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Supporting personalisation of ADAS through driver characteristics - a design science study

Bachelor of Science Thesis in Software Engineering and Management

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Supporting personalisation of ADAS through driver characteristics - a design science study

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Abstract. The identification of driver characteristics is an important step to allow the adaptation of Advanced Driver Assistance Systems (ADAS) to individual driver needs, and thus increase system performance and trust in the system function. However, most ADAS are designed for the average driver and we investigated which driving characteristics are relevant for personalised features, and how to derive them using Requirement elicitation. We conducted a design study in two iterative cycles and investigated the objectives by performing semi-structured interviews and literature review. From the interviews and literature review a list of characteristics was created. The list was later used to propose a way to derive the characteristics from a driver using a Human-Machine Interaction interface.

Keywords: Driver Characteristics · ADAS · Requirements Engineering.

1 Introduction

Autonomous driving, and especially Advanced Driver Assistance Systems (ADAS), is on the rise. In a recent report by Allied Market Research [1], it is predicted that partially autonomous cars will provide the highest level of revenue on the global market of autonomous cars in the near future. The ADAS is a system of multiple hardware and software components working together in order to support the driver when necessary. For instance, the system will warn when the driver is distracted or will take over when critical situations occur that the driver may not be able to handle.

With the growth of software in vehicles, new ways of interacting with the vehicle emerge. For example, driver assistance system will help drivers stay in the lane, but could also make drivers lose focus on the road, or the dashboard interface might have multiple features, which in turn could distract drivers even more. Moreover, the characteristics of a driver, such as age and driver experience, all have an impact on the interaction between the driver and the vehicle [2]. Boström [3] believes that a key factor to create trust in this interaction is to make the systems adaptive and personalised and that there is a lot of room for innovation in this area.

The personalisation approach, together with increasing complexity of software in vehicles [4], make Requirements Engineering (RE) an important step in order to develop software with the driver in focus. However, Shahin and Curta

[5] argue that there is a challenge when collecting requirements from users of intelligent and interactive systems in the automotive industry. To conclude, there is a lack of research about requirement elicitation of ADAS in the automotive industry.

The aim of our study was to identify which driver characteristics are important for a personalisation of an ADAS and how they could be derived using requirement elicitation. Furthermore, we investigated if these characteristics can be grouped and tried to find correlations between characteristics in order to create initial personas and make the data collection from the driver less redundant. To achieve this, we investigated what information is important about the driver and how to retrieve this data when interacting with the driver.

We carried out this research in collaboration with Veoneer, a pure play company which design, compile and sell software, hardware and systems for active safety, autonomous driving, occupant protection, and brake control.

1.1 Statement of the problem

Software is a big part of vehicles that are being built today and will be an even bigger part in the future [6]. According to Braun et al. [4] the number of software-based functions in vehicles have more than doubled in recent years and that the current ways of performing RE are limited because the systems are too complex.

In another study, Wang et al. [7] show that if a driver has been injured in a traffic accident, or is unfamiliar with the ADAS, it could be a disharmony in the interaction between the driver and assistance systems and the ADAS has a poor acceptance by the driver.

Furthermore, Endsley [8] argues that drivers may put too much trust in their car and as a result might not be aware of the surroundings. Thus, when the car is incapable of handling the situation, and the driver may fail to react, an accident can occur.

The challenges presented above show that further research is needed on how to elicit requirements when developing software for vehicles, and especially, when developing software for an ADAS. Here, the characteristics of the driver can be used to align the ADAS function to the driver needs and thus, to generate trust.

1.2 Objectives of the study

One objective of this study was to identify which characteristics are important for personalised features and functions and how to derive these characteristics. We have performed requirement elicitation to collect driver characteristics, in order to get a better understanding of the driver. We categorised the characteristics and displayed them in a list, which was used to see which characteristics should be considered when interacting with the ADAS and to present a starting point when collecting data. The second objective was to gather these characteristics, so that each driver could be pre-categorised and a baseline behaviour derived. To

achieve this, we created an Human-Machine Interface (HMI) and investigated what questions to ask through the HMI. The categorisation is initially based on the gathered characteristics but will later be extended through data collection while driving. We also investigated how to ask as few questions as possible to make the enquiry process less time-consuming.

1.3 Research questions

RQ1 What are the problems of gathering driver characteristics when performing requirement elicitation for software in an ADAS?

This research question aims to find challenges and problems of gathering driver characteristics for personalised systems in vehicles.

RQ2 What is a potential solution to collect driver characteristics when performing requirement elicitation for software in an ADAS?

In RQ2 we will identify which driver characteristics have an influence on the driving and propose an approach to derive them with the help of requirement elicitation.

RQ3 To what extent can the potential solutions address the problems of gathering driver characteristics when performing requirement elicitation for software in an ADAS?

In RQ3 we will evaluate the solution found in RQ2 in order to see if the approach is feasible or not.

2 Background

2.1 Literature review

In the literature review we decided to mainly focus on driver characteristics to be able to compare them to the answers from the interviewees.

We wanted to investigate which characteristics should be considered to support the personalisation of ADAS functions. We also have section with RE, where we investigate how driver characteristics are used in the automotive industry.

Driver Characteristics Lin et al. [9] address that the driver is a complex and uncertain individual, which might exhibit different driving characteristics in different driving situations (fatigue/drunk/drowsy/distracted driving). Additionally, different road adhesion, traffic conditions, and weather conditions will also impact driver characteristics. The authors state that the driving behaviours vary between drivers according to their age, gender, ethnicity, driving experience, emotion, and so forth is a common knowledge. Even for the same driver, driving behaviour may alter from situation to situation, which can be attributed to the driver behavior characteristics.

