Are You Ready for a Drive? User Perspectives on Autonomous Vehicles

Fig. 1 Robot Elf and autonomous car user interface

Andreea I. Niculescu
Institute for Infocomm Research
1 Fusionopolis Way 1,138632
Singapore
andreea-n@i2r.a-star.edu.sg

Alan Dix
University of Birmingham
School of Computer Science
B15 2TT, United Kingdom
alan@hcibook.com

Kheng Hui Yeo
Institute for Infocomm Research
1 Fusionopolis Way 1,138632
Singapore
yeokh@i2r.a-star.edu.sg

CHI'17 Extended Abstracts, *May 06-11, 2017, Denver, CO, USA*
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3053182

Abstract
In this paper, we present preliminary results of a user research study investigating factors with high potential impact on user experience (UX) of autonomous vehicles (AVs). The study was conducted in Singapore with 29 participants in 10 sessions, each one lasting around 2 hours. Participants conveyed their requirements verbally, as well as visually through sketching. The extensive rounds of discussions revealed an underlying trend of general mistrust towards AVs expressed in three requirement categories concerning: safety, empowerment and interaction style. In response to these requirements, designers need to ensure the vehicle's reliability is "expressed" in users' "language", passengers are allowed to have some decision power during navigation (despite the car being autonomous) and are able to interact with the AV in a flexible, easy and straightforward manner. We believe such design decisions would be beneficial to generate more trust towards AVs and improve the overall UX.

Author Keywords
User research; autonomous vehicle; UX; trust; reliability; safety; empowerment; interaction style;

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): User interfaces: user centered design

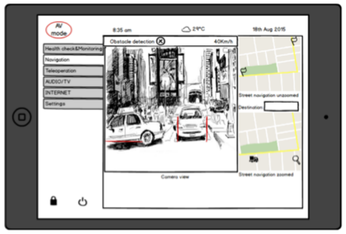

Fig. 2 Low fidelity sketch of the navigation screen

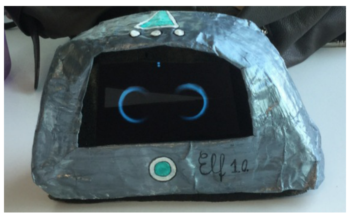

Fig. 3 Cardboard robot Elf

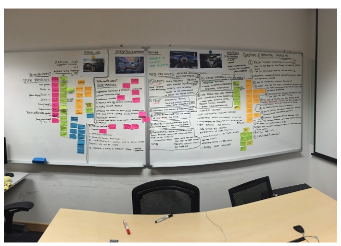

Fig. 4 White board at the end of the study

Fig. 5 Moderator demonstrating some of the robot's features

Introduction

Since Norman Bel Geddes envisioned self-driving cars in the 1939 World's Fair General Motors exhibit Futurama, autonomous vehicle technology has come a long way [12]. The first commercially-available driverless car Navia was launched in 2014 by France's Induct Technology followed by other car manufacturers, such as Mercedes, BMW and Tesla [11] [2]. However, while most work has been on technical features, little has been done in the way of UX design and user research [9][4]. Just a handful of studies report on designing UX for activities performed in AVs [10], gamification experiences [16] and conversational entertainment systems [17]. Similarly, the only available user research studies seem to be rather limited to public opinion surveys [6], [1], [15].

In this context, our study fills an important gap in the UX field by conducting in-depth user research in face-to-face settings. These settings enabled us to find out what people of different ages, backgrounds and life styles think about AVs, what needs they have and how these needs can be translated into user requirements. In short, our study goal was to determine factors with potential high impact on UX design of autonomous vehicles and gather design ideas from participants. Such ideas are interesting for us as we are currently working on a research project aiming at developing autonomous vehicles for daily city use. At the moment, our AVs can be driven in autonomous mode, but allow manual intervention and teleoperation: in cases of emergency, operators can use a minimal user interface to control the car [7]. For passengers, however, no particular UIs were developed. Therefore, with our study goal in mind we created some first interactive UI sketches (see fig. 2) along with a robot mock-up representing the car embodiment. The robot Elf, reminiscent of Nissan's Pivo [14] was built using a mobile phone mounted in a painted cardboard frame (see fig. 3). A voice and eye animation was run on phone each time the mock-up was demonstrated. The robot Elf's tasks were to greet passengers, check seat belts, "drive" the car to a desired travel destination and give information about traffic, estimated arrival time, monitor available parking places before arrival and redirect the car to another parking if no spots available [13]. The feedback received from the study was later used to develop our first high-fidelity prototypes for passengers[1] (see fig. 1).

