TIC
Trust in Intelligent Cars

Public report

Authors: Annie Rydström, Kaspar Raats and Jonas Andersson

Date: 20-09-18
Program: Electronics, Software and Communication

Table of contents

1 Executive summary

The objective of this project was to combine naturalistic and experimental car studies with an ethnographic approach to investigate user experience of automated driving on public roads, and to study how the increased intelligence in and around the automated car affects trust in the automated car.

Several studies have been conducted within the project, using various as well as combined research approaches. The main focus has lied in what makes people trust the automated car and how they experience and behave during automated driving on real roads. The literature, as well as the research conducted within this project point towards that trust is continuously ongoing and that it develops and changes over time. Trust is affected not only by the actual experience of automated driving on real roads, but also experiences with technology in everyday life situations. This aspect of trust is important to take into account when developing an automated car. You as a manufacturer need to look outside the actual car and build trust through other mediums as well. Furthermore, by using both quantitative and qualitative research methods it was revealed that people's behaviour and experience of automated driving change over time, as they get more accustomed to the automated car. It was, as an example, shown that a majority of the people can and do zoom out from the task of driving when in automated driving mode on public roads, and do engage in non-driving related tasks. It was also shown that people are sensitive to how the car behaves and acts in different traffic situations. It is evident though from the research made that individual differences and preferences need to be taken into account when designing the user interface of the automated car. It is also specifically important to carefully design the information and feedback for the transient manoeuvres, to make the experience of handing over and taking back control of the car safe and delightful.

In terms of methodology, this project brought to light that experimental (especially on-road Wizard of Oz testing) and ethnographic approaches add to each other. In the project it was shown that ethnography investigates aspects of trust and experience that are not revealed by most experimental approaches. An approach that combines experimental and ethnographic research contributes to knowledge about how the dynamics of trust and experience are" embedded in situational factors, as part of people's real-life complex social encounters, contingent circumstances and improvisations with technologies" (Raats, Fors & Pink, 2020, p. 8). Furthermore, the project has shown that both qualitative and quantitative methods add to the understanding of people's behaviour and experience of automated driving, also over time.

An additional ambition with this project was to explore how to feed in research findings from long-term projects to an agile product development. From what we have experienced within this project it is emphasised that *cooperation* (how), *format* (what) and *entry points* (when) are three essential aspects for improving the uptake of research findings in agile development.

2 Background

It has been highlighted that Automated Driving (AD) has the potential to give positive societal effects in terms of environment, safety and mobility. Moreover, the technology can give drivers time to relax or be more productive in their daily commute. However, the potential benefits are all dependent on the willingness to use highly automated vehicles, stressing the importance of user centred research to reach a high level of willingness to use. This project has focused on how unsupervised automated driving is anticipated and experienced when travelling on public roads and how the increased intelligence in and around the automated car affects trust.

2.1 Trust in intelligent vehicle technology

Intelligent vehicles have become important for the evolution of the transportation infrastructure in mega cities. Trust is a central concept in the design of new technologies and is particularly important in AD vehicle design in relation to both user experience and safety. As we move into a phase where AD cars are becoming a reality on the roads, we need to develop new ways of conceptualising and designing for trust that are specific to a new automated context where intelligent technology is an integrated part.

Existing research into trust in design research contexts and in sociology has tended to treat trust as an interactional or transactional relationship (Harper, 2014). This means that in the context of human-machine relations it has focused on human trust in interfaces and in technologies and in doing so has neglected the wider social, digital and material contexts in which trust is generated. A systematic review of trust in automation has suggested that we need to attend to the variability in types of trust, such as 'dispositional trust, situational trust, and learned trust' (Hoff & Bashir, 2015).

Being on the road is part of a social situation, both inside the car and in relation to other drivers (Merriman, 2007; Laurier & Dant, 2012; Meschtscherjakov et. al, 2017), and where digital technologies and communications, user communities of traffic platforms, artificial intelligence (AI) and IoT (Internet of Things) are becoming increasingly important. To understand trust in AD vehicles, AI and the digital technologies with which they will become interoperable in the future, there is a need to expand beyond existing traditions in research and gain an in-depth understanding of this social, digital and material context as it emerges. This includes investigating how trust is learned, experienced, and connected to safety in AD vehicle user experience and expectations. However, it is also of wider significance because it also contributes to new knowledge on questions relating to how trust in AI and automated technologies more generally is emerging in new social, material and digital relations of IoT contexts and the growing interest in new combinations of digital services and vehicles.

This research therefore has direct relevance to the existing and currently growing body of research and scholarship in design and user experience research, and the social sciences, relating to AD vehicles and AI and automated technologies generally (Meixner & Müller, 2017). By looking into how trust in AD is developed in a wider sense, both socially and in human-technology interactions, the knowledge can be used to inform more detailed experimental testing on the road. In this project design ethnography in combination with experimental testing has been used for studying trust in the combination of AI and AD.

