptability of a

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technology can be defined by the intention of use by future users [5], in other words, this is a predictor of its adoption [6]. Solutions to measure and support the acceptability of autonomous vehicles are being studied in the SUaaVE (SUpporting acceptance of automated VEhicle) project, which includes the work presented here to expand on an earlier communication [7]. The 10 partners in this project are looking at new uses and functionalities that can be offered by a "level 4+ AV", i.e. 100% autonomous but still with manual controls. With such a vehicle, the user could rest, watch a film, or telework instead of driving. However, these on-board activities could generate negative conditions (e.g. anxiety, motion sickness, stress) which could be minimized by considering e.g., understanding of the driving situation, dynamics, comfort, etc. These 5 study axes make up the ALFRED concept presented in Fig. 1. Its objective is to optimise vehicle behaviour and level of information according to user needs. The study axis presented here, the Smart Cognitive Assistant (SCA), focuses on the user-centred design of a "cognitive" Human Machine Interface (HMI), i.e. capable of helping the user to construct a mental representation rich enough to understand the driving situation.

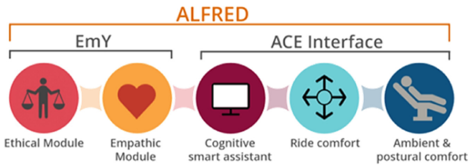

Fig. 1. ALFRED, a travel assistant from 5 axes of study. (Ethical Module, Empathetic Module, Cognitive Assistant, Conduit Comfort, Ambiant and Postural Comfort). ALFRED = Automation Level Four - Reliable Empathic Driver; EmY = EmpathY unit; ACE = Adaptive, Cognitive, Emotional [7].

Mental representation (and situational awareness) emerged as key for understanding both the principle of acceptability assessment and the trust process, but especially for achieving the supposed goal of a so-called cognitive interface. The theoretical concepts discussed are illustrated by the case of taxi use, which has notable similarities to the use of an AV.

1.2 Mental Representation to Situational Awareness in an Autonomous Vehicle

The mental representation of a device (e.g. a taxi) involves the activation in memory of specific concepts (e.g., car, driver, taximeter, yellow) or concepts related to use (e.g., airport, luggage, travel, reserved parking). Implicitly, the bricks that make up this representation are derived from previous experiences. Among these bricks, there are also event schemas [8] (e.g., the way the driver greets the customer and takes care of his luggage). Such a schema is a structure that encodes an action (goal) in memory and the intermediate actions (sub-goals, steps) necessary to achieve it [9].

To build or update a representation, an observer can spontaneously adopt the point of view of an observed actor. This is often referred to as an empathic mechanism, whereby the observer mentally simulates the actor's point of view and actions [8]. It is also an important process in social interactions: it allows e.g. two interlocutors to activate a set of shared representations on which dialogue can be based [10]. This empathic capacity is thought to be based on neural structures called mirror neurons [11, 12] that use observed behaviour to activate known action patterns in memory. The representation of the mental states of others helps the observer to understand what the actor perceives, how he formulates his goals, and how he carries out his actions [13].

These representation theories provide insight into the cognitive mechanisms at work in assessing, for example, a driver's abilities. They also show the limitations faced by the AV's user: if they cannot observe a virtual driver, how can they project themself in the driver's place and understand what they are doing? To go further, these theories are also applicable in the other direction: the driver is able to simulate the mental states of their passenger and adapt their driving. This is an avenue that is being explored in the project to support the user's situational awareness and correct negative emotions (not discussed here).

In the field of transport-related HMI, human factor specialists often substitute the psychological notion of mental representation with the more applied notion of situational awareness. The model proposed by Endsley [14] describes a continuous process of decision making and action evaluation. This process, represented in Fig. 2, is structured by three successive stages: (1) perception of the elements of the situation, (2) understanding of the situation, (3) projection of the future state. This model infers the interest of a cognitive interface to offer the user of an AV the possibility of quickly reintegrating important information on driving. For example, it is possible to help the user to detect an element of the situation (level 1), to understand its nature (danger, delay, discomfort factor, etc.; level 2), and its effects on the behaviour of the vehicle (level 3).