Age Caird et al. [10] examined the correlation between age and time to make a turn decision in an intersection. Overall, their result show that young (18-25) and middle-aged (26-64) drivers were more accurate in their decisions than the older drivers (65+). The older drivers had lower accuracy scores for spotting pedestrians and traffic sign changes and showed a tendency to rely heavily on traffic control devices to make decisions, often to the exclusion of pedestrians and vehicles. Philip et al. [11] address that the reaction time is different between young and old drivers, and usually young driver perform better. Furthermore, senior drivers generally have more experience, e.g. been driving to more places and have been driving a higher amount of mileage than younger drivers. Taubman-Ben-Ari et al. [12] showed that according to their analysis older drivers tend to driver more careful than younger drivers.

Gender Taubman-Ben-Ari et al. [12] showed tendencies that women exhibited more stress than men while driving. Johnson et al. [13] investigated the relation between drunk driving and gender. A portal survey was performed to randomly sample groups of electronic music dance event patrons as they entered and exited a club and then test the blood alcohol content (BAC) from the sample groups. The finding is that groups of females appear to have a particularly elevated risk of having a driver whose BAC exceeds 0.05 g/dL, and new intervention efforts should be particularly directed to these at-risk groups.

Driving experience Mohaymany et al. [14] studied a data set of 16 809 overtaking crashes in Iran in order to examine if there is a correlation between the driver characteristics and who is at fault for the crash. Their result show that drivers, who are younger than 28 years old, have a common driving licences for light vehicles, and have less than two years experience, are most probable to be at fault for an overtaking crash. According to Patten et al. [15] driver experience has an effect on the cognitive ability. An inexperienced driver will have less reaction time and a worse cognitive ability than an experienced driver. Taubman-Ben-Ari et al. [12] studied three self-reported behaviours: amount of weekly driving, number of involvements in car accidents and number of committed driving offenses. The result show that a small amount of driving correlates with a more anxious driving style and a risky or high-velocity driving style was associated with higher numbers of involvements in car accidents and committed driving offenses.

Trait and state In a paper by Mesken et al. [16] happiness, anger and anxiety are shown to affect the driving. Angry drivers take more risks and drive faster than other drivers in general. Anxious drivers are more aware of their driving and report more near-accidents. Both happiness and anger were related to sensation seeking. Furthermore, the happiness state was related to the happiness trait and the same was true for both anger and anxiety. The authors also mention that less driving experience correlated to happiness and more mileage correlated with being less anxious. Drivers who reported happiness more often also reported

more accidents. The sleepiness of drivers is also a characteristic that would affect driving behaviour. Connor et al. [17] stated that acute sleepiness of drivers significantly increases the risk of a crash in which a car occupant is injured or killed. Reductions in road traffic injuries may be achieved if fewer people drive when they are sleepy or have been deprived of sleep or drive between 2 am and 5 am. Taubman-Ben-Ari et al. [12] showed that high self-esteem was associated with a patient and careful driving style. Drivers with a high desire of control showed tendencies to drive either aggressive or careful, depending on the situation. Further, sensation seeking was associated with a risky driving style and extraverted people who showed lower tendencies to feel anxiety during the drive. Chen [18] focuses on the aggressive driver characteristics. This paper show that aggressive drivers have relatively low response time, minimum spacing to road traffic participants ahead and are often the cause of traffic oscillations.

Time pressure In a study by Inata et al. [19], the result show that the participants drove much more aggressive than usual, in which they detected that in hurry driving the operation of accelerator pedal is massively different from the normal case.

Experience of the situation Yanko Spalek [20] study show that drivers, who are driving on a familiar road tend to drive more aggressive, keep a shorter distance to the car ahead, and have less focus on the surroundings. The authors believe that the familiarity might lead to an unintentional blindness. Drivers that are unfamiliar with the road drive more passive and have a better focus on their surroundings. Daimon et al. [21] investigated the effects of national and regional factors such as urban layouts, on the method and components of information used by drivers for route selection. When the urban layouts and regional factors vary, the method originally used by a driver in her route selection can no longer be applied; accordingly, as information components used by a driver vary, her method of route selection changes. We can see that the experience of situation is a crucial driver characteristic. Awareness of the urban layouts, or in other words, more experience of situation will help driver have better performance.

Trust Hoff et al. [22] mention that accidents happen when the users both over-trust and under-trust a specific safety or comfort system. The user might expect the system to handle a situation and therefore relax, and then it the user might not react in time when the system cannot handle the situation. Endsley [8] explains that three key categories have been identified in to what affects the users trust; system factors, individual factors and situational factors, but the system factors, such as reliability and performance, have a much bigger impact than anything else. However, Hoff et al. [22] think that culture, age, gender, and personality should be considered as well. Older people tend to trust decision aids more than younger people, while younger people shows more trust when they see a face on the interface, on older people this had no significant impact. Overall, the authors think that trust to automation is a characteristic that does not change much over time.

Education Taubman-Ben-Ari et al. [12] showed that people with higher education tend to feel more anxiety while driving than people with low education. According to the authors, drivers that feel anxiety while driving tend to drive below the speed limit, feel worry while driving in bad weather condition and doubt their own driving abilities.

Other Beullens et al. [23] focused on people, who play video games. The results indicated that, even after controlling for aggression and sensation seeking, the amount of video game playing during adolescence is a significant indirect predictor of later risky driving behaviour through the attitudes towards risk taking in traffic and the intentions to exhibit this behavior in the future.