To successfully introduce automated cars, where automated mode is extensively engaged, the cars need to be experienced as safe and trustful, both by the people travelling in and people outside the automated car. Previous research has shown that "aspects known to determine current interactions, such as formal rules and regulations, informal rules and non-verbal communication, expectations, and behavioural adaptation are likely to play a different role in a system with automated vehicles or in a system with a combination of (partly) automated and manually-driven vehicles" (Vissers et al., 2016). Hence, this project has gone beyond testing experiences of automated driving at test tracks and entered the real world to get evidence and input for future design.

2.2 Research methodology

In this project different research methodologies have been used and also combined. Below, the experimental methodology Wizard of Oz, design ethnography and how the different (and other) approaches have been combined are described.

Experimental methodology – Wizard of Oz
In a publication by Osz et al. (2018), written within this project, the experimental research approach of Wizard of Oz (WOz) was described as the following:

> For an iterative UX design process there is a need to be able to put people in the right context when conducting evaluations. In the area of AD, evaluations need to be made in a realistic environment before fully functional AD cars are available. For this car simulators can be used, but to get a more realistic and ecologically valid test setup the WOz methodology is more promising. The WOz technique is an approach that has been used for evaluating user interfaces in various domains, from robotics (Hoffman & Ju, 2014) to mobile applications (Carter & Mankoff, 2005), and automotive industry (Mok et al., 2015; Habibovic et al., 2016). It is based on the idea of simulating a fully working technical system by a human operator – a wizard (Steinfield et al., 2009), and is used to gather data from users who believe they are interacting with an automated system. The WOz technique has been used in the automotive research community primarily for the design and study of automotive user interfaces, such as interfaces for driver assistance, information and entertainment (Alperm & Minardo, 2003; Geutner, Steffens & Manstetted, 2002; Lathrop et al., 2005; Schuller et al., 2006; Schmidt et al., 2008; Tsimhoni, Smith & Green, 2004). Recently, it has been applied for evaluation of interactions with systems of higher level of automation (Mok et al., 2015; Habibovic et al., 2016) to gather data from users who believe they are experiencing and interacting with a highly automated car. Compared with a real automated system, the WOz setup generally enables less constrained experiments - through use of improvisation. Also, it may enable more systematically constrained experiments - by cutting out the limitations of an automated system (Dahlbäck et al., 1993). It does this in a way that is not reliant upon the development of new software and algorithms to control the vehicle, as is the case in real computer-operated systems (Riek, 2012). Given its versatility, WOz is a good platform to examine interactions between humans and automated cars. However, the field of WOz testing, which is an important element of AD design research in the automotive industry (Coelingh & Nilsson, 2018), has tended to primarily remain attached to the specific psychological disciplinary orientation and set of analytic and research practices. Interactions have mostly been focusing on momentary usability in a simulated setting to gather information about the nature of driver-car interaction but has lacked consistent, theoretical understanding of the concept of human experience (Pettersson, 2016). (p. 13)

Design ethnography
Design ethnography combines methods from the social sciences and design to undertake in depth analysis of the real everyday contexts of product and service use. These methods have been successfully developed in the field of design anthropology (e.g. Gunn et al., 2013) and in applied research in other technology fields (e.g. Pink et al., 2013; Pink & Mackley, 2014; Pink, Morgan & Dainty, 2014; Lingard et al., 2015). The strength of ethnographic methods lies in their ability to illuminate and bring understanding about people's real behaviour and attitudes as they unfold as an aspect of their daily lives. This project has engaged design ethnography to undertake in depth analysis of people's real everyday contexts, also when using the WOz cars. The ethnographic research approach engaged in this project has used immersive participant observation and interviewing methods, innovative video and digital techniques.

Combined research approach

By combining qualitative and quantitative approaches data driven methods could be used to identify physical variables that predict a particular behaviour (Sivaraman & Trivedi 2013). In this project, we have explored how data driven methods can be used to model behaviour based on data collected from the user, the vehicle and the context. By probing collected qualitative and quantitative data by means of data mining methods, new correlations have been discovered that inform future user interface and vehicle system design. For example, particular human behaviour and reactions can be linked to how the vehicle behaves in the real traffic context. In addition, behaviour of surrounding vehicles also influences the behaviour of the human driver and could potentially affect the information content provided by the user interface.

