Exploring Empathetic and Cognitive Interfaces for Autonomous Vehicles

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Keywords: Autonomous Vehicle, Acceptability, Trust, Situational Awareness, Empathetic Interface, Mental Representation.

Abstract: The work presented is carried out within the framework of the European SUaaVE project, whose objective is to study different factors of acceptability of the Autonomous Vehicle (AV) and to test different solutions on a simulator. Among these solutions is an interface capable of informing the user at any time about the road situation and reassuring him/her about the information processed by the vehicle. To do this, it benefits from an empathic function to estimate the cognitive and emotional state of the user and offer answers in terms of comfort and information. This capability is based on a cognitive model of the passenger developed in conjunction with the interface. A comfort module (driving dynamics and ambient comfort) and an emotional module (participates in empathy functions) are developed in parallel by project partners. These modules will be integrated once the prototype presented here has been tested by users and adjusted.

1 STUDY CONTEXT

The Autonomous Vehicle (AV) seems to be emerging as a solution for the future. Some manufacturers are already proposing to take advantage of a certain level of autonomy (Endsley, 2017) and some States are opening their roads to these technologies. This is not really the case in Europe yet. Although road users are increasingly open to AV, there is still a long way to go to convince the population (Bel, Coeugnet & Watteau, 2019) and build a real transition. To achieve this, European countries are funding various projects around the AV (e.g. Autopilot, BRAVE). These projects examine everything that impacts its development, and everything that will be impacted by its deployment. An identified study question is acceptability, the intention of use (Nielsen, 1993)0, which is a predictor of the adoption of technologies 0Davis, 1989) such as AV. The SUaaVE project (SUpporting acceptance of automated VEhicle) brings together 10 European partners on this issue. In particular, SUaaVE questions new uses and features that can be offered by a "*level 4+* AV", i.e. 100% autonomous but still with manual controls. For example, a user freed from the driving task would be able to perform other activities that were previously impossible, such as sleeping, working or playing. However, these uses could generate inconveniences (e.g. motion sickness, fear) if certain factors are not taken into account, such as dynamics, comfort, emotions ...

To integrate these uses into VA development, the SUaaVE project focuses on 5 axes of innovation presented in Figure 1. Each axis involves the development of a concept that is refined iteratively, using user tests on a driving simulator.

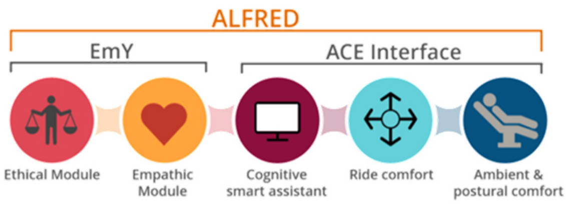

Figure 1: ALFRED, a travel assistant from 5 axis of study.

(Ethical Module, Empathetic Module, Cognitive Assistant, Conduit Comfort, Ambiant and Postural Comfort). ALFRED = Automation Level Four - Reliable Empathic

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Chateau, B., Unrein, H. and André, J.
Exploring Empathetic and Cognitive Interfaces for Autonomous Vehicles.
DOI: 10.5220/0010130701390144
In *Proceedings of the 4th International Conference on Computer-Human Interaction Research and Applications (CHIRA 2020)*, pages 139-144
ISBN: 978-989-758-480-0

Driver ; EmY = EmpathY unit ; ACE = Adaptive, Cognitive, Emotional.

The development axis presented here is based on a "cognitive" information system (Smart Cognitive Assistant), that is, capable of helping the user to construct a mental representation rich enough to understand the driving situation. The presentation of this work is based on the notion of mental representation, to understand the principles (1) of the assessment of acceptability, (2) of building trust and (3) of the design of a cognitive interface.

2 FROM MENTAL REPRESENTATION TO SITUATIONAL AWARENESS.

Mental representation is the key concept of this work. It is used here to define the measure of acceptability, to understand trust, to describe situational awareness and finally to propose a cognitive and empathetic interface. The theoretical concepts presented will be illustrated with the case of the use of a taxi, which has analogies with the use of an AV.

The mental representation of a device (e.g. a taxi) is the activation in memory of concepts specific to the device (e.g. car, driver, taximeter, yellow) or related to the use of this device (e.g. airport, luggage, travel, reserved parking). In other words, representation is based on elements from previous experiences. Among these elements there are also *event schemata* (Hard, Becchia and Tversky, 2011) (e.g. the way the driver welcomes the customer and handles luggage). Such a schema is a structure that encodes in memory an action (goal) and the intermediate actions (sub-goal, steps) necessary for its realization (Zacks and Tversky, 2001).