Requirements Engineering Due to the increasing complexity of software in vehicles, Braun et al. [4] wrote a guideline for requirement engineers in the automotive industry. In the guideline the authors state that the current practices of requirement engineering are not suitable to cope with challenges that arise.

Boulanger and Dao [24] resume the requirements engineering in a model-based methodology for embedded automotive software. The requirements engineering in the methodology describes phases of elicitation, modelling, traceability, verification and validation.

Hasenjäger and Wersing [25] did a review of the current personalisation approaches for ADAS and state that the general approach when designing ADAS is to do it for the average driver and by that, ignore that the drivers' preferences differs. Furthermore, the authors show that the interface design between the vehicle and the driver is an area which has not been fully investigated yet and argue that this will play a crucial role in the success of personalised systems. To add to this, Seyff et al. [26] explored an approach of gathering feedback on day-to-day activities continuously from users to elicit requirements. Schneider [27] argues that continuous user feedback is essential for the evolution of a system and propose an approach to translate user feedback into requirements. In this paper we will explore a similar approach and apply it to an ADAS.

3 Methodology

We decided to use the Design Science Research (DSR) methodology, which is an approach that is used to develop or create a new method, design or artefact to address a problem [28]. By creating and analysing innovative artefacts, researchers gain new knowledge that help them understand and improve aspects in their domain [29]. Initially, we also considered to do a case study. However, case studies do not produce artefacts [30], so we discarded this consideration.

3.1 Regulative cycle

To structure our study, we followed the regulative cycle, introduced by Van Strien [31]. The regulative cycle consists of five steps; problem investigation,

solution design, design validation, implementation and evaluation [32]. The cycle is visualised in Fig. 1 and the steps are explained below. In this thesis, we executed the cycle twice. In the initial investigation of the problem, we discovered that there were two main problems that we needed to consider in order to answer RQ1. Which driver characteristics are considered important and how to derive these characteristics. Therefore, we went through the cycle once for each of the main problems.

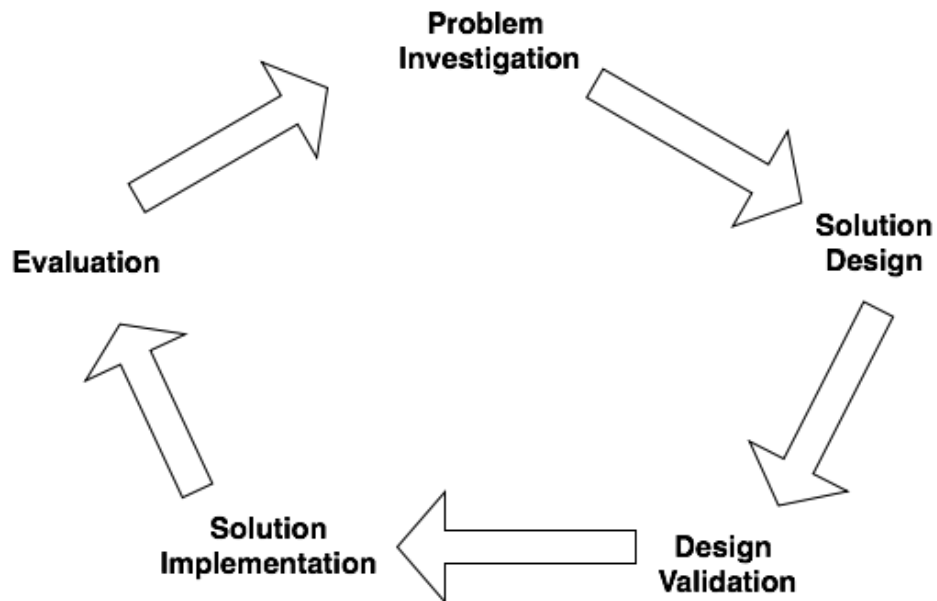


Fig. 1. The regulative cycle.

Investigation of the problem In the first step of the cycle we identified the problems and investigated what was needed to be done in order to solve them. To achieve this, we discussed the topic with the stakeholders.

Solution design After the investigation we created a design for the solution.

Design validation In the third step we presented our proposed solution to the stakeholders to get their input and feedback.

Solution implementation After the validation we implemented the solution based on the feedback.

Evaluation In the final step of the cycle, we presented our solution to the stakeholders to evaluate if it solved their problem or if more iterations were needed.

3.2 Data collection methods

Interviews. We decided to conduct face-to-face, semi-structured interviews in this study. A semi-structured interview enables researchers to dig deep into a specific topic and collect data in a conversational manner [33], which was suitable in our case since we strived to explore and understand which driver characteristics were considered important by experts in the industry and to be able to compare the findings against characteristics existed in academy papers. Moreover, we aimed to conduct the interviews face-to-face, since that would give us a chance to ask follow-up questions and clarify the questions to avoid misunderstandings. The interviewees were chosen based on their background and occupation.. We wanted to interview experts that had knowledge about Veoneers learning-intelligent vehicle, but also have expertise in the field of human factors and driver behaviour in general. Veoneer gave us some candidates and we were able to interview three of them. The other were not interviewed because it was either inconvenient or they did not have the time.

When constructing the interviews, we followed a set of rules [34]:

- Use open-ended questions to avoid yes/no answers and instead get more detailed answers
- Avoid leading questions
- Start with demographic questions to warm up
- Group questions about each characteristic together

The interviews were recorded, which made it possible for us to be active and ask follow-up questions [35], and were later transcribed into a document.

3.3 Data analysis

We used content analysis to analyse the interviews during the first iteration. The purpose of content analysis is to summarise and organise a large amount of text by breaking it down into smaller parts [35]. In our case, we followed the steps, purposed by Erlingsson Brysiewicz [36], in order to get the essence of the interviewees' answers and to be able to categorise the findings.