In a publication by Raats, Fors & Pink (2020, p. 8), written within this project, it is described how this project "entailed an interdisciplinary approach to researching trust in intelligent cars, in terms of experimental and ethnographic methodologies in on public roads by engaging both the strengths of laboratory experiments in hypothesis testing through rigorous control measures to pinpoint sole explanations to a phenomena (Tanner, 2018) and those of ethnographic approaches in capturing the rich explanation and meanings of people's everyday life interactions with technology (Balfe et al., 2018)." Further, Raats, Fors & Pink discuss how ethnographic and experimental research methodologies were combined within the project:

> The implications [...] for the TIC project was to design a methodology that rather than chronologically ordering one approach before the other, integrated the different approaches and enabled them to feed into each other. Experimental studies involved participants driving WOz cars to assess and measure trust through fixed questionnaires, video and audio analysis, and biometric data collection. Exploratory investigations involved ethnographic fieldwork and in-depth interviews to investigate how intelligent technology influences trust development in participants' everyday lives. Three iterations of this process allowed the experimental methods to evolve by taking into account insights from the ethnographic fieldwork while insights from the experiments were used to design ethnographic studies to validate the measurement findings in real-life situations (Balfe et al., 2018). (p. 8)

3 Objective

The objective of this project was to combine naturalistic and experimental car studies with an ethnographic approach to investigate user experience of automated driving on public roads, and to study how the increased intelligence in and around the automated car affects trust in the automated car.

4 Research questions

The research questions were divided into user experience and research methodology:

User Experience

1. How does intelligence in vehicles (AI) influence expectations and experiences of trust in AD?
2. How is unsupervised AD experienced when used on public roads?
3. How should drivers be supported as they change their behaviour and attitudes over time when travelling in unsupervised AD mode?

Research methodology

1. When using WOz, what are the most suitable combinations of data (qualitative and quantitative) for exploring driver behaviours in a combined naturalistic-experimental test setup on public roads?
2. How can trust in intelligent technology (AI) and AD be studied?

5 Results

The project has been divided into two Work Packages (WPs): Experimental WOz testing and Trust in AI technologies. WP1 has focused on developing the Wizard of Oz (WOz) technique to enable studies of AD user experience on public roads, as well as conducting and analysing data from tests in real life traffic scenarios where the test participants perform tasks available in future automated vehicles. WP2, which is a PhD project, has focused on studying how users engage with the possibilities and potentials in AI and AD in cars and how they trust in the technology. In addition, within this project there has been an analysis on how to best conduct and feed in user experience research within agile development.

5.1 Experimental WOz testing

In the experimental WOz-testing a variety of qualitative and quantitative data sources have been used and explored, such as car signals, eye-tracking, biometric sensors, questionnaires and interviews.

AstaZero methods study
The aim of the study was to use quantitative and qualitative methods to investigate participants' behaviour over time when experiencing highly automated driving and capture effects of repeated interaction between drivers and AVs. Each of the eight drivers participated in the experiment on two 90-minute tests with a one-week interval. On both occasions, the drivers travelled approximately 40 km on a rural road at AstaZero proving grounds in Sweden and encountered various traffic situations. The participants could use automated driving (SAE level 4) or choose to drive manually. Examples of data collected include biometrics, gaze behaviour, perceived safety, as well as interviews and questionnaires capturing general impressions, trust and acceptance. It was found that perceived safety increased and then stabilized with increased AD experience and that first encounter effects were attenuated over time. There were smaller variations in driver behaviour during the second occasion and drivers were then faster to engage in non-driving related tasks. There were decreased eyes on road time with more AD experience.

Gothenburg commute
The aim of this study was to explore the usefulness of a highly automated driving system operational in congested traffic situations when commuting in Gothenburg. In this study five participants got to use a WOz-car in their daily commute to and from work two days in a row. In the study, before and after ethnographies were conducted (see section “Ethnographic fieldwork on trust”). The results showed that the operational design domain of the highly automated driving system does not provide sufficient AD time in a city like Gothenburg.

Sunnyvale commute
This study investigated drivers’ performance and experience when resuming control from a highly automated driving system operational in congested traffic situations. This study put the focus on non-critical take-overs. Twenty drivers drove a route in rush-hour traffic in the San Francisco Bay Area, USA. The highly automated driving system became accessible when the external availability conditions were fulfilled. The session was concluded with an interview where the participants were specifically asked how they experienced the take-over situations. The results showed considerably long take-over times at the first occasion, but it decreased with exposure and the experience of the take-over situation varied between different user groups. It is emphasised that first encounters and individual differences need to be considered when designing the human-machine interface for highly automated driving systems to ensure safe and pleasant take-over situations.