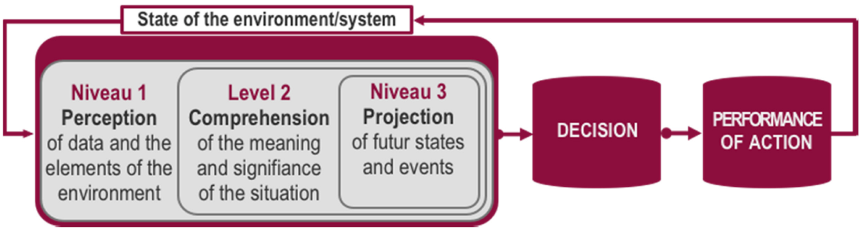

Fig. 2. Simplified model of situational awareness, based on Endsley's model (from [14]).

In addition to the principles of situational understanding, the notion of mental representation also sheds light on the possibility of assessing the acceptability of an AV based on a simulation.

Acceptance of a product is a quality valued by designers as it is closely linked to product success. This quality can be pursued using a variety of methods to improve the user experience of future products [15]. In particular, an iterative design approach can be applied, alternating design and test phases, to gradually adjust the product. During the test phases, the product is evaluated by measuring the user's attitude using questionnaires such as the TAM3 (Technology Acceptance Model, version 3) [16] or the UTAUT2 (Unified Theory of Acceptance and Use of Technology) [17]. These types of tools are designed to obtain a prediction of the acceptance of the future product from a real or simulated experiment carried out by testers (potential users). The testers are immersed in a real or simulated situation in order to construct a mental representation of the object in its context of use as accurately as possible, and then they answer the questionnaire. Each group of questionnaire items is comparable to a probe that extracts a specific fragment of the representation. For example, the first group of TAM3 items extracts the representation of the performance gain offered by the product; another group extracts the perceived ease of use, etc. The TAM3 thus offers a look at the different dimensions of product acceptability such as practical aspects (e.g. perceived usefulness and perceived ease of use), hedonic aspects (e.g. perceived pleasure), or social aspects (e.g. subjective norms), etc.

However, the acceptability of technologies based on forms of artificial intelligence (AI), such as AV, seems to be hampered by the issue of trust [18]. Trust is not addressed head-on in reference models of acceptability such as the TAM [16, 19], UTAUT [17] or the Nielsen model [5]. Nevertheless, the link between trust and acceptability has been studied for a long time and the emergence of AI has enriched the models [20]. Some determinants of trust are close to those of acceptability. Starting with attitude, which is associated with both acceptability [21] and trust [16, 18].

1.3 A View on the Attribution of Trust

On the same principle as acceptability, trust in a system is determined by various factors, including the ability to mentally imagine how it works. But first, what exactly is trust? There are many definitions of trust in a person [22]. A fairly general description would be to associate trust with "expectations, assumptions, or beliefs about the likelihood that another person's future actions will be beneficial, favourable, or at least not detrimental to one's interests" [23]. This prognosis is based on indices of attributes, such as competence [24, 25] or reliability [26].

These attributes are found in the questionnaire proposed by Jian, Bisantz and Drury [27] to measure trust in a system. In their model, they differentiate between non-trust factors (e.g. deceptive, lack of transparency…) and trust factors (e.g. reliable, understandable). The determinants of trust in a system [20, 22] are close to those of trust in a third party, especially for reliability which is fundamental for AVs [26]. Reliability can be assessed over the long term, which introduces a notion of familiarity that is favourable to trust [28]. In this case, it is possible to assign a level of trust to a target (person, group of people, object or type of object) based on observations made over the course of experiences with it. However, some situations are not supported by recurrent experiences. For example, when travelling in a taxi in a foreign country, it is necessary to quickly obtain information on the driver's ability to provide the desired result. For this purpose, it is possible to use action patterns that are based on driving experiences and that allow the user to check whether the observed actions are consistent. If so, confidence can be established. These patterns are building blocks of mental representation or situation awareness, which can be offered to the user through a specific interface.