We started by re-reading the interview transcriptions thoroughly and then we broke down the text into smaller parts. These short units of text were then labelled with codes. Afterwards, the coded sentences were mapped to categories and sub-categories.

3.4 First iteration

Investigation of the problem In order to identify the problem, we discussed the topic in detail during our weekly meetings with the stakeholders. We came

to the conclusion that two problems needed to be solved. First, we needed to identify which characteristics should be considered. The second problem was how we would gather the characteristics from the driver.

Solution design We performed literature review in order to gather information about driver characteristics in general. Afterwards we constructed interview questions to get a deeper understanding of the topic from experts in the field.

We conducted face-to-face interviews with two road traffic safety experts and received input from one expert in human factors by email. The reason why we could not do a face-to-face interview with the human factors expert was her availability. The interviews were structured in two parts, with general demographic questions in the beginning followed by open-ended questions regarding driver characteristics. For each characteristic mentioned by the interviewee we asked follow-up questions in order to get a deeper understanding about the importance and issues regarding the characteristic. The interview guide is shown in Appendix 1.

The two face-to-face interviews were recorded and transcribed after each session. We then moved on to code the resulting text and the email answer. To do this, we broke down the text into short sentences and mapped them to driver characteristics. The resulting data set is displayed in Appendix 2.

Our proposed solution was to categorise the characteristics found in the interviews and in existing literature. We proposed to divide the characteristics into two different dimensions, importance level and variation over time. The descriptions of the importance levels are shown in Table 1 and the descriptions of the levels of variation over time are shown in Table 2.

Table 1. The importance levels

Level	Description
Important	The characteristic is considered important by the interviewee.
Out of scope	The characteristic is interesting but is out of scope of this thesis.
Neutral	The characteristic is mentioned, but not considered as important by the interviewee.

Design validation After presenting our proposed solution to the stakeholders, we received feedback that we should compare the results from the interviews to the results from the literature review.

Solution implementation For the implementation we compared all the characteristics, that were considered important by the interviewees, to existing literature. Afterwards, we created a table with all the characteristics sorted according to our suggested solution.

Table 2. The variation levels

Level	Description
Static	The characteristic are likely not to change, e.g. gender.
Semi-static	The characteristic are changing slightly over time, e.g. age.
Dynamic	The characteristic change for each driving session, e.g, mood of the driver.
Semi-dynamic	The characteristic change irregularly over time, e.g. experience of driver could change a lot or not at all over time, depending on how much the person has driven.

Evaluation After presenting the solution to the stakeholders it was suggested that we should try to find correlation between characteristics. This was to eliminate questions when gathering characteristics from the drivers, if two characteristics correlates it could be that we would only need to derive one of these.

3.5 Second iteration

Before we started the investigation of the problem of the second iteration we adjusted our solution, based on the feedback from the evaluation of the first iteration. We found one correlation, between trait and state, and according to Mesken et al. [16] there is a high correlation between the state happy and the trait happy, and the same goes for the state anger and the trait anger.

Investigation of the problem In the second iteration we asked the stakeholders what we should proceed with, and what the remaining problem was. The stakeholders explained that currently, they do not have a solution for collecting information about the driver when she enters the car. While driving, data can be collected, such as how the driver accelerate and brake, in order to identify a baseline for the driver. However, they need a solution where they can put the driver in a category before she starts to drive. For example, this driver presumably belongs to group of drivers that drive carefully with low tendency of high acceleration. This base information about the driver can later be updated as the driver drives.

The feedback from the stakeholders was written down during the meeting and in order to structure it, we decided to translate their input into user stories as shown in Table 3.

Table 3. User stories

User story
As a researcher, I want the collected data to be stored in a database for future development.
As a researcher, I would like to get feedback from driver after she experienced the function of the desktop application.
As a developer, I want the software to be developed in Python, so that I can continue the development.
As a driver, I would like to have a simple user interface to have easy understanding of what I should give as input.
As a driver, I would like a user profile stored in database, so that I can login.
As a stakeholder, I would like to have the matched characteristics to be collected by the desktop application.

Solution design Our proposed solution for the problem is an desktop application that gathers information from the driver with a questionnaire. The reasons behind this decision are as follows: Our software is not limited to Veoneer’s ADAS function interfaces. Instead, it is a prototype of a general approach to derive non data-driven characteristics, which could be applied elsewhere. Also, since we are not going to implement the software in the ADAS, we cannot use any existing technology, such as sensors, to gather information about the driver.

The goal with the tool is to gather information in order to pre-categorise the driver before she starts to drive, and our approach is similar to the process used in driving-simulator studies [37], where the participants have to fill out a lengthy form before they start to drive. However, we cannot ask that many questions, since that might annoy the driver [38].

The proposed concept of the software is presented in Table 4, where every characteristic is mapped to a question, an answer format and an explanation. The frequencies of the questions vary according to their type, for example the questions for the static characteristics will be asked once, while questions regarding dynamic characteristics will be asked regularly.

We decided to exclude time pressure and experience of the situation, because these characteristics should be gathered automatically from personal calendars and GPS data, respectively. To ask if the driver is in a hurry will only annoy the driver. Instead, this could be derived by comparing data of probable destination, destination event schedule, and current time. Furthermore, we decided to also exclude trait since according to Mesken et al. [16] trait and state are highly correlated. The authors found that happy people frequently report happiness while angry people frequently report anger. We decided to exclude traits instead of state since asking for someone’s trait once could give an inaccurate view, while continuously asking for how a person’s mood we can both see how they feel currently, but also try to derive their trait through data analysis.