Biometric sensor feasibility mini study
The purpose of the mini study was to explore the feasibility of a few novel biometric sensors in experimental WOz testing. The study included a sweater with advanced pulse sensors developed by RISE and an emotion face recognition system. The aim was to see how well the emotion recognition system corresponded to subjective ratings of emotions rated post-test by the participants and also to test the feasibility of using a sensor sweater in vehicle user testing. Two participants were recruited and tested the equipment in city traffic and on a highway around Gothenburg. In the city environment the vehicle was driven manually, and the AD mode was offered and tested on the highway by means of the WOz capability. In the study we found no correlations between the emotion recognition system and the emotions rated by the participants. The sensor sweater performed well and provided higher accuracy and data quality as compared to a wrist type pulse watch, avoiding motion artefacts in the data. The results also show large differences between participants (however only n=2) in terms of both biometric data and subjective ratings, indicating a need for a personalised approach to data analysis when using biometrics.

Driver behaviour and experience in different levels of automation
The aim of this study was to explore how well drivers are able to engage in a non-driving related task (NDRT) while in automated driving mode in real traffic. The study was performed on a highway route in Gothenburg. The NDRT consisted of a mental rotation task administered on an iPad. The task was designed to be visually and cognitively demanding and require manual interaction. Driver behaviour and performance was measured using visual behaviour (eye-tracking), secondary task, subjective ratings and interviews. The results show that the drivers could shift attention from the driving task and hold focus on the secondary task while in AD mode. Participants performed the secondary task equally well in the car on the highway as in an office (e.g. correct answers, time to completion), indicating that task performance does not deteriorate in the automated vehicle. However, several participants reported that they reacted to changes in the traffic environment and sudden changes in the vehicle motion. For some, this was a factor in feeling safe. Also, several participants were surprised by their own ability to let go of the driving and engage in another task. The results give further evidence to the ability and promise of automated vehicles to “free up time” and in fact enable drivers to engage in non-driving related activities.

5.2 Trust in AI technologies

Literature review on trust
An extensive review of the Human-Computer Interaction (HCI) trust in automation and autonomous vehicles literature was undertaken, building up the understanding of how trust is being conceptualised as well as investigated. The review was made in order to answer a) what are the key themes in HCI methodologies used to research trust in automation and Autonomous Vehicles (AVs), b) how do they account for trust in AVs as part of wider contexts, and c) how can these methodologies be developed to include more than momentary and individual human-machine interactions. The results from the analysis of the state-of-the-art has been published in a conference paper (Raats, Fors & Pink, 2019) and a journal article (Raats, Fors & Pink, 2020).

The review showed that theoretical understanding of trust in automation and Autonomous Vehicles (AVs) in transportation HCI considers trust to evolve over time, and to be influenced by dispositional, situational and learned factors. Nevertheless, analysis of HCI trust in automation and AVs literature shows that HCI trust research tends to dominantly rely on quantitative research in simulated scenarios in laboratory settings. Focus has mainly been on reliance related factors such as system performance and design features. This has created a significant body of knowledge on how trust is being rationalised, assuming that trust evolves between a person and technology in a momentary interaction (Hassenzahl, 2010; Harrison et al. 2007). Simultaneously, a growing body of research proposes moving beyond laboratory experiments and exploring also the situational and dispositional aspects of trust development.

Emerging research argues also that trust is continuously ongoing and evolves through people's experiences with technology in contingent everyday life situations in socially and culturally specific circumstances (Pink et al., 2020). Raats, Fors and Pink (2020, p. 9) emphasized that "few of the reviewed methodologies are designed to capture social and technological complexities the smart automation and artificial intelligence (AI) enable in form of entangled interfaces between human and non-human actors (Frauenberg, 2019)". Therefore, to develop this body of knowledge it is proposed to engage with social theories that account for wider social and cultural context in which the trust evolves (Corsín Jiménez, 2011). As Raats, Fors and Pink (2020) further explain:

> [...] experimental and ethnographic insights complement each other within the framework of existing trust models, demonstrating how ethnographic (and other real-life based approaches) investigate aspects of trust that are not revealed by dominant experimental approaches. An approach that combines experimental and ethnographic research thus contributes to knowledge about how the dynamics of trust formation are embedded in situational factors, as part of people's real-life complex social encounters, contingent circumstances and improvisations with technologies. (p. 8)

Ethnographic fieldwork on trust
In 2018 ethnographic field work was conducted with drivers in the Gothenburg area. The main purpose was to explore mixing explorative methods with experimental testing; and to develop skills in ethnographic field work. This resulted in a conference paper (Osz et al., 2018) submitted to the Australian Conference of Computer-Human Interaction (OzCHI'18).