To construct or update his representation, an observer is able to rely on an empathetic mechanism by spontaneously taking the perspective of an observed actor. The observer then mentally simulates the actor's point of view and actions (Hard et al., 2011). It is also an important process in social interactions, for example it allows two interlocutors to activate a set of shared representations on which dialogue can be based (Knutsen and Lebigot, 2015). This empathic capacity would rely on nervous structures called mirror neurons (Sinigaglia & Rizzolatti, 2011 ; Lamm, Batson, & Decety, 2007) that activate in memory known patterns of action from observed behaviors. This allows the observer to understand what is the actor perceiving, how is he drawing his goals and how is he operating his actions (Davis, 1983).

These theories about representation provide a relevant perspective on the empathic mechanism at work to assess, for example, the abilities of a driver. They also show the limitations faced by the AV user: *how does he know what the virtual driver is doing?* However, these theories are also applicable in the other direction: the driver is able to simulate the mental states of his passenger and adapt his driving. This is a track that is explored in the project to support the user's situational awareness.

Situational awareness is an applied approach of mental representation. The model proposed by Endsley (Endsley and Jones, 2012) describes a continuous process in decision-making and evaluation of actions. This process is structured by three successive steps: (1) The perception of the elements of the situation, (2) the understanding of the situation, (3) the projection of the future status. Mental representation and situational awareness provide an understanding of the process of assessing acceptability and building trust, and outline the principles of a cognitive interface for AV.

3 TESTING THE ACCEPTABILITY OF AV FROM SIMULATIONS

Designers have a variety of methods at their disposal to improve the user experience of their future products (Lallemand and Gronier, 2018). In particular, it is possible to apply an iterative design approach, alternating design phases and testing phases, to gradually adjust the product. During the testing phases, the product is evaluated by measuring the user's attitude using questionnaires such as the TAM3 (Technology Acceptance Model, version 3) (Politis, et al., 2018) or UTAUT2 (Unified Theory of Acceptance and Use of Technology) (Venkatesh, Thong, and Xu, 2012). This type of tool offers a prediction of the acceptance of the future product from a real or simulated experiment performed by testers (potential users). Testers are immersed in a physical or virtual situation to construct a mental representation of the object as accurate as possible, and then they answer the questionnaire. Each item group in the questionnaire is comparable to a probe that extracts a specific fragment from that representation. For example, the first group of items in TAM3 extract the representation of the performance gain offered by the product; another group extracts the perceived ease of use, etc. TAM3 thus offers a look at different dimensions of product acceptability on practical (e.g. Perceived Usefulness), hedonic (e.g. Perceived Enjoyment) or social aspects (e.g. Subjective Norm), etc.

However, the acceptability of technologies based on forms of Artificial Intelligence (AI), such as AV, seems to encounter the issue of trust (Wintersberger et al., 2019) Trust is not tackled frontally in acceptability reference models such as the TAM (Bastien & Scapin, 1993 ; Politis et al., 2019), UTAUT (Venkatesh et al., 2012) or model of Nielsen (1993). However, the link between trust and acceptability has been studied for a long time and the emergence of AI has led to the enrichment of models (Hegner, Beldad, & Brunswick, 2019). Some determinants of trust are close to those of acceptability. Starting with the attitude that is associated with both acceptability (Davis & Venkatesh, 1996) and trust (Politis et al., 2018 ; Wintersberger et al., 2019).

4 A POINT OF VIEW ON TRUST ATTRIBUTION

On the same principle as acceptability, trust in a system is determined by different factors. There are many definitions of trust in a person (Rajaonah, 2006). 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 his or her interests." (Robinson, 1996).* This prognosis is based on clues of attributes, such as competence (Degenne, 2009 ; Karsenty, 2015) or reliability (Payre, Cestac & Delhomme, 2014).

These attributes can be found in the questionnaire proposed by Jian, Bisantz and Drury (2000) to measure trust in a system. In their model, they differentiated non-confidence factors (e.g. misleading, lack of transparency...) and confidence factors (e.g. reliable, understandable). The determinants of trust in a system (Henger et al., 2019 ; Rajaonah, 2006) are close to those of trust in a third party, especially for reliability that is fundamental for AV (Payre et al., 2014). Reliability can be assessed over the long term, which introduces a notion of familiarity that is favourable to trust (Rajaonah, 2006). In this case it is possible to assign a level of confidence in a target (person, group of persons, object or type of object) based on observations made over the course of the experiences with it. However, some situations do not have the support of recurrent experiences. This is the case, for example aboard a taxi in a foreign country, it is necessary to obtain quickly clues on the driver's abilities to provide the desired result. For this it is possible to use action schemata constructed on the basis of road experiences, and which allow the user to check whether the actions observed are compliant. If this is the case, trust can be established. These schemes are bricks of mental representation, but also of situational awareness.