In addition, the software will also ask for name and email address when a new user fill out the questionnaire. The reasons for including name system is to establish a sense of connection between the driver and the software and to be

Table 4. Initial version of the questionnaire

Characteristic	Question	Answer format	Frequency of question
Age	Birth date: (ddmmyy)	Date	Once
Gender	Gender identity:	man, woman, prefer not to disclose	Once
Driving experience	When did you receive your driver license?	Date	Once
	How much have you driven during the last year?	Scale with different mile span	Once a year
Education	What is your level of education?	Scale with different education levels	Once
State	How do you feel today?	Scale visualised with faces (angry face, happy face etc.)	Every drive
Trust	How much do you trust assistance system?	Scale with different trust levels	Once a year

able to define profiles. The purpose of gather the email addresses is to be able to contact the driver.

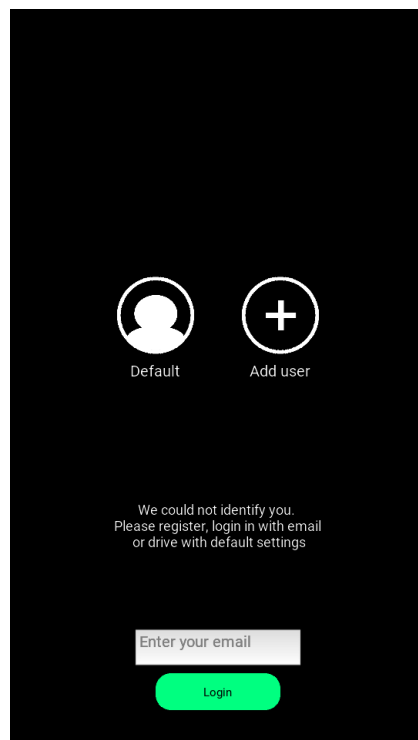
Once the user has registered, we save the data as a user profile locally. Each time the user profile is selected, dynamic data can be saved to the selected profile.

Design validation During the validation session, we presented the characteristics that is going to be derived; the questions that implicit how to derive those characteristics; and the mock user interface of the desktop application that we would develop for the implementation.

The feedback we received can be divided into the following areas. Exclude sensitive data, such as education; blur the specific data, such as date of birth and the date that the driver license was issued; provide more options for driver to pick the suitable one for herself, such as mood. The user interface design received positive feedback. Therefore, we altered the questions for the characteristics based on the feedback from the stakeholders and initiated the implementation session.

Solution implementation Based on the validation feedback we implemented the solution as presented below.

The start-up window in Fig 2 shows a basic interface where the user can either select a default profile, register a new user or login to an existing profile. The default profile will not take any characteristics into account when the vehicle interacts with the user. Our initial solution displayed the registered users in a grid but this could be intrusive, for example in a rental car a user could have forgotten to remove her profile and thus other users can see her information. To solve this we changed the user grid to a login system with email instead.

**Fig. 2.** Start-up view

The registration view is a form with a dark background. It contains the following fields and questions:

- Name: Firstname
- Email: example@email.com
- Age: 23
- Gender: Prefer not to disclose
- At what age did you receive your drivers license?: 20
- Have you driven other cars during the last year?:
- Can you estimate how far you have driven during the last year? (Km): 8000-11 999
- How often do you drive?: Once a month

At the bottom, there are two buttons: "Go back" and "Register".

Fig. 3. Registration view

In Fig 3 the registration window is presented. Since it is designed for a touch screen, where typing could be an issue, the only text inputs are for the name and email. For the age it is a range of 18-120. To choose the gender we have the options of male, female or prefer not to disclose. We also ask the user when they received their driver licence which is a range from 18 to their current age. The user can check if they have driven another car in the past year, if they have they will input how much they have driven and how often. The user can edit at any time their profile.

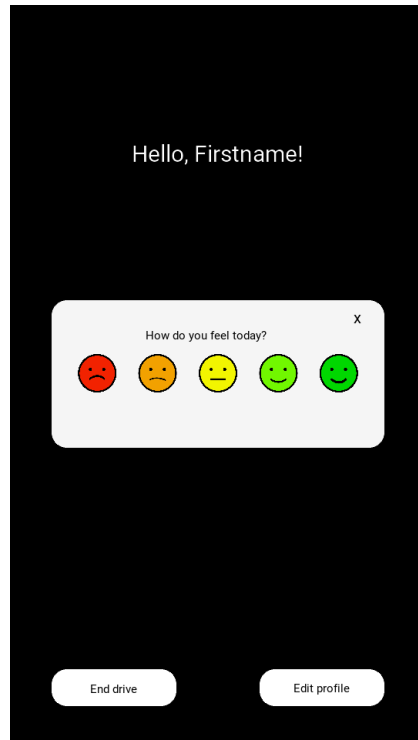


Fig. 4. Mood view

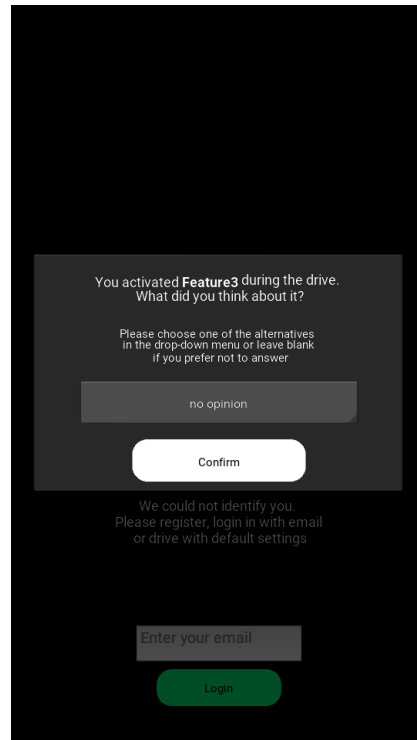


Fig. 5. Rate of feature view

Once the driver is registered and logged in she is prompted to answer how she is feeling currently. To answer she will choose between different faces that represent a mood-state as shown in Fig 4. After the driver has finished the drive she is asked to give feedback about the activated features of the vehicle.

