

Needs of senior and novice drivers for Human Machine Interaction design of autonomous vehicle back to manual control

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ABSTRACT

This study investigated drivers' needs and preferences for HMI design at the transition phase from automated to manual driving. This phase is crucial for road safety as the human will have to fit to the upcoming driving task requirements and to be fully aware of the external situation. Several focus groups involving seniors, novices, experts, and mixed population have been conducted to investigate needs related to these HMI features. Results allow identifying preferred perceptual modalities for each group in relation to the increase emergency of the takeover. Novice drivers and seniors can have similar needs to be reassured, with different HMI to reach this goal. The need to have messages with visual and auditory redundancy has been identified for the seniors. In addition to visual and auditory displays, young participants proposed innovative HMI solutions. The recommendations based upon these drivers' propositions are made available for HMI designers, in a process of human centred design involving users at the early stage of the development.

Keywords:

Autonomous vehicle, HMI design, road safety

1. Introduction

The concept of autonomous car is nowadays wide spreading, with a great hope in terms of road safety, replacing the human driver by reliable technology. But the presence of a human driver in the car at this stage of technical development stays necessary, as the entire road network will not be equipped, requiring transition phases between automation and manual control according to the zone. Then, as pointed out by several experts for many decades, until the driving task will be wholly automated on the full road network, there will be still an appreciable role for the human driver (Alecandri & Moyer, 1992; Barfield & Dingus, 1998; Fenton, 1970; Hancock & Parasuraman, 1992; Sheridan, 1970). In this framework, automated vehicles will create special challenges for the design of the Human-Machine-Interaction to allow safe transitions, to avoid potential confusion between human and automated system actions and to bring the driver back into the loop when necessary in a safe way (Flemisch, Schieben, Schoemig & Strauss, 2011a). Previous research on the safety of transitions from automated to manual driving has focused on assuring that the driver was aware of the transition, pointing out the importance of the design of the vehicle-driver interfaces (Flemisch *et al.*, 2011b). Further studies have shown that drivers' ability to take over when transition to manual control is required can be improved by providing information about the limits and the reliability of the automation (Seppeltand & Lee, 2007; Beller, Heesen, & Vollrath, 2013).

In order to overcome the potential negative impact due to non-acceptance or misunderstanding between user and automated system, HMI of autonomous vehicle will have to be intuitive, self-explanatory and well adapted to the reality of the activities conducted by the driver, especially before these critical phases of transition.

Several studies showed the importance of the user-centred approach in this context of design and implementation of technology in automotive context (Pauzie & Amditis, 2010). User-centred design principles state that human specificities should be taken into consideration at each step of the system development, from the design concept till the evaluation of the prototype, but it is important to correctly understand users' expectations at the very first stage of the concept development. Indeed, a concept correctly designed at the early stage will require less iterative processes to improve further

versions of the system and will limit the weight of further iterative improvements. So, in order to reach this goal, this study aims to involve future users at the early stages of the development of the autonomous vehicle HMI and to gather their opinions and preferences in order for the human factors team to set the ergonomic HMI design recommendations for the prototype. This approach has been recommended by the ISO norm 9241-210 “Ergonomics of human-system interaction, part 210: Human centred design for interactive systems” (2010) and demonstrated its efficiency in HMI design processes (Pauzié, 2012). In this framework, we investigated HMI design features proposed by samples of drivers, diversified by their age and their driving experience. The use cases were transition phases from automated to manual driving, with two levels of situation awareness for the driver during the autonomous phase. Results will allow setting up Human-centred design recommendations for the engineers in charge of the HMI development for an autonomous vehicle prototype in the framework of a research project funded by the French Research National Agency named “Autoconduct” (2017-2020).