Methods

The study was conducted by a moderator whose task was to lead the discussion and encourage participants to share ideas. Each session had three distinct phases. In the **first phase**, participants were shown short video documentaries about AV technology. The videos served as introduction for the participants to elaborate on user profiles, requirements, as well as possible dangers and problems associated with AVs. Since requirements are context dependent we chose a specific scenario as the basis for discussion: a daily AV drive with normal traffic in Singapore. Main discussion points were written on the whiteboard and grouped under several categories (see fig. 4).

To set the sessions on more concrete ground, participants received in the **second phase** our UI sketches and watched the moderator demonstrating the robot prototype (fig. 5). The sketches and the robot

[1] The development of these new prototypes is however, not the objective of this paper, but rather its by-product. We mention it for the sake of completeness at this particular stage as it gives readers a follow-up perspective on our current work-in-progress.

Fig. 6 Surrounding screen settings (info kiosk, video projector, TV screen)

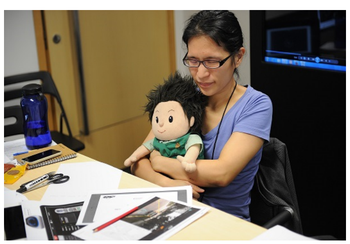

Fig. 7 Participant hugging a doll representing her daughter

prototype were meant to provoke reactions and boost discussions while at the same time to give informal feedback on our first design ideas.

Finally, in the **third phase** participants had the opportunity to articulate requirements visually by sketching their own concepts. During this phase, we played on the screens surrounding the participants continuous video-clips of people traveling in AVs (see fig. 6). We chose this method in an attempt to re-create the atmosphere inside of an AV.

All phases were meant to help participants express their deepest thoughts and fears towards AVs and translate them into requirements.

Experimental settings

The sessions were held in our design lab and lasted for 7 consecutive days. Two pilot test studies with 3 participants were run in advance. The studies helped us to restructure the session chronology more efficiently and to keep the schedule on track. Participants filled in a questionnaire with personal data, driving habits/preferences, as well as a consent form allowing us to record the sessions.

The sessions were recorded with three cameras: a frontal camera facing the participants and two ceiling cameras. Additionally, two annotators trained in psychology and linguistics took notes during the entire study. Their task was to observe participants' behavior, as well as the group interactions. One of our team members was in charge of taking photos while another one was responsible for the multimedia setup.

A total of 29 people participated in the study: 23 adults (ages 18–56), 3 teenagers (all age 15) and 3 children (ages 1, 3 and 8). Children were included as intrinsic part of their families participating in the study. 61% of the participants were male and 39% were female. We conducted 10 sessions in total (8 + 2 pilot studies). The sessions were held in groups of 3-5 people to enable more efficient group discussions.

One of the challenges we faced was to organize the participants in compatible groups. Compatibility makes people comfortable with each other and more prone to discussion. We took into account differences in age, gender, power distance (especially important in Asian contexts, such as in Singapore where our study was conducted), domain expertise, language fluency, nationality and family membership. As such, we formed groups of teenagers, young university students, HCI experts, work colleagues with same staff grade, English fluency and local/foreign nationality. Also, two young families with children took part in the study. Our goal was to get a broad sample of people of different backgrounds and lifestyles.

Results

The extensive round of discussions with our participants enabled us to identify several important aspects with high potential impact on the UX. These aspects can be categorized into three groups: 1. concerns about safety, 2. fears of lacking decision power and 3. worries of being overwhelmed by a complex interaction style with the vehicle. We also found that an unspoken lack of trust towards the AV seemed to subtly connect these aspects together, influencing the requirements our participants chose to express. In the following, we will discuss in detail each aspect group and their associated requirements as proposed by our participants.

***Safety**:* unsurprisingly, discussions around safety while riding in an AV in city areas were predominant in all participant groups. To provide a safe environment for

UX aspects	Requirements
Safety	- Report anomalies -Display obstacles detected -Enable AV tracks -Signalize AV mode with beacon -Predict emergencies -Multiple back-up plans for failure -Proven ability to cope human sabotage
Empowerment	-enable passages to change stop, change driving direction and take over in case of failure
Interaction style	- minimalistic interface design - info on request: travel to destination, traffic jams, calendar, connectivity to teleoperation desk, maps info on gas/charging station & toilets - modular interface allowing customization -physical buttons & voice feedback - wearables & robot presence

Tab1. Overview AV requirements

all traffic participants, the car is required to constantly monitor outdoor surroundings to detect anomalies. A reliable and up-to-date system was found to be a top factor influencing feelings of safety by other studies as well [3]. However, our participants found that simply having a reliable system is not enough: users need to be aware of its capabilities. As such, they requested any detected anomalies to be immediately reported back to users. Furthermore, road obstacles (e.g. pedestrians, traffic lights) and distance to the next vehicle should be constantly displayed on the UI. "Seeing" through the car's "eyes" would make passengers feel safer and would give them a feeling of control. One participant proposed special tracks for AVs on streets and expressways. AVs should also highlight their presence to other traffic participants by turning on a rotating beacon. This would warn drivers to be careful when driving nearby.