Evaluation To evaluate the tool, we presented it to the stakeholders. The overall response was positive, and they thought that this solution was a good starting point for them to iterate further on. In order for them to do so, they asked for documentation of the desktop application and the database design, which we

would provide to them. The improvement suggestion for further implementation that they had was to have more feedback options. For instance, an open-ended comment section to provide additional reflection.

4 Results

In this paper we have aimed to answer the research questions: RQ1: What are the problems of gathering driver characteristics when performing requirement elicitation for software in an ADAS? RQ2: What is a potential solution to collect driver characteristics when performing requirement elicitation for software in an ADAS? RQ3: To what extent can the potential solutions address the problems of gathering driver characteristics when performing requirement elicitation for software in an ADAS?

The result of each research question is presented below.

4.1 RQ1

In order to answer the first research question, we first had to investigate which driver characteristics should be considered and how they affect the driving. In the literature and through discussion with the stakeholders we found that characteristics could be of dynamic or static nature and this creates issues when gathering them. If the characteristics can change over time (dynamic) we need to ask the driver more often to get accurate measurements. Some characteristics are more difficult to measure, e.g. we do not know how accurately measure trust. The second problem was how to derive the characteristics from the driver. Our solution was to gather them through a questionnaire, but this presents more problems. We found that some questions could be sensitive for the driver to answer, e.g. education. We also needed to make sure we do not ask too many questions because this could make it a chore for the driver instead of solving a problem.

4.2 RQ2

As a first step to answer the second research question, we created a list of categorised characteristics. Initially, we performed literature review, which resulted in the following characteristics: age, gender, driving experience, trait, state, time, experience of the situation, trust, and education.

In addition, we conducted interviews and analysed the them using content analysis and the resulting data set is shown in Appendix 2. The driver characteristics that were considered important by the interviewees, are as follows: age, gender, experience of the situation, driving experience, intention of driving, destination, time, driver state, driver trait. The characteristics were also categorised as static, semi-static, semi-dynamic and dynamic, according to our definitions stated in the methodology section 3.4. In Fig 6, the result of the interviews is displayed. We compared the results from the literature review with the results of

the interviews and created a list of matching characteristics. We decided to proceed with the matching ones since having multiple sources raises the credibility of the characteristics and the list is presented in Table 5.

We presented the table of matching characteristics to the stakeholders and based on their feedback, we constructed a final questionnaire, displayed in Table 6. Education was eliminated because the suggestion from the stakeholders was to exclude sensitive data when we derive characteristics. Trust was exchanged for a feedback question. After each drive the driver is prompted to give feedback about the activated features. If the user continually finds the same feature useful we can conclude that the user finds the feature reliable, and therefore trust the feature according to the study by Hoff et al. [22].

Important			
<u>Static</u>	<u>Semi-static</u>	<u>Semi-Dynamic</u>	<u>Dynamic</u>
gender	Trait age Driving culture	driving experience experience of situation	State intention of driving mood time pressure Destination
Neutral	education		driving under the influence
Out of Scope physical condition	driving law		comfortzone boundaries eye movement

Fig. 6. Characteristics result from interviews

Table 5. Matched driver characteristics from interviews and literature review.

Characteristic	Type	Description	Effect
Age	Semi-static	The age of the driver	The reaction time and cognitive ability diminishes at older ages [11].
Gender	Static	The gender of the driver	Women tend to exhibit more stress than men while driving[12].
Driving experience	Semi-dynamic	The amount of driving time the driver has	Reaction time and cognitive ability are worse with inexperienced drivers[15].
Driver trait	Semi-static	The personality of the driver	People with high self-esteem were associated with a patient and careful driving style [12].
Trust	Semi-static	How much the driver trusts the vehicles comfort and safety features	People who put too much trust into the ADAS might lose focus of the surroundings [22].
Experience of the situation	Semi-dynamic	How familiar the driver is with the route	If the driver is familiar with the road she tends to pay less attention the the surroundings [20].
Time pressure	Dynamic	How much time the driver has to reach her destination	If the driver is in hurry driving, the driving behaviour is different from normal cases[19].
Driver state	Dynamic	The current mood of the driver	Angry drivers take more risks and drive faster than other drivers in general [16].
Education	Semi-static	The education level of the driver	People who have high education level felt more anxiety than people who received low education [12].

Table 6. Final set of questions.

Characteristic	Question	Answer format	Frequency
Age	Age:	Integer 18-120	Once
Gender	Gender identity:	Male, female, prefer not to disclose	Once
Driver experience	Have you driven other cars during the last year?	yes/no	Once
	How far have you driven during the last year?	Scale with different distance ranges in kilometres	Once
	How often do you drive?	Five step scale of driving frequency	Once
State	How do you feel today?	Scale visualised with faces (angry face, happy face etc.)	Every drive
Trust	What did you think of feature X	Five step scale, from useless to very helpful	Every drive, if the driver activated feature X

4.3 RQ3

Based on the final questionnaire, we developed a prototype of the tool, displayed in Fig. 2-5 in the methodology section. After the evaluation of the tool, the stakeholders explained that they were satisfied with the result and that they saw it as a good starting point for future development. They considered the tool to be useful in the following ways: It is extendable, the design was simple, it saved the data in a database and the user could give feedback about the system.