1.4 Guidelines for an Empathetic and Cognitive Interface

The activities that can be carried out in an AV will divert the user's attention from the road. Cognitive user assistance covers two important aspects of the driving situation: the road situation and autonomous driving [29]. The road situation is composed of a static infrastructure and dynamic elements constituting a flow of information on the environment (e.g. traffic, presence of pedestrians, signs, weather, etc.). Autonomous driving corresponds to the driving actions developed from the information taken by the AV from the environment. The flow of information associated with the actions allows the user to understand the vehicle's behaviour. The processing carried out by the AV is not very visible to the user due to its speed and complexity. However, it is possible to make some of the "objectives" visible (e.g. increasing speed, anticipating a traffic jam) and to share some of the environmental information processed by the AV. This information is useful for passengers to understand the operation of the AV but also to support their representation of the situation. It is possible to communicate information symbolically or verbally through different sensory channels: visual, audio, haptic, etc.

There is a lot of information available about the AV and the road situation. The design of the HMI must respect a certain minimalism to avoid cognitive overload [17, 30]. The sensory channels (auditory, sensory, etc.) and codes (verbal, symbolic) used by the system to communicate must be carefully chosen to inform the user without overly competing with his onboard activities [31]. This is where the empathetic nature of the interface comes into play. This empathy is ideally bidirectional within a communication situation: the user must understand the operation of the AV; the AV must "understand" the state of the user to adjust its level of information. According to the principle of iterative design, the first version of the interface provides a standard level of information. This information level is optimised in a second phase, based on user feedback and future measurements of the passenger's cognitive and emotional states (see Fig. 1: Empathic module).

Within the framework of an iterative design, a first design phase was initiated based on the first principles: informing about the situation and informing about the actions of the AV. An initial interface mock-up was developed, with a view to refining the nature of the information presented and its mode of presentation on the basis of a user test.

2 Interface Description

To follow the above principles, the design of the interface has been made to highlight data on the road situation and on the actions or operation of the AV.

2.1 Information on Traffic Situation

For data on the road situation, functions available on recent vehicles, such as a Tesla, were used i.e. detection of other road users, traffic signs, and weather, and detection of the road configuration (e.g. presence of an intersection). Information on the type of road (e.g. town, country, motorway, car park) is provided to infer appropriate behaviour for the uses and risks of each type of road. A GPS was initially desired, but this function involved developments that were too extensive for the project. However, geolocation information (street name) was added. The implementation of the information presented in Fig. 2 refers to the following functions:

- *The Radar* indicates on a grid the presence of other users around "my car" (blue dot). Other vehicles are shown with a colored dot according to the risk of collision (low = green; medium = orange; high = red).

  Each cell corresponds to a time distance related to safe distances. For example, a vehicle travelling in the same direction is displayed in green (peripheral cells of the radar) if safety distances are respected. If this vehicle is too close, it turns orange and flashes to indicate a risk. If a vehicle follows a different trajectory (perpendicular or opposite) it is displayed in red. The cells in which pedestrians or bicycles are present are highlighted (see the cell in the top right corner of the radar).

  By comparing the radar to a real situation presented, we can see that a glance at the radar captures more information on other road users than a glance at the real environment.
- *The contextual flow* related for example to the presence of an intersection, the state of the road, etc. The displays of the type of road (e.g. urban, motorway) and the weather are permanent, the other information disappears when its becomes obsolete.
- *The signage flow* that impacts driving only (e.g., speed limit, pedestrian crossing). Other signs are ignored (e.g. parking entrance, direction, etc.). Each item disappears when it becomes obsolete.