Another requirement mentioned was the car's capacity to predict emergencies and to have backup plans in case of failure. Participants requested manufacturers to provide at least two backup plans and inform passengers accordingly before starting the trip. Our initial proposal in emergency cases was a direct connection to a tele-operation desk that would offer instant advice or drive the car remotely to a safe location. Further, "*insurance companies*", said a male participant in his 30s, "*need to ensure that in emergency situations teleoperation services will be available within 10 seconds*".

The car's ability to cope with human sabotage was also mentioned as an important safety requirement. Here a distinction was made between voluntary (using a laser pointer to mislead car's sensors, hijacking, etc.) and involuntary human sabotage (during routine checks maintenance engineers could accidentally delete important files; this would lead to navigation problems resulting in accidents). While no immediate solutions to human sabotage were found, another further question was raised: "*Who is responsible if the car hits someone: the manufacturing company or the maintenance engineer?*", which was asked by a male participant in his 40s.

The car hijacking topic was extensively discussed especially in the context of children travelling alone- a particular topic of interest in Singapore where the majority of parents (due to high living costs) are both working [5]. To help participants to imagine themselves in such a scenario we gave them a doll and asked them to imagine the doll was their baby child (see fig. 7); the technique is inspired from theater performances and has been successfully used in previous design studies [8]. From a total of ten, six groups included at least one parent participant while four groups had no parents.

While both groups (parents/non-parents) reacted with additional sets of requirements (double safety locks for children, cameras that connect to a remote desk for parents to see their children, special safety belts, alarm baby sensors etc.) the parent group reacted more strongly, generating more discussions around the topic. The doll managed to raise parents' emotions to the point where one participant refused to return it while another discarded the possibility of ever leaving small children alone in the car considering it "*abusive and irresponsible*". Some participants requested highly secure authentication protocols to prevent hijackers from kidnapping passengers while several others warned against the danger of having too strong safety policies: *"[…] too much safety sometimes can be*

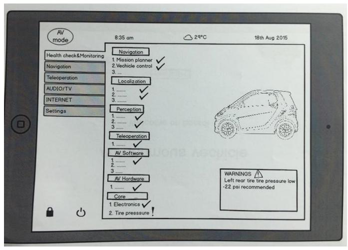

Fig. 8 Health check screen

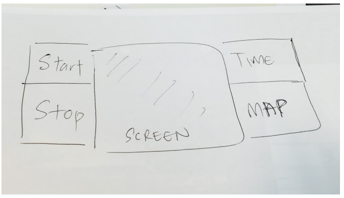

Fig. 9 Simple interface STAR/STOP

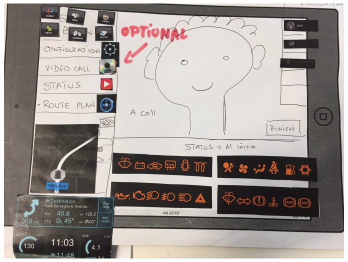

Fig. 10 UI with optional information

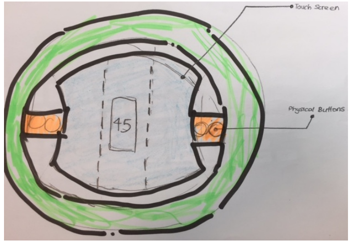

Fig. 11 Physical buttons

counterproductive. What happens if I have an accident and the authentication does not allow me to get out of the car?!", said a father of two in his 30s. Generally, the parent groups considered the use of AVs for children traveling alone unacceptable while the non-parent groups were rather neutral.

Empowerment: AV technologies promise a stress-free travel experience, but for those enjoying driving giving up control and decision power might not sound all too appealing. In our study, we found that concerns regarding lack of control arose more frequently among groups where enthusiastic drivers (a total of 16 people) were predominant. In particular, these participants requested a flexible vehicle that allows passengers to stop, speed up, slow down or change the driving direction at any point in time. While such requirements relate to a normal desire to decide where and how to be driven, several comments showed an unspoken underlying mistrust: *"I don't want to be trapped inside and go where the car wants me to go*", "*I think if the car takes a wrong path I need to do something", "What if the car is too slow and I am really in a hurry …?"* (male participants in their 30s). Additionally, the driving enthusiasts requested to be allowed to change completely from autonomous to manual mode. This would enable drivers to take over in cases of emergency when the internet fails and no further connection to a tele-operation desk is possible. This finding is similar to other studies reporting on people being more likely to use AVs if they could take back the control if needed [6] [1] while perceived control and fun decreased continually with higher autonomy [15].