5 Discussion

In this section, we discuss the answers to our research questions and describe the threats to validity of the thesis.

5.1 Research questions

RQ1 When investigating the problems of collecting characteristics, the biggest one we identified was which characteristics should be considered. If we select too many, it could be difficult to create clusters when identifying personas or groups. There is also the problem of how to measure some characteristics. We mentioned trust as an issue with this, and according to Hoff et al. [22], a user who perceives features to be useful and reliable, usually trusts the feature. However, this does not mean that the driver does not trust the feature because she finds it unnecessary.

There is also a problem in how to gather the characteristics. We chose to gather the characteristics through a questionnaire, and we found this to be the most convenient way, especially when we gather basic characteristics as age and gender. We were also technically limited since the software was developed outside of the vehicle environment. Therefore, we could not use sensors to gather information automatically. Furthermore, some characteristics were considered out of scope because of the limit of accessibility to the vehicle. Distance to the car ahead was considered a useful characteristic according to one interviewee. Usually the driver keeps the same distance, but if she would keep a closer distance than usual this could indicate that the driver is in a hurry. Time, i.e. if the driver is late to an appointment, was something we not consider as well. If we ask the user if she is in a hurry it could be considered annoying, this could instead be gathered from the users online schedule or she could enter it manually once. We could then combine this with the distance to the next car to get an accurate measurement of the drivers' intention, if she is in a hurry or not.

RQ2 We found multiple characteristics that could be used when personalising an ADAS for a specific driver. The one characteristic that came up more than others where age. We found many different sources in the literature on how age affects the driving and at what ages and mostly it was younger driver, around the age of 18, and senior drivers, older than 60, where the significant effects took place. For younger drivers it is clear that it is a direct correlation with experience, i.e. a young driver will not have that much driving experience in general. When we look at senior drivers it is more about their physical condition, the reaction times and vision may have decreased.

Four characteristics were coded as out of scope for this thesis. The reasoning behind this is as follows: Physical condition, i.e. if the driver has a permanent injury, was considered too complex to measure, since it demands a lot of questions, and also medical expertise, to find out how the injury would influence the driving. Driving under influence, is a very important characteristic, since the driver should not operate a vehicle under the influence of alcohol or drugs. However, to ask the driver this would not be sufficient, since you can't expect the driver to be honest about it if she has been drinking. Instead the car should have a specific system to determine this. Comfort zone boundaries can be described by the distance the driver keeps the surrounding traffic or how much time the driver let pass between intersection paths. Further longitudinal and lateral acceleration thresholds can be used to define comfort zone boundaries. Since we do not have access to a car and cannot get input from sensors, these characteristics are cannot be considered in the context of this thesis. The same reasoning was behind the decision to neglect eye movement, i.e. tracking the driver's eye movement to measure experience.

During the literature review, we found that education could be considered when personalising the vehicle for the driver. Taubman-Ben-Ari et al. [12] showed that people with higher education level tend to express more anxiety while driving than people with lower. However, during our weekly meetings, the stake-

holders expressed that even though education is interesting to address, it could be sensitive to ask the driver. To be able to include it, more research has to be carried out, and that is not feasible in the time frame of this thesis. Such data might be possible to derive from linking the driver with her social network account, e.g. Facebook or LinkedIn.

RQ3 The implementation of our second cycle was to develop a Python-based desktop application, which can be integrated with the existing Veoneer vehicle system. During the research time for the second cycle, we performed a brainstorming session.

The desktop application collects data and feedback from the users continuously. The collected data could be used by the engineers to personalise the system and the feedback could be used to elicit requirements continuously. As stated in the background section, Schneider [27] argues that continuous feedback is essential for the evolution of a system. We believe that our solution will help Veoneer to evolve their way of eliciting requirements for their systems.

To further improve our solution, we believe that building a mobile application, along with the desktop application, might bring more value to Veoneer in their process of deriving characteristics from drivers. Also, it would improve the continuous data collection. Based on a study by Wallbridge and Noyes [39] about fragmented time and the tendency of humans to spend fragmented time with smartphone, a suggestion for collecting user data would be to develop a companion mobile application which most of the input will be made in. With the mobile application, we could use the fragmented time of the driver to ask for mood and the current day's schedule, ask the driver to make a weekly schedule or even import the calendar from another source. Moreover, drivers would be able to answer the questionnaire via their smartphone whenever and wherever, instead of filling in the questionnaire in the car.

For deriving characteristics, we initially had an idea of scanning the driver license. By scanning the driver license, we would be able to collect gender, age, type of driver license and date and place where the license was issued. Instead of getting input from the driver via a questionnaire, scanning the driver license is faster and also provides more validity to the data, because the driver might provide fake data, with or without intention. However, due to the fact that we had no access to the vehicle environment and a tight schedule, this function was not implemented.

5.2 Validity threats

In the following section we will discuss the threats to validity based on the classification of Runeson et al. [30].

Construct validity In order to avoid a threat to the construct validity we contacted each interviewee and briefly explained our topic and intention of the interview in an email. Also, before the interview we explained the topic again.

However, it is still possible that they were not fully prepared. This could result in the interview becoming more of a brainstorming session and that the interviewees forget to mention information they would otherwise remembered.