Ethnographic fieldwork on trust in algorithm development process for intelligent vehicle technologies
In 2019 and 2020 ethnographic field work was conducted with algorithm developers in Sweden and in the US. The focus of the study was on how trust is present in the practices and meaning making of AV algorithm developers. It was found that trust is embodied differently depending on the situation. The preliminary results show that these embodiments can be categorised into seven different, but connected, categories. The categories are being presented, and arguments on how acknowledging these categories can help HCI research and design in designing trustworthy intelligent technologies are being currently written into a journal paper and planned to be submitted in 2020.

5.3 User experience research in agile development

For the automotive industry to stay competitive, more rapid development cycles are needed. This can be managed by adopting agile processes. Research can influence industry by showing the way by exciting results or by giving input by close collaboration in daily development work. In this project we explored how to integrate user experience research efforts into agile development processes in the vehicle industry. There are clear similarities between traditional research and agile development. It is iterative, development starts with a hypothesis, it includes testing and evaluation and dissemination. From our experience, there are also major differences that pose challenges in the synchronization between the two, as well as in the traceability of the implementation of research results. From what we have experienced within this project it is emphasised, that *cooperation* (how), *format* (what) and *entry points* (when) are three essential aspects for improving the uptake of research findings in agile development.

As an applied example, the industrial PhD student has brought the knowledge and findings from field work and literature review into the agile product development process by taking part in a collaborative environment (cooperation), involving both academics and people from industry, and sharing the latest research findings weekly on debrief meetings with teams within product development at (format and entry points). He will continue to do so as the new results and understanding emerge through further analysis and learnings.

6 Dissemination and publications

6.1 Dissemination

Insights from design ethnography have been developed in dialogue with the experimental studies throughout the project. In addition, workshops with stakeholders within Volvo Cars have been conducted to discuss how to incorporate insights from long-term research in an agile way of work. The following international research internships, presentations and workshops have been carried out by project members:

- **Newsletter notice:** “Ja, vi kan! Svensk forskning”. In OmAD Newsletter, December, 2017.
- **Internship:** The industrial PhD student spent a month as a guest PhD researcher at Monash University, Melbourne, Australia in 2019 where he networked with people researching and designing in fields of transportation e.g. automated vehicles, and sustainable development and innovation. He also became part of an international research initiative of Re-Humanising Automated Decision Making where scholars share knowledge and experiences on topics such as big data, digitalisation, AI. In 2020 he became part of the Center Of Excellence in Trust in Automated Decision Making connecting researchers from Australia, Singapore and Sweden.
- **Conference presentation:** “Combining WOz testing and ride along video ethnographies: advancing methodologies for Autonomous Driving car development for mixed traffic environments”. Annual Halmstad University School of Information Technology conference. Båstad, Sweden. February, 2019.
- **Presentation at seminar:** “Exploring user experiences of the autonomous car – outcomes from the HEAD and TIC projects”. Future Mobilities Workshop. Monash University, Melbourne, Australia, March 2019.
- **Presentation at seminar:** “Ethnography and Self-Driving Cars”. Digital Design Ethnography: Technologies, People and Futures. Monash University, Melbourne, Australia, March 2019.
- **Conference presentation:** “Combining WOz testing and ride along video ethnographies: advancing methodologies for autonomous driving car development for mixed traffic environments”. Australian Conference on Computer-Human Interaction (OzCHI’18). Melbourne, Australia. December, 2018.
- **Workshop presentation**: “Micro-FESTA - ongoing projects at RISE”, Utrecht, Netherlands, February 2018.
- **Seminar presentation:** “Designing Trust in Mobility Services and Technologies”. Embedded and Intelligent Systems Industrial Graduate School (EISIGS) seminar. Varberg, Sweden. November, 2019.
- **Seminar presentation:** “Understanding Trust in Automated Vehicles”. Halmstad University School of Information Technology seminar. Halmstad, Sweden. October, 2019.
- **Conference presentation:** “Designing Trust in Mobility Services and Technologies”. Annual Volvo Industrial Phd Program conference (VIPP 2019). Gothenburg, Sweden. October, 2019.
- **Conference presentation:** “Understanding Trust in Automated Vehicles”. Australian Conference on Computer-Human Interaction (OzCHI’19). Perth/Fremantle, Australia. December, 2019.
- **Seminar presentation:** “Trusting Smart Mobility Solutions - A Human Approach”. Re-Humanising Automated Decision Making (RHADM) network meeting. Melbourne, Australia. December, 2019.
- **Seminar presentation** to DongFeng delegates visiting RISE and other Swedish R&D companies, Nov 2019.
- **Presentation** to Ladies Circle network of female engineers, as part of visit to RISE Mobility and Systems, October 2019.
- **Conference presentation:** “Literature Review for Identifying Research Opportunities”. Annual Halmstad University School of Information Technology conference. Varberg, Sweden. March, 2020.