5 PRINCIPLES OF AN EMPATHETIC AND COGNITIVE INTERFACE

The activities that can be carried out on board an AV will distract the user's attention from the road. The user's cognitive support covers two important aspects of the driving situation: road situation and autonomous driving. The road situation corresponds to the flow of information available in the environment that allows the user to understand the vehicle's behaviours (e.g. traffic, pedestrian presence, signage, weather, etc.). Autonomous driving refers to driving actions developed from information taken by the AV in the environment. The treatments operated by the AV are not very visible to the user given their speed and complexity. On the other hand, it is possible to make visible certain "goals" (e.g. increase speed, anticipate a traffic jam) and share some of the environmental information processed by the AV. This information is useful for passengers to understand how the AV works 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...

There is a lot of information available about the AV and the road situation. Design must respect a certain minimalism (Bastien & Scapin, 1993 ; Maeda, 2006) to avoid cognitive overload. The choice of information and sensory channels is an important issue, which should not compete too much with the activities of the passenger, at the risk of questioning the interest of the AV. This is where the empathetic nature of the interface comes into play. This empathy is ideally bi-directional in the same way as a communication situation: the user needs to understand how the AV works; the AV needs to "understand" the user's status to adjust their level of information. According to the iterative design principle, the first version of the interface provides a standard level of information. This level of information will be optimised in a second phase, based on user feedback and future measurement of the passenger's cognitive and emotional states. (see Figure 1 : *Empathic Module).*

6 INTERFACE DESCRIPTION

Two categories of information are displayed on the interface presented in Figure 2 : AV information, and road situation information.

To begin with, a first information group presents the state of the AV-passenger system in order to check his ability to travel. Three thematic sub-groups have been distinguished:

- *Traveling*, 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 (mechanical and computer), and an icon related to the current driving dynamics (calm, normal, sporty).
- *The passenger*, with an icon for the state of the monitoring (operational or not), and an icon for the activity detected (e.g. 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)

A second group of information provides feedback on the road situation in order to feed the user's situational awareness on the one hand, and on the other hand to enable him to check that the VA has relevant information to drive safely. Three subgroups are presented:

- *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.
- *The contextual flow* related for example to the presence of an intersection, the state of the road, etc. The type of road (e.g. urban, motorway) and the weather are permanent, the other information disappears when its becomes obsolete.
- *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 the safe distances. For example, a vehicle travelling in the same direction is displayed in green (peripheral cells of the radar) if the safety distances are respected. If this vehicle is too close, it turns orange and flashes to alert of a risk. If a vehicle follows a different trajectory (perpendicular or face) 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 real situation presented in Figure 3, we can presume that a glance at the radar captures more information on other road users than a glance at the real environment.

Figure 2: Interface overview. The coded information corresponds to the driving situation presented in Figure3.

Figure 3 : Baseline driving condition. Three minutes of real driving were filmed using glasses equipped with a camera. The path has been coded to dynamically generate the interface display.

The interface is presented on a touch screen to access additional information or settings for each item described above (e.g. User monitoring icon, general AV status icon, radar, etc.). This information or settings are displayed in a dedicated window (the grey frame in the top left corner). Information related to the trip is displayed by default. The content is automatically changed in the event of an alert (e.g. if a change in passenger activity has resulted in a change in vehicle dynamics). Finally, some information will be coupled with an audible signal (e.g., light clicks to indicate the presence of a vehicle that is too close) or a voice message (e.g., to reassure the passenger if road event has generated fear or anger).

7 CONCLUSION AND PERSPECTIVES

The design of this interface has raised many theoretical (e.g. cognitive impact) and practical questions (e.g. choice and cohabitation of technologies involved). First of all, each piece of information or interaction that makes up the interface involves a more or less important technical development. Therefore, choices were made in order to respect the schedule of the European project phases. Also, according to the principle of an iterative development, it was decided to validate the concept from a simplified version before engaging more technical and aesthetic developments (e.g. add audio or voice functions, refine visual code, etc.). As a result, some questions remain unsolvable, but preliminary tests have already made it possible to identify opportunities for improvement (e.g. too much visual presence of cars in the opposite way which are displayed in red on the radar). To go further, a test with 30 drivers is to be carried out on board a virtual simulator. Preliminary results will be presented in the final communication. These tests have the following objectives:

- Check whether functions and interface elements are correctly understood,
- Gathering the opinion of users on the contribution of this interface in an AV,
- Evaluate the gain in acceptability and confidence of an AV equipped with this interface compared to an AV without this interface,
- Collect passengers' needs for information about the situation according to their activity and emotional state.

In summary, the first user-test will have to provide leads to improve the interface's ability to help the user to mentally represent the environment and the functioning of the AV. In addition to this main objective, this test will also enable the concept to be validated and refined from a technical point of view, i.e. the system's ability to collect and process information of the vehicle in real time. The validation of this principle is important to prepare the integration of the modules developed by the partners (ethical, cognitive and emotional modules, comfort modules). A new version of the interface enriched with these modules and new functionalities will then be developed and tested in a second and third iteration. The final results will be integrated into a virtual demonstrator in order to present technological opportunities to the automotive industry. It is important to note that virtual environments offer increasingly richer representations, however the absence of validation in real conditions will be the main limitation of the developments carried out.