2. Context of use and hmi intrusiveness requirements

2.1 Driver’s diagnosis, emergency of the situation and impact on HMI intrusiveness requirements

In this study, the guidelines stated in the ISO norm 9241-210 have been followed. The first step of this recommended normalized process is to understand and to specify precisely the context of use covered by the scope of the investigation. The defined purpose of the study is to identify drivers’ needs and preferences related to HMI design, in terms of perceptual modalities and nature of the content, during the transition phase from autonomous to manual driving. This transition phase is crucial for road safety, as the driver has to be fully able to take back control of the vehicle, whatever was the driver state during the autonomous phase of the trip. The challenge of the HMI in this situation is related to its adequate level of intrusiveness, in order to attract driver’s attention, without being too much disturbing. This level of HMI intrusiveness will have to evolve in relation to the level of emergency of the situation, as the time to take control back for the driver will become more and more closer. In this framework, we identified several successive steps (figure 1): anticipation (soft informative HMI informing the driver about the happening of the transition phase), preparation (2 possible levels of HMI according to the diagnosis made by the system about the driver’s reaction to the first informative HMI: driver is in correct posture or driver is not ready), then additional steps based upon the various potential levels of driver’s readiness and responses diagnosed by the system with an increase level of HMI intrusiveness in relation to the increase of the emergency.

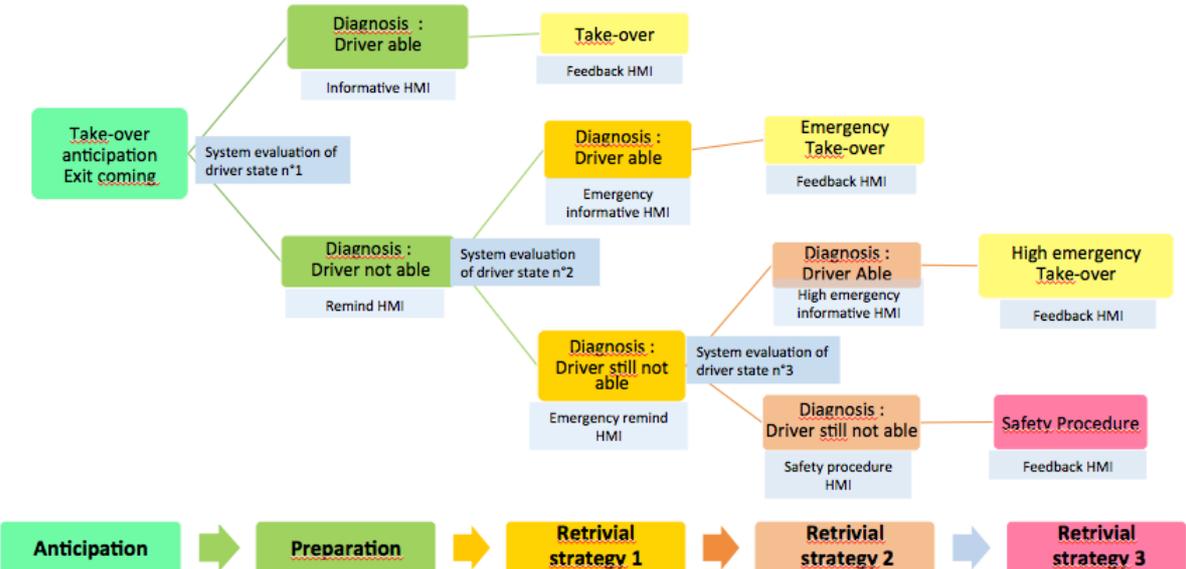


Figure 1: The various steps and the corresponding HMI intrusiveness in the context of use of transition phase from autonomous to manual driving

This schema allows identifying clearly that the level of HMI intrusiveness will be closely linked to the level of emergency of the situation, with a dynamic evolution from informative to intrusive, and to the driver's reaction diagnosed by the system at each step of this dynamic process.