How are the project results planned to be used and disseminated?	Mark with x	Comment
Increase knowledge in the field	x	
Be passed on to other advanced technological development projects	x	
Be passed on to product development projects	x	
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions		

6.2 Publications

Published

Malmsten-Lundgren, V., Andersson, J., Asker, E., Habibovic, A., Klingegård, M., Lindström, D. & Voronov, A. (2018) *Recurrent Measurements of User Experience in AVs - A Method Development Experiment at AstaZero Proving Grounds*. Poster presented at Automated Vehicles Symposium (AVS2018), San Francisco.

Osz, K., Raats, K., Fors, V., Pink, S., & Lindgren, T. (2018). Combining WOz testing and ride along video ethnographies: advancing methodologies for autonomous driving car development for mixed traffic environments. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction (OzCHI'18)* (pp. 252–255).
DOI: https://doi.org/10.1145/3292147.3292211

Osz, K., Rydström, A., Pink, S., Fors, V., & Broström, R. (2018). Building collaborative testing practices: design ethnography and WOz in autonomous driving research. *IxD&A Journal, 37,* 12-20.

Osz, K., Raats, K., Lindgren, T., Rothmüller, M., Holm Rasmussen, P., & Vendelbo-Larsen, A. (2018). A design anthropology approach to experiential futures and autonomous driving. In *Proceedings of the 15th Participatory Design Conference: Short Papers, Situated Actions, Workshops and Tutorial - Volume 2 (PDC'18)* (pp. 1–3).
DOI: https://doi.org/10.1145/3210604.3210627

Pink, S. Osz, K. Raats, K. Lindgren, T. & Fors, V. (2020). Design anthropology for emerging technologies: Trust and sharing in autonomous driving futures. *Design Studies, 69*.
DOI: https://doi.org/10.1016/j.destud.2020.04.002

Raats, K., Fors, V. & Pink, S. (2019). Understanding Trust in Automated Vehicles. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction (OZCHI'19)* (pp. 352–358).
DOI: https://doi.org/10.1145/3369457.3369493

Raats, K., Fors V. & Pink, S. (2020). Trusting Autonomous Vehicles: An Interdisciplinary approach. *Transportation Research Interdisciplinary Perspectives, 7.*
DOI: https://doi.org/10.1016/j.trip.2020.100201

In preparation

Andersson, J., Broström R., Habibovic, A. & Rydström, A. (2020). *Embracing UX research in agile development.* Manuscript in preparation.

Andersson, J., Habibovic, A., & Rizgary, D. (2020). *First encounter effects in testing of highly automated vehicles – the need for recurrent testing*. Journal manuscript accepted with revisions to Information Technology - Automotive Special Issue

Klingegård, M., Andressson, J., Habibovic, A., Nilsson., E., & Rydström, A. (2020). *Drivers' ability to engage in non-driving related tasks while in automated driving mode in real traffic*. Manuscript submitted for publication.

Raats, K., Bergquist M. & Fors, V. (2020). *Contextualising Design of Trust in Intelligent Vehicles.* Manuscript in preparation.

Rydström, A., Söderholm Mullaart, M., Novakazi, F., Johansson, M., & Eriksson, A. (2020). *Drivers' Performance and Experience of Non-Critical Take-Overs from a Highly Automated Car – A Real Road Study.* Manuscript in preparation.

7 Conclusions and future research

The objective of this project was to combine naturalistic and experimental car studies with an ethnographic approach to investigate user experience of automated driving on public roads, and to study how the increased intelligence in and around the automated car affects trust in the automated car.

At first, it can be concluded that trust is continuously ongoing and that it develops and changes over time. It is affected not only by the actual experience of automated driving on real roads, but also experiences with technology in everyday life situations. This aspect of trust is important to take into account when developing automated cars. Furthermore, individual differences and preferences need to be taken into account when designing the user interface of the automated car. It is also important to carefully design the information and feedback for the transient manoeuvres, to make the experience of handing over and taking back control of the car safe and delightful.

Another conclusion is that a research approach that combines experimental and ethnographic methods contributes to deeper insights and knowledge of user experience and trust. Furthermore, the project has shown that both qualitative and quantitative methods add to the understanding of people's behaviour and experience of automated driving, also over time.

Finally, experiences from this project point out that *cooperation* (how), *format* (what) and *entry points* (when) are three essential aspects for improving the uptake of research findings in agile development.

Future research is required on how trust evolves over time, on dispositional and situational factors influencing trust development, and studying trust in complex social real-life situations. In addition, as Hoff and Bashir (2015) and Lee and See (2004) have emphasized, investigations should also focus on:

- how culturally different knowledge and expectations towards automation can influence trust and reliance behaviours
- how trust in automation develops in people from different nationalities, religions and ethnicities
- how context dependent internal factors (e.g. mood, self-confidence) guide trust formation
- how stress, boredom, energy levels, and task motivation influence trust in automation
- how different relationships between previously listed characteristics would guide trust development.