Internal validity The interviews were recorded, transcribed and later coded in order to interpret the answers given by the interviewees. This could be a threat to the internal validity, since we might interpret the answers differently to what the interviewee meant. To mitigate this threat, we first coded the transcripts independently and then discussed our coding in order to create a final data set.

External The research was conducted with one company and interviews worked for the same company. Furthermore, our research is mainly directed towards ADAS, but our findings are equally applicable for any software in any car and to some extent any vehicle that is driver in traffic.

Reliability There were three participants for the interview, whereof one participants took the interview via email. There is a potential threat to reliability because the low number of participants. The solution was to create the interview with open-ended questions and follow-up questions, in order to gather sufficient information from the interviewees.

6 Conclusion

The goal of this thesis was to investigate which characteristics should be considered when a driver interacts with an ADAS and how to gather these characteristics with the help of requirement elicitation.

To achieve this, we performed DSR. Two iteration cycles were executed, which were constructed with problem investigation, solution design, design validation, implementation, and evaluation. The first iteration focused on the problems of gathering driver characteristics, which was our first research question. We performed literature review and conducted interviews. The outcome of the first iteration was a list of driver characteristics, which was combined with the literature review and the interviews.

The second iteration aimed to find the potential solutions for deriving the characteristics that we found during the first iteration and to explore how much the chosen solution solved the problem. The result from the second iteration was the Python-based desktop application which gathered the characteristics from the driver. The version we delivered was a standalone desktop application that only worked with manual input but will serve as a starting point for Veoneer and will later in be integrated with their system and will gather more data through sensors and data collection during a longer time span to create personas.

Finally, by the end of our thesis, we answered the three research questions that we proposed in introduction. For research question 1, the answer was combined with the result of our first iteration, while for research question 2 and

3, answers were conducted by executing our second iteration cycle. Detailed answers for research questions can be found in the result section.

6.1 Future work

The result of our thesis could be seen as starting point for another Bachelor thesis. The most obvious way of carry it on would be to test the application on end-users during a third iteration and then integrate it into a vehicle and combine the manual characteristics with characteristics from the sensors. The resulting set of characteristics could then be mapped to pre-defined groups, which the vehicle could base the interaction on.

Another interesting exploration would be to use our methods during the first iteration with more interviewees to see if the resulting set of driver characteristics change.

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A Appendix 1 - Interview guide

1. What's your current job position?
2. What is the field you are working in?
3. How many years of experience do you have in this field?
4. Do you have experience that is related to working with driver characteristics?
5. Which driver characteristics could be of relevance to consider when looking into driver – system interaction?
 - (a) Why is this characteristic important?
 - (b) What influence does this characteristic have on the interaction between the driver and the car?
 - (c) Are there any potential hindrance of gather this characteristic from the driver?
 - (d) What could be the source to gather this characteristic from the driver?

B Appendix 2 - Interview data

Category	In literature	Type	Code	Condensation	ID
Out of scope		Static	physical condition	If the driver is injured permanently. Eg. metabolic arthritis in knee cap for senior drivers	1
Important	Matched	Semi-static	age	Difficult to prioritize characteristics, the most dominant one is age	1
Important	Matched	Static	gender	Gender will be another aspect, because many studies has shown that	1
Important	Matched	Semi-dynamic	experience of situation	If the driver has driven on such big city or in a place with new law	1
Important	Matched	Semi-dynamic	driving experience	The total length that the driver has driven after he/she received driving license.	1
Neutral		Semi-static	driving law	If the driver is aware of the law in the country he/she is driving in. Eg. driver with US driving license might not aware of Swedish driving law.	1
Important	Matched	Dynamic	mood	If the driver is driving in a relaxed condition.	1
Important		Dynamic	intention of driving	If the driver is driving for work or driving to summer house for holiday.	1
Out of scope		Dynamic	driving under the influence	If the driver is drunk/drug driving or not.	1
Neutral	Matched	Semi-static	education	The education background behind the driver.	1
Out of scope		Dynamic	Comfort zone boundaries	Measure the distance to the car in front of you and how much time needed for making a left turn. Unique for each driver.	2
Out of scope		Dynamic	Eye movement	In the future it will be possible to find out the driver's experience by tracking their eye movement, but not nowadays.	2
Important	Matched	Semi-dynamic	experience of situation	What you are used to and in what environment you drive in have an influence on the driving.	2
Important	Matched	Semi-dynamic	Driving experience	How far and regular has the person driven during the last year as well as totally in her life.	2
Important	Matched	Dynamic	Destination	Where you're going and if you are in hurry have an influence on the driving.	2
Neutral	Matched	Static	Gender	Gender is common to include, but my experience tells me that it seldom matters	2
Neutral	Matched	Semi-static	Age	Age per se doesn't have that much influence, it's more about experience. However, young and old drivers are overrepresented in the statistics regarding car accidents.	2
Important	Matched	Dynamic	Time pressure	We told the participants to drive as if they were late for a work interview and we could see that they drove much more aggressive.	2
Important	Matched	Semi-static	Trust	How the drivers feel about technology. If they think it's cool and important.	2
Important	Matched	Dynamic	State	What is the current situation and how do I feel right now	2
Important	Matched	Semi-static	Trait	Characteristics of you as an individual, for example aggressiveness	2
Important	Matched	Semi-dynamic	Driving experience	the only individual difference I know makes a difference when testing driver responses in various environments is how often you drive	3
Important	Matched	Semi-static	Age	age is relevant (older = lower response times)	3
Important	Matched	Semi-static	Trust	Relevant factor for whether systems are at all used is if you're an early adopter	3
Important	Matched	Static	Gender	gender is relevant at least for younger drivers (younger men are very risky drivers)	3