2.2 Level of driver's situation awareness and impact on HMI intrusiveness requirements

Studies have shown that high automation levels will lead to an increase for the driver of non-driving-related tasks (e.g., Jamson, Merat, Carsten, & Lai, 2013). Thus, investigation on driving takeover safety should also involve consideration on the role and the impact of non-driving-related tasks previously run by the driver. In this framework, HMI will have to be more or less intrusive based upon the nature of driver's activities conducted before the manual takeover and their impact on the driver's state and his/her situation awareness. In order to investigate this issue, we proposed two contexts of use corresponding to two levels of driver's situation awareness: in one case, the non-driving tasks during autonomous driving were free, going from playing game, to reading or working on the computer; in the other case, the non-driving task was defined as the driver sleeping deeply. The purpose was to make participants setting up HMI design propositions according to the level of situation awareness corresponding to each of these two situations.

3. Focus group methodology

The methodology of focus group has been chosen to gather qualitative data about these needs and preferences regarding the HMI design. This method is an established and accepted part of the range of methodological tools available to academic researchers (Parker & Tritter, 2007). It consists in gathering individuals to openly discuss a particular issue, with one or two moderators guiding the discussion and leading the group through a number of activities (Caplan, 2010). The synergy between participants, through sharing and comparing of ideas with people stimulating and encouraging each other, is a distinctive characteristic of the focus group. The technique is suited for exploratory purposes, as questions with an open-ended nature can be examined. The information gained is qualitative, and consists of experiences, opinions, ideas, and motivations for behaviour, rather than "figures and facts" (Morgan, 1998). It is a well-established technique in market research for the designing of new products (Langford & McDonagh, 2003), as well as for human factor research and usability evaluation (Jordan, 1998). According to McKenna, (1990), the qualitative information from this techniques is particularly vital for design decision-makers as it is a relevant and fruitful approach from industrial design purposes to elicit user needs, aspirations and emotions for the development of successful new products (Bruseberg and McDonagh-Philp, 2001, Bruseberg & al., 2002). This workshop format appears to have several advantages in terms of methodology such as minimal participant training, collaborative group activities, individual and collective creativity and free expression.

3.1 Participants

There is a debate about the type of profile to choose to participate in focus group. Some authors recommended having **homogeneous group** of people (Ivanoff & Hultberg, 2006). In this case, participants share social and cultural backgrounds, they may feel more comfortable talking to each other and also are more likely to talk openly. **Heterogeneous group** of people have been also identified as working favorably by some other authors (Litosseliti, 2003; Hennink, 2007) because it is an efficient way to maximize the possibility of exploring topics from different perspectives (Kitzinger, 1995).

We consider that each point of view has relevant aspects so we decide to set up:

- 4 **homogeneous** groups of people: one group of seniors (over 65 years old), one group of novice (less than 2 years of driving license), one group of expert drivers (more than 10 years practice), one group of "professionals" (drivers obliged to drive intensively in the framework of their job).
- 2 **heterogeneous** groups of people mixing a combination of the 4 criteria above: senior, novice, expert and professional.

For a total of 6 groups with 8 participants each, so an overall sample of 48 drivers.

Seniors: In an ageing society, where the number of people over 65 years old is projected to double between 2010 and 2050 (Lanzieri, 2011), seniors users should imperatively be taken into account while designing innovative systems, in order to design adapted products to this population, especially in the context of road safety (Davidse R.J., 2006). Indeed, elderly drivers have specific functional abilities due to age, in terms of perception, cognition and motor control, with a high sensitivity of their level of performance in relation to time constraint (Pauzie, 2015). For example, they have more difficulties with maneuvers related to gap acceptance for crossing non-limited access highways, and high-speed lane changes on limited-access highways (Wang & Carr, 2004). They have also difficulties in attention sharing between several informative sources (Emmerson & col., 2012). So, we consider it was important to identify their needs and requirements in terms of HMI for the autonomous vehicle, in order to design adapted product that fit with this part of the population, knowing that seniors could benefit greatly from autonomous driving concept in the future. As a matter of fact, automation could be helpful to maintain seniors' mobility, and consequently seniors' health (as there is a strong relationship between the two: Dickerson et al., 2007), but this objective will be reached only if the vehicle design fits with their functional abilities.