2.2 Information on the Functioning of the Vehicle

Information about vehicle operation was further considered in view of project constraints and limitations on data from the simulator. First of all, information on the situation was considered as information that the AV is able to process since it is displayed. Secondly, in the European project, information about the vehicle operation was not only about driving, but also about comfort services, such as driving dynamics and empathic functions. Finally, we were not able to recover satisfactory information on actions planned by the simulator: neither on route, nor on speed variations to negotiate a bend, for example. For vehicle actions, only speed information was available, from which the interface was able to calculate accelerations and decelerations. The implementation of this information presented in Fig. 3 refers to the following functions:

- *Traveling (i2 and i3)*, with information about speed, autonomy (battery) and distance remaining. Arrows above and below the speed indicate the acceleration or braking process.
- *The AV*, with a general status icon (i4: mechanical and computer), and an icon related to current driving dynamics (i5: calm, normal, sporty).
- *The passenger*, with an icon for the state of monitoring (i6: operational or not), and an icon for the activity detected (i7: attentive, rest, daydreaming/reflection, oral communication, reading/screen). The emotional state is not displayed so as not to accentuate a possible negative emotion (e.g. fear, sadness, anger).

Fig. 3. Correspondence of the interface fields: i1 = contextual information; i2 = autonomy and remaining distance; i3 = speed, acceleration and deceleration; i4 = technical status of the AV; i5 = dynamics; i6 = passenger status detection capability; i7 = passenger status; s1 = radar; s2 = conditions; s3 = signaling; s4 = location. (Color figure online)

Fig. 4. Visual of the HMI implementation on the ScanerStudio 1.9 simulator. The image (taken from a video) allows to see on the radar the presence of a pedestrian (yellow square) and a distant car on the right lane (green circle). (Color figure online)

3 First Version of the Interface Tested

The first version of the cognitive interface (CI) was connected to a realistic driving simulator (see Fig. 4) and the first test compared acceptability and confidence levels of an AV equipped with the interface vs. without the interface. The second test identified user needs based on an interview.

3.1 Method

After a hands-on phase in manual and autonomous driving, users performed three 100% autonomous driving scenarios of about 15 min each. A total of 40 experienced drivers (minimum 3 years of regular experience) participated, 20 were equipped with the CI, and 20 were not. Of the 40 participants, 4 were excluded from the study after having been cyber-sickness. Participants completed two questionnaires at the end of the driving experiment.

The first questionnaire assessed acceptability based on a French adaptation of the UTAUT [17]. This questionnaire has 9 dimensions (Performance Expectancy; Effort Expectancy; Social Influence; Facilitating Conditions; Hedonic Motivation; Price Value; Habit; Behavioral Intention; Use), each composed of 3 or 4 items. The Price Value dimension was of little relevance at this stage of the study and was removed. The Use dimension predicts the use of different functionalities of a device. This dimension was ignored in this study as the two devices compared were identical, with the exception of the presence of the interface, whose effect on acceptability was being assessed. A final acceptability score was calculated in two steps: a score for each dimension from the average of the associated items, and then the acceptability score from the average of the dimension scores.

The second questionnaire assessed trust [27]. It had 10 items, half of which were negatively valenced. The confidence score was obtained by first inverting the 5 negative scales and then averaging the 10 items.

Finally, the participants were interviewed orally to collect their impressions of autonomous driving. The interviews focused on the following 8 themes (1) Opinion of the experimentation; (2) Opinion of the autonomous vehicles; (3) Opinion of the simulator; (4) Description of the tablet from a visual; (5) Usefulness of the tablet; (6) Defects of the tablet; (7) Additional needs for information or functions; (8) Optional or annoying information on the tablet. The participants were invited to talk freely about the experience, and then they were directed to the targeted themes if necessary. They were then invited to discuss the visual interface.

3.2 Results

• Assessment of Acceptability and Trust

First, analysis of the internal consistency of the scales was carried out using a Cronbach's Alpha test [32]. The test focuses on each of the 7 dimensions of the UTAUT, for which the Alpha was between 0.66 and 0.94 ($m = 0.80$). The full UTAUT Alpha, calculated from the 7 dimension scores, was 0.85, that is an acceptable consistency. The same analysis carried out on the Trust questionnaire (12 input items) returned an alphla of 0,91; that is near the top threshold suggesting too much consistency.