8 Participating parties and contact persons

Volvo Car Corporation
User Experience
Torslanda
405 31 Göteborg
Contact person: Emma Rubin

RISE Research Institutes of Sweden
Unit of Humanized Autonomy
Lindholmspiren 3A
417 56 Göteborg
Contact person: Jonas Andersson

Halmstad University
School of Information Technology
Kristian IV:s väg 3
302 50 Halmstad
Contact person: Vaike Fors

9 References

Alpern, M., & Minardo, K. (2003). Developing a car gesture interface for use as a secondary task. In *Proceedings of CHI'03 extended abstracts on Human Factors in Computing Systems* (pp. 932- 933).

Balfe, N., Sharples, S., & Wilson, J. R. (2018). Understanding is key: an analysis of factors pertaining to trust in a real-world automation system. *Human Factors 60,* 477–495.

Carter, S., & Mankoff, J. (2005) Momento: Early-Stage Prototyping and Evaluation for Mobile Applications. Retrieved from https://www.eecs.berkeley.edu/Pubs/TechRpts/2005/5224.html

Coelingh E. & Nilsson, J. (2018). Creating Driving Tests for Self-Driving Cars. *IEEE Spectrum*. Retrieved from https://ieeexplore.ieee.org/abstract/document/8302386/

Corsín Jiménez, A., 2011. Trust in anthropology. *Anthropol. Theory, 11,* 177–196.

Dahlbäck, N., Jönsson, A., & Ahrenberg, L. (1993). Wizard of Oz studies—why and how. *Knowledge-Based Systems, 6,* 258-266.

Dow, S., MacIntyre, B., Lee, J., Oezbek, C., Bolter, J. D., & Gandy, M. (2005). Wizard of Oz support throughout an iterative design process. *IEEE Pervasive Computing, 4,* 18-26.

Frauenberger, C., 2019. Entanglement HCI the next wave? ACM Trans. Comput.-Hum. Interact. 27, 1–27 (https://doi.org/10/ggqfcj).

Geutner, P., Steffens, F., & Manstetted, D. (2002) Design of the VICO spoken dialogue system: Evaluation of User Expectations by Wizard of Oz Experiments: A speech driven in- car assistance system. In *Proceedings of the 3rd International Conference on Language Resources and Evaluation (LREC '02)*.

Gunn, W., Otto, T. & Smith, R. C. (2013). *Design Anthropology: Theory and Practice*. London, UK: Bloomsbury.

Habibovic, A., Andersson, J., Nilsson, M., Lundgren Malmsten, V., & Nilsson, J. (2016). Evaluating interactions with non-existing automated vehicles: three Wizard of Oz approaches. In *Proceedings the IEEE Intelligent Vehicles Symposium (IV).*

Harrison, S., Tatar, D., Sengers, P. (2007). The Three Paradigms of HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'07).*

Harper, R. H. R. (2014). *Trust, Computing and Society*. Cambridge, UK: Cambridge University Press.

Hassenzahl, M. (2010). *Experience Design: Technology for All the Right Reasons, Synthesis Lectures on Human-Centered Informatics.* San Rafael, CA: Morgan & Claypool Publishers.

Hoff, K. A. & Bashir, M. (2015). Trust in Automation. *Human Factors, 57*, 407 - 434.

Hoffman, G., & Ju, W. (2014). Designing Robots with Movement in Mind. *Journal of Human-Robot Interaction, 3*, 89-122.

Laurier, E. & Dant, T. (2012). What else we do while driving: towards the driverless car. In M. Grieco & J. Urry (Eds.), *Mobilities: New Perspectives on Transport and Society* (pp. 223-244). Surrey, UK: Ashgate Publishing.

Lathrop, B., Cheng, H., Weng, F., Mishra, R., Chen, J., Bratt, H., Cavedon, L., Bergmann, C., Hand-Bender, T., Pon-Barry, H., Bei, B., Raya, M, & Shriberg, L. (2005). A Wizard of Oz framework for collecting spoken human computer dialogs: An experiment procedure for the design and testing of natural language in-vehicle technology systems. In *Proceedings og the 12th World Congress on Intelligent Transport Systems*.

Lee, J. D., See, K. A. (2004). Trust in automation: designing for appropriate reliance. *Human Factors, 46*, 50-80.

Lingard, H., S. Pink, J. Harley and R. Edirisinghe (2015). Looking and learning: using participatory video to improve health and safety in the construction industry. *Construction Management and Economics, 33,* 740-751.