Novices: The novice drivers have difficulties in self-calibration, hazard and risk perception due to their low level of practice (Ivers et al., 2009; Konstantopoulos et al. 2010). For example, novice drivers do not show awareness about road complexity in comparison with experts, suggesting that they fail to attend to potential dangers involving the behaviour of other road users (Underwood, 2007). In the case of transition phase, when the driver will have to take back control of the vehicle, it is possible that novice drivers need more informative HMI about the road context such as traffic density and complexity of the infrastructure than the other drivers, in order to compensate their lack of experience.

Professionals: We consider it was interesting to gather opinion and propositions from "professionals", as they can have specific needs related to their intensive driving activities under job constraints. Some authors in industrial design identified the value to involve regular users, defined as "lead users" who could expect to benefit significantly from a solution to their needs, as they are good candidates for drawing the attention of designers and developers to potentially important design requirements (Herstatt and von Hippel, 1992). Indeed, taking into consideration the fact that "professionals" are driving a lot under time constraint and with potential fatigue, their opinion toward autonomous vehicle context and adequate HMI design in transition phase will be certainly of interest for developers.

Experts: This group has a good practice of the driving activity, but no specific constraints like the professionals. Participants are middle-aged and in good health. Results from this group will constitute a baseline that will help us to define the potential specificities of the other groups.

3.2 Session

Each session was 3 hours duration. The first 2 hours were dedicated to investigate image, feeling, fears and expectations from participants related to autonomous car through various exchanges, discussions and questionnaires. The full session was video recorded, the recording serving as a material for the further analysis by the human factors team. In addition, facilitators observed the participants to make notes of the issues, the debates and the ideas that were produced.

In this paper, we are going to focus only on the final part of the session, where participants were asked to imagine, to create and to describe the HMI design for 2 identified use cases presented in the section 3.4.

3.3 Experimental protocol for HMI design

Each participant is asked to set a pair with an other one. The 4 teams are distributed in each corner of the room and one of the 4 use cases is given to each team (among the 4, only 2 use cases will be discussed in this paper for a question of available space). Based upon the context of their use case

description, teams are asked to describe and to draw the HMI design they imagine using pencils and the sketch of a car dashboard.

3.4 Use cases for HMI design

The use case description was the trigger element to aid the participants to imagine what was the context of use and what type of HMI design would be then relevant according to their view and preferences. We did not demonstrate any solutions in advance on purpose, in order for the participants to feel free to express their creativity without any external influence.

The objective was to gather elements of the HMI features proposed by participants based upon 2 use cases involving 2 different levels of driver's situation awareness in the transition phase. The description of the use cases was handed to each pair of participants as a support for their discussion and propositions. The texts were the following:

Use case n°1: "Your car is under autonomous mode for several hours and you reach the motorway exit you want to take. As planned, the car is asking you to take back control of the commands. How do you imagine this dialogue between you and your car?"

Use case n°2: "Your car is under autonomous mode for several hours and you are lying on your seat, sleeping deeply. The car indicates you that the planned motorway exit is close. How do you imagine this dialogue between you and your car? "

It has to be noted that for the non-related-driving tasks in the Use case n°1, most of the participants imagined to have recreational activities, such as reading, playing Sudoku or other games, except the "professionals", and some participants of the expert group willing to take this free time to work. The use of the phone for personal and professional purposes was widely mentioned by all the groups, including the seniors one. Most of them mentioned also looking at the countryside, which revealed activities corresponding to a high level of situation awareness in this case, with a state facilitating the next step of manual driving takeover.

When they were done, each pair of participants presented their proposition through sketch, drawing and verbal explanation to the group. Their propositions were presenting the successive steps of the visual, auditory and haptic HMI according to what they would have expected in the described situation of the use case.