A second analysis focused on the impact of the tablet on the evaluation of the autonomous vehicle in each dimension. For this, a Friedman ANOVA was carried out (via SPSS) on the scores given by users in conditions WITH tablet versus WITHOUT tablet. The results of the analysis are presented in Table 1. No significant effect of the presence or absence of the HMI appears on the evaluation of the Acceptability (UTAUT) of the autonomous vehicle. Similarly, no effect of the HMI is observed on the assessment of Trust (TR) in the autonomous vehicle, nor on any dimension of acceptability (BI, EE, FC, HM, HT, PE, PV and SI).

A third analysis presents the overall averages per dimension. The objective is to visually identify the dimensions that have the greatest impact on the final score. The graph presented in Fig. 5 shows the score for Trust (TR), Acceptability (UTAUT), and for the 7 dimensions used in the UTAUT. Interestingly, it is possible to distinguish two groups whose dimensions diverge by more than 1 standard deviation from the UTAUT score: on the one hand, EE and FC pull the UTAUT up, and on the other hand, HT, PE and SI pull the UTAUT down.

Table 1. Friedman's ANOVA per dimension: Trust (TR), Acceptability (UTAUT), Behavioural Intention (BI), Effort Expectancy, (EE) Facilitating Condition, (FC) Hedonic Motivation (HM), Habits (HT), Performance Expectancy (PE), Social Influence (SI).

Dimension	ANOVA	Sum of squares	df	Average square	F	Sig.
TR	Inter-G	1,556	1	1,556	1,056	0,311
	Total	51,66	35			
UTAUT	Inter-G	0,607	1	0,607	0,531	0,471
	Total	39,516	35			
BI	Inter-G	8,407	1	8,407	2,696	0,11
	Total	114,432	35			
EE	Inter-G	1,182	1	1,182	1,054	0,312
	Total	39,311	35			
FC	Inter-G	1,259	1	1,259	0,854	0,362
	Total	51,417	35			
HM	Inter-G	0,131	1	0,131	0,043	0,837
	Total	104,083	35			
HT	Inter-G	1,382	1	1,382	0,612	0,44
	Total	78,172	35			
PE	Inter-G	4,696	1	4,696	2,749	0,107
	Total	62,775	35			
SI	Inter-G	1,124	1	1,124	0,549	0,464
	Total	70,775	35			

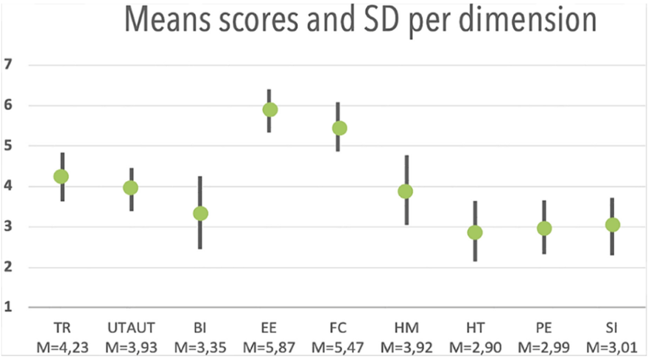

Fig. 5. Means scores (and standard deviation) per dimension: Trust (TR), Acceptability (UTAUT), Behavioural Intention (BI), Effort Expectancy, (EE), Faciliting Condition (FC), Hedonic Motivation (HM), Habits (HT), Performance Expectancy (PE), Social Influence (SI).

Table 2. Example of coding based on the verbatim interviews in the theme Additional information or functions needed. Similar verbatim statements were grouped into counted "ideas" (column n.). The ideas were then categorised into 3 defined sub-themes, and a sub-theme "Other suggestions".