Meixner, G., & Müller, C. (2017). *Automotive User Interfaces. Creating Interactive Experiences in the Car*. Springer International Publishing.

Merriman, P. (2007). *Driving spaces*. Oxford, UK: Blackwell

Meschtscherjakov, A., Perterer, N., Trösterer, S. Krischkowsky. A. & Tscheligi, M. (2017). The Neglected Passenger - How Collaboration in the Car Fosters Driving Experience and Safety. In G. Meixner & C. Müller (Eds.), *Automotive User Interfaces. Creating Interactive Experiences in the Car* (pp. 187-213). Springer International Publishing.

Mok, B. K. J., Sirkin, D., Sibi, S., Miller, D. B., & Ju, W. (2015). Understanding Driver - Automated Vehicle Interactions through Wizard of Oz Design Improvisation. In *Proceedings of the Fourth International Driving Symposium on Human Factors in Driving Assessment, Training, and Vehicle Design.*

Osz, K., Raats, K., Fors, V., Pink, S., & Lindgren, T. (2018). Combining WOz testing and ride along video ethnographies: advancing methodologies for autonomous driving car development for mixed traffic environments. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction (OzCHI'18)* (pp. 252–255).

Osz, K., Rydström, A., Fors, V., Pink, S., & Broström, R. (2018b). Building Collaborative Test Practices: Design Ethnography and WOz in Autonomous Driving Research. *IxD&A, 37,* 12-20.

Pettersson, I. (2016). *The temporality of in-vehicle user experience - exploring user interfaces from past to future* (Licentiate thesis).

Pink, S., Leder Mackley, K., Mitchell, V., Hanratty, M., Escobar-Tello, C., Bhamra, T., & Morosanu, R. (2013). Applying the Lens of Sensory Ethnography to Sustainable HCI. *ACM Transactions on Computer-Human Interaction, 20.*

Pink, S. & Leder Mackley, K. (2014). Reenactment Methodologies for Everyday Life Research: Art Therapy Insights for Video Ethnography. *Visual Studies, 29*, 146-154.

Pink, S., Morgan, J. & Dainty, A. (2014). Safety in Movement: mobile workers, mobile media. *Mobile Media and Communication 2,* 335-351.

Pink, S., Osz, K., Raats, K., Lindgren, T., Fors, V., 2020. Design anthropology for emerging technologies: trust and sharing in autonomous driving futures. *Design Studies, 69.*

Raats, K., Fors, V. & Pink, S. (2019). Understanding Trust in Automated Vehicles. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction (OZCHI'19)* (pp. 352–358).

Raats, K., Fors V. & Pink, S. (2020). Trusting Autonomous Vehicles: An Interdisciplinary approach. *Transportation Research Interdisciplinary Perspectives, 7.*

Riek, L. D. (2012). Wizard of Oz Studies in HRI: A systematic review and new reporting guidelines. *Journal of Human-Robot Interaction Inaugural Special Issue: Intersection of Systems Sciences and Human Sciences, 1*, 119- 136.

Schmidt, G., Kiss, M., Babbel, E., & Galla, A. (2008). The Wizard on Wheels: Rapid Prototyping and User Testing of Future Driver Assistance Using Wizard of Oz Technique in a Vehicle. In *Proceedings of the FISITA 2008 World Automotive Congress*.

Schuller, B., Lang, M., & Rigoll, G. (2006). Recognition of spontaneous emotions by speech within automotive environment. *Fortschritte Der Akustik, 31*.

Steinfeld, A., Jenkins, O. C., & Scassellati, B. (2009). The oz of wizard: simulating the human for interaction research. In *Proceedings of the 4th ACM/IEEE international conference on Human Robot Interaction* (pp.101–107).

Sivaraman, S. & Trivedi, M. M. (2013). Looking at Vehicles on the Road: A Survey of Vision-Based Vehicle Detection, Tracking, and Behavior Analysis. *IEEE Transactions on Intelligent Transportation Systems, 14,* 1773-1795.

Tanner, K. (2018). Experimental research. In K. Williamson & G. Johanson (Eds.), *Research methods: Information, Systems, and Contexts* (pp. 337–356). Elsevier.

Tsimhoni O., Smith D., & Green P. (2004). Address entry while driving: Speech recognition versus a touch-screen keyboard. *Human Factors, 46,* 600-610.

Vissers, L., van der Kint, S., van Schagen, I., & Hagenzieker, M. (2016). *Safe interaction between cyclists, pedestrians and automated vehicles* (Report no. R-2016-16). SWOV Institute for Road Safety Research, The Netherlands. Retrieved from https://www.swov.nl/publicatie/safe-interaction-between-cyclists-pedestrians-and-automated-vehicles