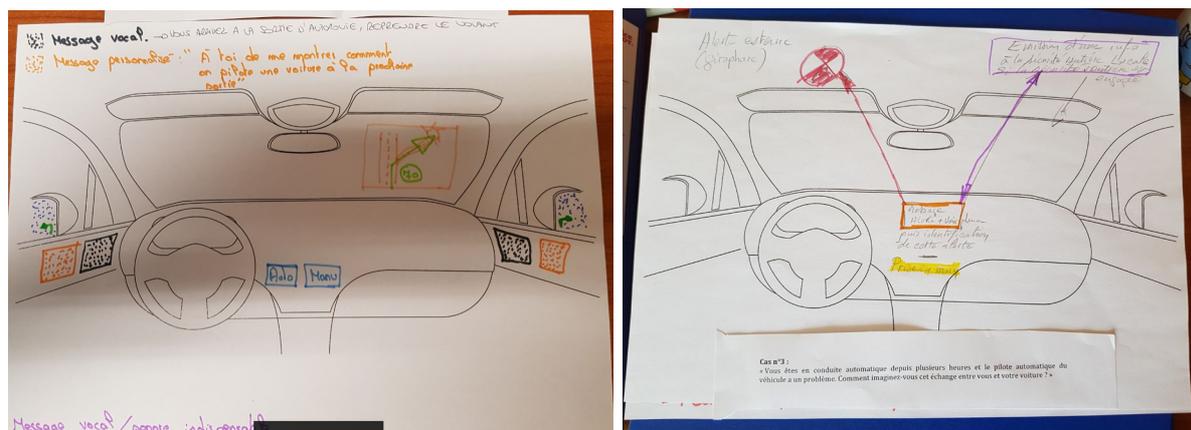


Figure 2 : Two examples of participants production concerning proposition of HMI design.

4. Results

4.1 HMI design in terms of perceptual modalities, technology and location

Propositions from participants have been analyzed and categorized according to the perceptual modalities involved, the corresponding technological displays and the locations in the vehicle:

- perceptual modalities such as visual, auditory, olfactory and haptic,
- technological displays such as screen, HUD for visual; vocal messages, music or sound signal for auditory; scent for olfactory, vibrations for haptic,
- locations in the vehicle such as car ceiling, around the windshield or on the steering wheel, on the windshield, on the dashboard or on the mirrors for visual; speakers in the car interior for auditory; car interior for olfactory and in the seat for haptic.