Sub-thematic	Ideas	n.
Navigation information needs	Time and duration of journey	6
	GPS and journey progress	6
	Road anomalies (incidents, risks, traffic…)	7
	Touristic information	1
Need for information and functions related to autonomous driving	Wake up or stop if inattentive/sleepy	7
	Audible + visual alarm in case of emergency recovery	2
	Info if VA mode active, for User and road users	3
	Management of the speed and movements of the VA, to anticipate	6
	Decision process, what the VA understands, how it anticipates	15
	Information on the ability to handle the situation well	10
Information needs to support road situation awareness	Video monitoring (TNY YOLO, LIDAR…)	3
	Types of vehicles: autonomous, manual, trucks, motorcycles, etc	2

(*continued*)

Table 2. (*continued*)

Sub-thematic	Ideas	n.
	Trajectory of other Vehicles	1
	Road signage	2
	Help the user to locate the road users	11
Other suggestions	Help for understanding/general tutorial	3
	Categorization of information, more visibility	3
	Ejector seat	1
	Music	2
	Check-up, technical information	4

• Data from the Interviews
In sum, 570 ideas were identified and divided amongst the eight themes. Overall, the participants were very satisfied with the experience. They were enthusiastic about the idea of delegating leadership but expressed limited confidence. The main findings are as follows. Firstly, most of the needs expressed by the participants without an interface were on the CI. It should be noted that participants who saw the CI in operation had a good overall understanding of the functions presented, whereas the descriptions were more hesitant and unclear for the others, especially for the RADAR function and the accelerometer. Similarly, an excess of information was reported and a lack of meaning of the icons relating to the status of the passenger and the vehicle. Finally, data on additional information or function requirements was particularly needed to further develop the concept. Table 2 shows the coding of the verbatim reports produced on the theme of maintenance.

4 Discussion

• Discussion on the Assessment of Acceptability and Trust
The analyses did not find any effect of CI on the assessment of acceptability or trust. These results are surprising because the CI frequently met needs identified by users. The explanation put forward here is that users paid more attention to the simulation than to the CI, thus reducing the impact of the CI on the their representation of the AV. To increase the impact of the CI on user mental representation, 3 possibilities are proposed: (1) improving the experimental task to induce the stated need for information in reality; (2) adding sound and visual prompts to draw attention to the CI, (3) adjusting the presentation and level of information to situational needs.

Regarding the overall analysis of acceptability, it is interesting to note that the facilitating conditions (knowledge, information, technical compatibility) and the ease of use are perceived very positively. The real impacts are observed on the side of performance and social influence. In other words, the simulation did not convince the users about the performance of the AVs. The low performance score could be related to the social influence score given the lack of acceptability of the population towards AVs [2].

• Interview Data

The interviews highlighted areas for improvement for the next round of the CI. The design of the new CI will have to meet the challenge of following these improvement paths while integrating new functions related to the other modules developed in the project. The technical architecture (IT) and the main functions (radar, accelerometer) can be preserved and improved. Some examples of improvements are listed below:

- Concerning the radar, the differences in the "with" and "without" interface conditions indicate a learning process. In other words, the radar is not very intuitive. It had a "discrete" display, i.e. it displayed elements of the situation in boxes, to situate them in relation to the vehicle. This display required a recoding of the spatial information from the simulator, which proved to be technically quite complex. To follow the suggestions of some users, it would be interesting to explore a more "continuous" display, for example by presenting the elements of the situation on a dynamic map. This solution seems more complex, but in reality the situation is easily transposable thanks to the OpenDrive protocol [33].
- The level of information will have to be adjusted according to needs expressed by the users. For example, they have indicated that they want to be reassured about the AV's ability to identify signage, rather than being informed about the signs themselves. Currently, 8 items can be displayed simultaneously for 30 s; a solution would be to display only the last sign for a few seconds and then replace them with the default speed limit, or a new sign if necessary.
- Finally, regarding visual density, the current interface highlights too many framed, coloured and juxtaposed elements. More subtle solutions should be explored to give visual priority to the most important elements in a given situation.

Other elements could have a significant impact on the redesign of the CI. Some participants mentioned a lack of appeal of the CI because it is positioned too low. However, raising the CI means hiding the field of vision. One solution would be to place the CI horizontally. Its attractiveness could also be increased with a sound dimension. Based on the empathic module, gentle sound cues could be emitted when the user is not paying attention to the road or the interface. These cues would focus on the location of other road users and emergency manoeuvres, which are frequently mentioned by the participants as being of concern.