Interaction style: given the fact that AV technology is fairly complex, participants expressed their concerns of seeing this complexity translated into the vehicle's interface and communication style. Our first UI sketches brought up this topic. Participants criticized the vehicle health-check screen as being too technical (see fig. 8): the information regarding several modules being successively checked was regarded as incomprehensible: "*Just show me what doesn't work and what I have to do*". Most of participants suggested a scanning visualization displaying percentages until completion with optional details for technicians[2]. It is crucial that reporting anomalies is done in users' "language" followed by an indication on how the problem should be solved.

The general look and feel of the interface is expected to be very simple, minimalistic, like for "dummies": "*something that indicates START/STOP and the address but nothing more"* said one of the female participants in her 30s (see fig. 9). Additional information on the interface should be displayed only on request to avoid cluttering; such information could include time & distance to destination, traffic conditions, daily schedule, maps highlighting the driving area with public toilets, etc. (see fig. 10). However, the connectivity status of the teleoperation desk is important to be always highlighted, i.e. whether it is on or off. The interface should be modular, i.e. it should allow customization depending on user's preference. This idea of modularization and flexibility was presented in a sketch by one male participant in his 20s. In his vision, the modularity would enable ordinary cars to become autonomous by connecting certain modules downloaded from internet to the interface.

[2] This suggestion was incorporated in our high-fidelity prototype as shown in fig. 1

Fig. 12 Wearables & interface focusing on detecting alcohol intake

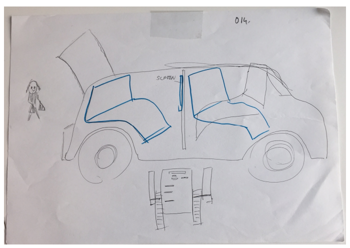

Fig. 13 Wearables & car with sensors opening doors to welcome a shopping mom

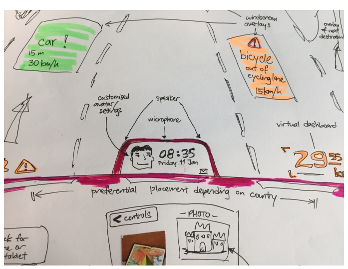

Fig. 14 UI with a customizable speech avatar/presence

Another interesting idea came from a male participant in his 30s (with no driving license) who suggested physical buttons; such buttons -similar to those typically encountered in trains and subway wagons- could be pressed or pulled in case of an emergency (see fig. 11). The suggestion exposes subtle hidden mistrust and fear not only about safety, but also about communication incomprehensibility in cases of failure.

Further, participants proposed several interface ideas relating to wearables. Wearables could, for example, detect alcohol intake and prohibit users from using the car in manual mode (collective work, teenager group – fig. 12); wearables could inform the car of users' immediate needs, such as opening the car doors when the user approaches with grocery bags (mother in family group – fig. 13) or set the optimal climate temperature according to user's body temperature (member of the university student group) etc.

Our idea of having a robot presence in the AV was welcomed by 19 out of 26 people. Three people indicated they would prefer a virtual character on the screen (see fig. 14) while the other four said they would like just a voice as a surrounding 'presence'. Such presence could be useful to offer guidance, help users find certain functionalities, undo actions performed by mistake and generally simplify the interaction through natural language use.

Conclusions and Future work

Autonomous vehicles are inevitable as technology advances. Consequently, investigating the UX design in this area becomes increasingly important. Discussions with our participants revealed an underlying trend of general mistrust towards the AV connecting through all three requirement categories: safety, control, and interaction style. Such mistrust is natural since the technology is new and people have never experienced it before, i.e. safety records are not yet proven. On the other side, mistrust can be a real handicap in bringing AVs to commercial success. As such, designers need to ensure an appropriate UX design that responds appropriately to people's concerns. Passengers have to be aware of the car's reliability and designers needs to communicate this reliability in a way users can understand. Further, the driving experience shouldn't give passengers the feeling of being trapped in the car, but rather offer alternatives for direct control. The participants made several concrete suggestions on how such requirements could be addressed from a UX perspective. In the future, we plan to test the new prototypes inside the AV under real driving conditions and deepen the analysis of our data collection to extract more differentiated user profiles. This would enable us to generate modular interface prototypes capable of adapting to different user categories. Further, our interest extends into the study methodology: we are interested in finding out how knowledge is generated by stimulating creativity and group dynamics. We plan to perform comparative studies to test the effectiveness of our methods in generating creative design ideas for generating trust towards AVs.