REFERENCES

Bastien, J. M. C., and Scapin, D. L. (1993). Ergonomic criteria for the evaluation of human-computer interfaces. *Technical report, INRIA*, (0156).

Bel., M., Coeugnet, S. and Watteau, P. (2019). Monograph: Acceptability of the autonomous vehicle. Manuscript delivered by Vedecom on March 25, 2019 to the General Directorate of Infrastructure, Transport and the Sea (DGITM).

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13,* 319-339.

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology, 44*, 113-126. doi:10.1037/0022-3514.44.1.113

Davis, F.D., Venkatesh, V. (1996). A critical assessment of potential measurement biases in the technology acceptance model: Three experiments. *International Journal of Human-Computer Studies*, *45*(1), 19-45. https://doi.org/10.1006/ijhc.1996.0040

Degenne, A. (2009). *Types of interactions, forms of trust and relationships.* 30.

Endsley, M. R. (2017). Autonomous Driving Systems: A Preliminary Naturalistic Study of the Tesla Model S. *Journal of Cognitive Engineering and Decision Making*, *11*(3), 225-238. https://doi.org/10.1177/1555343417695197

Endsley, M. R., and Jones, D. G. (2012). *Designing for situation awareness: an approach to user-centered design (Second Edition)*. London: Taylor and Francis.

Hard, B., Recchia, G., and Tversky, B. (2011). The shape of action. *Journal of Experimental Psychology: General, 140*, 586-604. http://dx.doi.org/10.1037/a0024310

Hegner, S. M., Beldad, A. D., and Brunswick, G. J. (2019). In Automatic We Trust: Investigating the Impact of Trust, Control, Personality Characteristics, and Extrinsic and Intrinsic Motivations on the Acceptance of Autonomous Vehicles. *International Journal of Human-Computer Interaction*, 1-12. https://doi.org/10.1080/10447318.2019.1572353

Jian, J.-Y., Bisantz, A. M., Drury, C. G. (2000). Foundations for an empirically determined scale of trust in automated systems. International Journal of Cognitive Ergonomics, 4(1), 53-71. https://doi.org/10.1207/S15327566IJCE0401_04.

Rajaonah B. (2006). *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.

Karsenty, L. (2015). How can we maintain relationships of trust and build meaning in the face of a crisis? *Human work*, *78*(2), 141. https://doi.org/10.3917/th.782.0141

Knutsen, D., and Le Bigot, L. (2015). The influence of reference acceptance and reuse on conversational memory traces. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(2), 574-585. https://doi.org/10.1037/xlm0000036

Lallemand, C., Gronier, G. (2018). *Ux Design Methods: 30 basic methods to design optimal experiences.* Paris: Eyrolles.

Lamm, C., Batson, C.D., and Decety, J. (2007). The Neural Substrate OF Human Empathy: Effects OF Perspective-taking and Cognitive Appraisal. *Journal of Cognitive Neuroscience*, *19*(1), 4258. https://doi.org/10.1162/jocn.2007.19.1.42

Maeda, J. (2006). *The Laws of Simplicity*. Cambridge, MA: MIT Press

Nielsen, J. (1993). *Usability Engineering.* Boston: Academic Press.

Payre, W., Cestac, J., Delhomme, P. (2014). Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation Research Part F: Traffic Psychology and Behaviour*, *27*, 252263. https://doi.org/10.1016/j.trf.2014.04.009

Politis, I., Langdon, P., Bradley, M., Skrypchuk, L., Mouzakitis, A., and Clarkson, P. J. (2018). 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 G. Di Bucchianico and P. F. Kercher (Eds.), *Advances in Design for Inclusion* (Vol. 587, 161-173). Springer International Publishing. https://doi.org/10.1007/978-3-319-60597-5_15

Robinson, S.L. (1996). Trust and breach of the psychological contract. *Administrative Science Quaterly, 41,* 574-599.

Sinigaglia, C., And Rizzolatti, G. (2011). Through the looking glass: Self and others. *Consciousness and Cognition*, *20*(1), 6474. https://doi.org/10.1016/j.concog.2010.11.012

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.

Wintersberger, P., Frison, A.-K., Riener, A., & Sawitzky, T. von. (2019). Fostering User Acceptance and Trust in Fully Automated Vehicles: Evaluating the Potential of Augmented Reality. *PRESENCE: Virtual and Augmented Reality*, 27(1), 46–62. https://doi.org/10.1162/pres_a_00320

Zacks, J., and Tversky, B. (2001). Event structure in perception and design. *Psychological Bulletin, 127*,3-21.