Finally, the next version of the CI will be connected to the comfort modules mentioned in the introduction. The changes will include a control and information area linked to these modules. This area will replace elements of the initial CI that were not very functional or well understood, such as information regarding the vehicle and the user.

5 Conclusion

Often, product developments are driven by integration of new technologies into everyday objects or professional tools. In other words, designers look for use cases for technologies designed by their engineers, this is called "techno push" design. This study put into practice the opposite approach: knowledge about humans and their needs in a given situation was the starting point for a so-called "user-centred design". The theoretical foundations around mental representation outlined a first concept of AV control that responded, at least theoretically, to the needs formulated by a sample of users. On the technology side, this approach implies initially using existing software and hardware solutions, and reworking the developments needed to make them work together. The first prototype is not fully functional or very reliable, but it is sufficient to allow users to imagine its use.

In terms of methodology, user interviews proved to be a powerful tool for identifying areas of improvement for the interface, but also, more broadly, for gathering participant opinions on the future technology. At this stage of development, quantitative evaluations did not prove relevant for an object that was not yet fully functional. One explanation could be that the current interface was not functional enough to qualitatively or quantitatively enrich the mental representation of the IL. The next round of development will focus on an interface that is sufficiently finalised to observe an acceptability benefit for the (virtual) autonomous vehicles that are equipped with it.

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References

1. Endsley, M.R.: Autonomous driving systems: a preliminary naturalistic study of the Tesla model S. J. Cogn. Eng. Decis. Mak. **11**(3), 225–238 (2017). https://doi.org/10.1177/1555343417695197
2. Bel, M., Coeugnet, S., Watteau, P.: Monographie: acceptabilité du véhicule autonome. Manuscrit livré par Vedecom le 25 mars 2019 à la Direction Générale des Infrastructures, des Transports et de la Mer (DGITM) (2019)
3. BRAVE European Project (2021). https://www.brave-project.eu. Accessed 12 Sep 2021
4. Autopilot European Project (2020). https://autopilot-project.eu. Accessed 24 Feb 2020
5. Nielsen, J.: Usability Engineering. Academic Press, Boston (1993)
6. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. **13**, 319–339 (1989)
7. Chateau, B., Unrein, H., André, J.-M.: Exploring empathetic and cognitive interfaces for autonomous vehicles. In: Proceedings of the 4th International Conference on Computer-Human Interaction Research and Applications. SCITEPRESS - Science and Technology Publications (2020). https://doi.org/10.5220/0010130701390144
8. Hard, B., Recchia, G., Tversky, B.: The shape of action. J. Exp. Psychol. Gen. **140**, 586–604 (2011). https://doi.org/10.1037/a0024310
9. Zacks, J., Tversky, B.: Event structure in perception and conception. Psychol. Bull. **127**, 3–21 (2001)
10. Knutsen, D., Le Bigot, L.: The influence of reference acceptance and reuse on conversational memory traces. J. Exp. Psychol. Learn. Mem. Cogn. **41**(2), 574–585 (2015). https://doi.org/10.1037/xlm0000036
11. Sinigaglia, C., Rizzolatti, G.: Through the looking glass: self and others. Conscious. Cogn. **20**(1), 6474 (2011). https://doi.org/10.1016/j.concog.2010.11.012