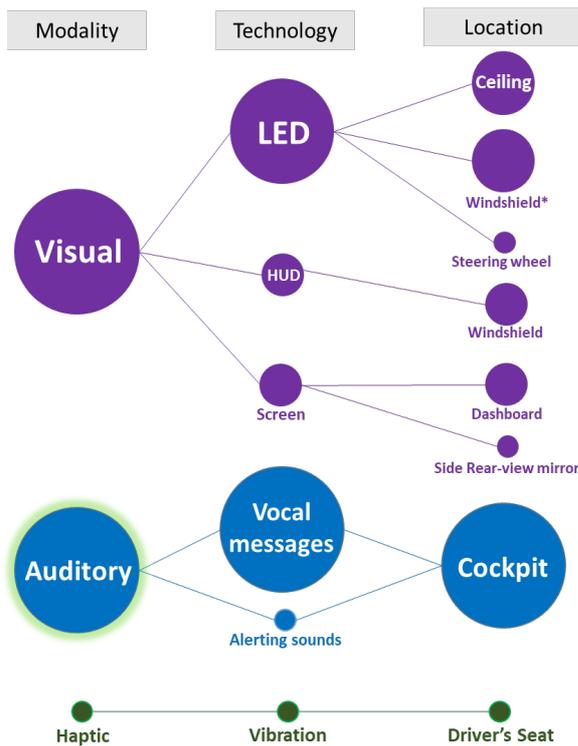


Figure 3: HMI for transition phase from autonomous to manual

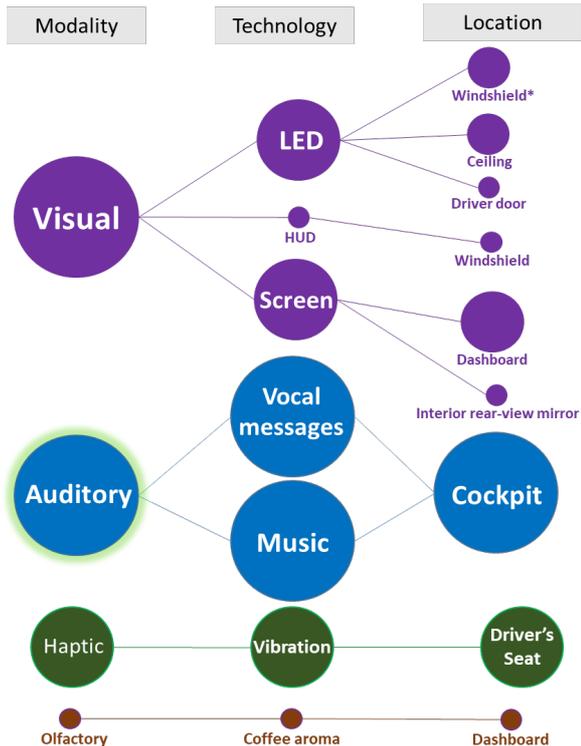


Figure 4 HMI for transition phase from autonomous to manual with low driver's situation awareness

These schemas displayed the HMI propositions for transition phase while drivers are awake but involved in non-driving-related tasks (figure 3) and for transition phase where drivers are deeply asleep, having then a very low level of situation awareness (figure 4). Bubbles' size is proportional to the number of propositions, giving then an insight about the importance of each HMI features based upon the participant's point of view. In both cases, the bubbles corresponding to auditory modality are encircled in green, showing the fact that, even if the number of propositions was similar to the visual ones, the participants insisted on the fact that this modality was more important. Music is the preferred mode of auditory information for the HMI to awake drivers (figure 4), with the justification that it is less stressful than sound. Advantages of vocal messages in the two situations are clearly stated, as it is a relevant way to give details about the coming events and the recommended actions to take. In relation to the low level of situation awareness in the second case, the haptic modality with the vibration of the seat is highlighted as a modality playing an enhanced role if auditory and visual ones happened to be not enough efficient, in order to ensure awaking when the time to take control back becomes close. Olfactory modality such as coffee aroma has been also suggested to awake driver.

4.2 HMI design propositions in relation to participants' age and experience

All participants proposed both auditory and visual messages for the HMI, insisting on the complementarity of the two modes. Seniors drivers insisted more than the other groups on the advantage of displaying both modalities even if the message content is redundant.

The auditory mode was preferred for most of the participants (that is why the blue bubble "auditory" on the graph is surrounded by green), as it was considered as being the most adapted perceptual mode to attract their attention. Indeed, there was a clear understanding from them that they were not having too much availability for the visual perception because they were involved in non-driving tasks, or even when they were having no activities and daydreaming.

All the drivers put forward usefulness of alerting sounds to alert them in emergency situations when actions are imminent. Only seniors insisted to have also some visual information in this context to confirm their perception, as most of them seemed to be a little afraid to have only one perceptive modality to rely upon. Their concern was to miss the auditory message or sound, as its emission is limited in time, while the visual message can stay displayed. In urgent situation, suggestions were that visual messages can present some characteristics of emergency such as the pictogram from road sign indicating "danger" with an exclamation mark in a red triangle or LED lights flashing in red, this color being widely understood as referring to danger.