Acknowledgements

We thank our helper team comprising Lorraine Yang and Felicia Ang (annotators), Terence Zheng (photographer) and Julian Martinez (technical support), as well as to all our study participants. Special thanks go to Ryan Koh (Orka design), Boon Siew, Alvin Wong, Li Haizhou and the entire team of the Autonomous Vehicle department from I2R.

References

1. Accenture. Consumers in US and UK Frustrated with Intelligent Devices That Frequently Crash or Freeze, New Accenture Survey Finds. Feb. 10, 2011. Retrieved on Dec. 28, 2016 from http://newsroom.accenture.com/article_display.cfm?article_id=5146
2. Business Insider. 10 Million self-driving cars will on the road by 2010. Jun 15, 2016. Retrieved on Dec. 22 2016 from http://www.businessinsider.com/report-10-million-self-driving-cars-will-be-on-the-road-by-2020-2015-5-6
3. Michelle S. Carlson, Munjal Desai, Jill L. Drury, Hyangshim Kwak, and Holly A. Yanco. 2014 Identifying factors that influence trust in automated cars and medical diagnosis systems. In AAAI Symposium on The Intersection of Robust Intelligence and Trust in Autonomous Systems, pp. 20-27.
4. Tove Helldin, Göran Falkman, Maria Riveiro, Steffan Davidsson 2013. Presenting system uncertainty in automotive UIs for supporting trust calibration in autonomous driving. In Proc. of the 5th. International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2013)
5. Lai-Yun Ho. 2009. Raising Children in Singapore: A Paediatrician's Perspective. Retrieved from http://www.annals.edu.sg/pdf/38volno2feb2009/v38n2p158.pdf
6. Daniel Howard and Danielle Dai. 2014. Public perceptions of self-driving cars: The case of Berkeley, California. *Transportation Research Board 93rd Annual Meeting*. No. 14-4502.
7. IIRAV - Autonomous vehicle technology software. Retrieved on Jan 9th, 2017 from http://www.i2r.a-star.edu.sg/autonomousvehicle/technology/software
8. Christina, Jakobson. Dolls as propos representing users in design: physical qualities and their application. 2012. In Proc. of the 24th Australian Computer-Human Interaction Conference. ACM, OZICHI
9. Dagma Kern, Albrecht Schmidt. 2009. Design Space for Driver-based Automotive User Interfaces. In Proc. of the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2009).
10. Hyang Sook Kim, Sol Hee Yoon, Meen Jong Kim, Yong Gu Ji. 2015. Deriving Future user experience in autonomous vehicle. In Proc. of the AutomotiveUi '15, 112-8.
11. Samantha Murphy. World's First Commercially Available Self-Driving Car Launches. Jan 07, 2014. Retrieved on Dec. 22, 2016 from http://mashable.com/2014/01/06/navia-driverless-shuttle
12. Dan Neil, Driverless Cars for the Road Ahead. The Wall Street Journal (online edition). Sept 27, 2013. Retrieved on Jan 13, 2016 from http://www.wsj.com/articles/SB100014241278873238082045790852710659233340
13. Andreea I. Niculescu, Mei Quin Lim, Seno A. Wibowo, Kheng Hui Yeo, Boon Pang Lim, Michael Popow, Dan Chia, and Rafael E. Banchs. 2015 Designing IDA -an intelligent driver assistant for smart city parking in Singapore." In Proceedings of INTERACT, Springer International Publishing, 2015. pp. 510-513.
14. Nissan Pivo. Retrieved on Dec.30, 2016 from: http://www.nissan-global.com/EN/PIVO2/index.html
15. Christina Rödel, Susanne Stadler, Alexander Meschtscherjakov, and Manfred Tscheligi. 2014 Towards autonomous cars: The effect of autonomy levels on acceptance and user experience. In Proceedings of the 6th International Conference on

Automotive User Interfaces and Interactive Vehicular Applications, pp. 1-8. ACM

16. Ronald Schroeter, Andry Rakotonirainy, and Marcus Foth. 2012. The Social Car: New Interactive Vehicular Applications Derived from Social Media and Urban Informatics. In Proc. AutomotiveUI, ACM, 107–110

17. Jason Tester, B.J. Fogg and Michael Maile. 2000. CommuterNews: a prototype of persuasive in-car entertainment. In Proc. of CHI Extended Abstracts on Human Factors in Computing Systems, pp. 24–25.