12. Lamm, C., Batson, C.D., Decety, J.: The neural substrate of human empathy: effects of perspective-taking and cognitive appraisal. J. Cogn. Neurosci. **19**(1), 4258 (2007). https://doi.org/10.1162/jocn.2007.19.1.42
13. Davis, M.H.: Measuring individual differences in empathy: evidence for a multidimensional approach. J. Pers. Soc. Psychol. **44**, 113–126 (1983). https://doi.org/10.1037/0022-3514.44.1.113
14. Endsley, M.R., Jones, D.G.: Designing for Situation Awareness: An Approach to User-Centered Design, 2nd edn. Taylor & Francis, London (2012)
15. Lallemand, C., Gronier, G.: Méthodes de Design UX: 30 Méthodes Fondamentales Pour Concevoir des Expériences Optimales. Eyrolles, Paris (2018)
16. Politis, I., Langdon, P., Bradley, M., Skrypchuk, L., Mouzakitis, A., Clarkson, P.J.: Designing autonomy in cars: a survey and two focus groups on driving habits of an inclusive user group, and group attitudes towards autonomous cars. In: Di Bucchianico, G., Kercher, P.F. (eds.) AHFE 2017. AISC, vol. 587, pp. 161–173. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-60597-5_15
17. Venkatesh, V., Thong, J.Y.L., Xu, X.: Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS Q. **36**, 157–178 (2012)
18. Wintersberger, P., Frison, A.-K., Riener, A., von Sawitzky, T.: Fostering user acceptance and trust in fully automated vehicles: evaluating the potential of augmented reality. PRESENCE: Virtual Augmented Reality **27**(1), 46–62 (2019). https://doi.org/10.1162/pres_a_00320
19. Bastien, J.M.C., Scapin, D.L.: Ergonomic criteria for the evaluation of human-computer interfaces. Rapport Technique, INRIA (0156) (1993)
20. Hegner, S.M., Beldad, A.D., Brunswick, G.J.: In automatic we trust: investigating the impact of trust, control, personality characteristics, and extrinsic and intrinsic motivations on the acceptance of autonomous vehicles. Int. J. Hum. Comput. Interact. **35**(19), 1769–1780 (2019). https://doi.org/10.1080/10447318.2019.1572353
21. Davis, F.D., Venkatesh, V.: A critical assessment of potential measurement biases in the technology acceptance model: three experiments. Int. J. Hum. Comput. Stud. **45**(1), 19–45 (1996)
22. Rajaonah, B.: Rôle de la confiance de l'opérateur dans son interaction avec une machine autonome sur la coopération homme-machine. Thèse de doctorat de l'Université Paris 8. 27 février 2006. 234 (2006)
23. Robinson, S.L.: Trust and breach of the psychological contract. Adm. Sci. Q. **41**, 574–599 (1996)
24. Degenne, A.: Types d'interactions, formes de confiance et relations. Revista hispana para el análisis de redes sociales, 16. REDES (2009)
25. Karsenty, L.: Comment maintenir des relations de confiance et construire du sens face à une crise? Le travail humain **78**(2), 141 (2015). https://doi.org/10.3917/th.782.0141
26. Payre, W., Cestac, J., Delhomme, P.: Intention to use a fully automated car: attitudes and a priori acceptability. Transp. Res. F Traffic Psychol. Behav. **27**, 252–263 (2014). https://doi.org/10.1016/j.trf.2014.04.009
27. Jian, J.-Y., Bisantz, A.M., Drury, C.G.: Foundations for an empirically determined scale of trust in automated systems. Int. J. Cogn. Ergon. **4**(1), 53–71 (2000). https://doi.org/10.1207/S15327566IJCE0401_04
28. Rajaonah, B.: Rôle de la confiance de l'opérateur dans son interaction avec une machine autonome sur la coopération humain-machine. Thèse de doctorat de Psychologie Cognitive. Université Paris 8 (2000)
29. Bengler, K., Rettenmaier, M., Fritz, N., Feierle, A.: From HMI to HMIs: towards an HMI framework for automated driving. Information **11**(2), 61 (2020). https://doi.org/10.3390/info11020061

30. Maeda, J.: The Laws of Simplicity. MIT Press, Cambridge (2006)
31. Wickens, C.: Multiple resources and performance prediction. Theor. Issues Ergon. Sci. **3**, 159–177 (2002)
32. Howell, D., Yzerbyt, V., Bestgen, Y.: Méthodes statistiques en sciences humaines. De Boeck, Bruxelles (2008)
33. Association for Stadardization of Automation and Measuring Systems. ASAMA Open Drive. ASAMA, Standards (2021). https://www.asam.net/standards/detail/opendriv/