The visual messages were valued in their capacity to give precise and detailed information to be consulted anytime by the driver at will. Participants proposed to have this type of visual messages during the anticipation phase, allowing them to know about the time left before the takeover maneuver and the related conditions to it. The professional drivers asked to have full information about the traffic surrounding, the type of road they will have to take, and some of them refer also to information on weather conditions, revealing that this group understood the importance of situation awareness recovering after the autonomous phase to be fully operational again, due to their high driving experience.

One of the requirements of the novice drivers was to have a kind of "avatar" displayed on the central screen of the dashboard, or even on the windshield with HUD technology, in order to get a dynamic and personalized dialogue, with vocal messages and vocal recognition, during the anticipation phase. Indeed, some novice drivers, around half of the sample, happened to be not fully comfortable to give control to the autonomous vehicle, while the other half seemed to be relieved in entrusting the driving responsibility to the system. In both cases, certainly linked to personality profile, a personification of the vehicle seems to answer to their concern. In the first case, the novice driver is reassured by the "human like" dialogue of the system, while, in the second case, the novice driver has the feeling to be comforted in his choice of trusting the system because it keeps him informed about important information. This expressed need for the novice group would be the result of both lack of driving experience and generational culture. It has to be noted that the seniors also expressed the same type of concern related to trust in the system, with the split in two categories of personality such as the novice group: one happy to rely on the autonomous system, to get some rest during long trip, and the other one not feeling a high level of confidence and trust to the reliability and the safety of the automation. Without referring to "avatar" like young people, some seniors formulated the wish to have a soft personalized voice to reassure them.

Most of the participants, whatever age and experience, stressed the importance to be informed well in advance before the takeover, in order for them to get ready, especially of course in the use case with low situation awareness. They stressed the necessity to have plenty of time before the manoeuver, in order to be fully prepared, to remove presbyopia glasses, to put away books and phone, ... During this preparation phase, the suggested HMI would be "soft" such as music and/or blue LED light. They propose to display this type of HMI to begin with and to increase little by little its intrusiveness, in order to raise their awareness progressively and smoothly. This concept of progressive HMI intrusiveness is even more highlighted in the situation where the participants were sleeping, with a high concern about setting up sweet wake up conditions.

Several participants, whatever age and driving experience, have proposed vibration of the seat as a way to attract their attention in case of lack of reaction to the previous set of messages, arguing that it would be difficult to miss this type of mode of communication, even if you have some problem of presbycusis, leading to difficulty to detect auditory messages, or if their eyes are closed.

In the scenario where the driver was asleep, novice participants proposed to emit coffee smell in the cockpit, inducing for some people a conditioned reflex of awakening. This mode of human system communication is clearly innovative nowadays, with several attempts since some decades in the area of digital scent (Hockmuth, 2013) but still technical difficulties to make it available on the market. Nevertheless, using smell as a mode of communication with the driver in addition to the visual and auditory ones is a relevant proposition in terms of concept to be used the day this technology will be fully mature.

5. Conclusion

Taking back control of the vehicle after a period of automated driving raised serious issues in terms of road safety due to uncertainty of the driver's functional abilities facing driving task requirements and the driver's level of awareness of the road context (Merat et al., 2014). During this phase, the human will be monitored by the system, with successive diagnoses to establish his/her level of awareness and ability to drive, leading to an adapted multimodal Human Machine Interaction (HMI) displays. In this framework, an important care will have to be devoted to investigate drivers' expectation and needs to ensure there will be an efficient cooperation between the Human and the Automated System via the HMI displays, especially before and during this transition phase. Investigation of HMI propositions design by a diversified sample of drivers indicated specific needs and preferences in relation to age and experience of driving, but also related to job constraints for professional drivers. In addition to these specific needs, there are also several requirements shared by most of the participants whatever these criteria. The human factors team will translate these data into applicable design recommendations in order to support the engineers' work in charge of the development of this driver's monitoring during the transition phase.

Acknowledgment: This research has been conducted in the framework of the Autoconduct project (2017 to 2019) funded by the French National Agency of Research (ANR).

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