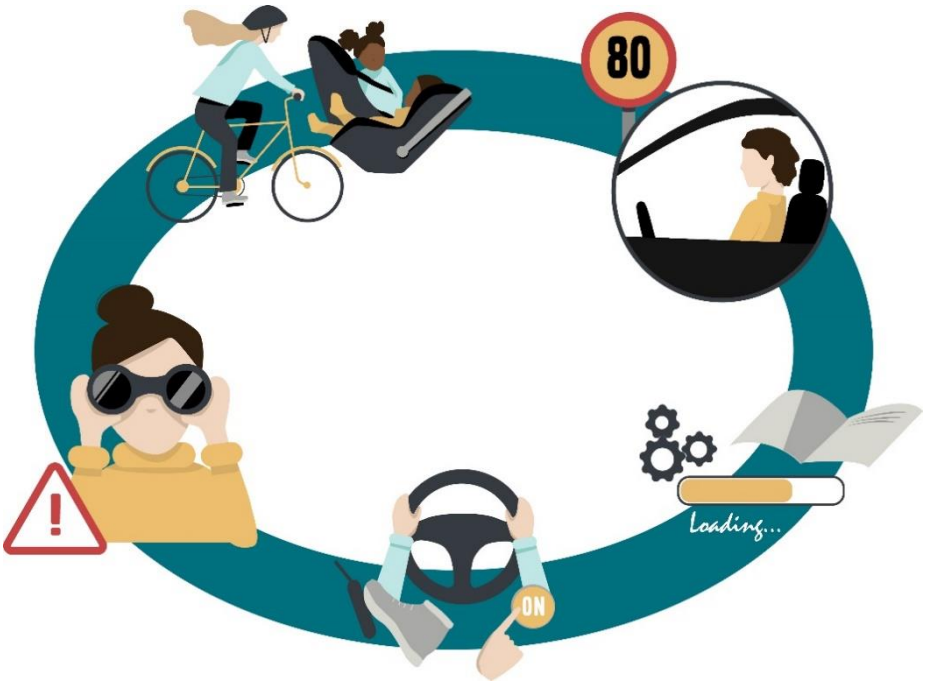
CHALMERS
UNIVERSITY OF TECHNOLOGY



Who's in charge?

Drivers' Perceived Responsibility in Automated Driving

Master's thesis in Industrial Design Engineering

GUSTAV ERHARDSSON

LINNÈA LIDANDER

DEPARTMENT OF INDUSTRIAL AND MATERIAL SCIENCE

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2020
www.chalmers.se

MASTER'S THESIS 2020

Who's in Charge?

Drivers' Perceived Responsibility in Automated Driving

GUSTAV ERHARDSSON
LINNÉA LIDANDER

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Industrial and Material Science
Division for Design & Human Factors
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

Who's in charge?
Drivers' Perceived Responsibility in Automated Driving

Master of Science Thesis

In collaboration with Volvo Car Corporation

Department of Industrial and Material Science

Chalmers University of Technology

SE-412 96 Göteborg, Sweden

Phone +46(0) 31 - 772 10 00

Cover illustration: Responsibility areas, by Linnéa Lidander

Printed by Repro Service Chalmers
Gothenburg, 2020

ABSTRACT

The automotive industry is getting closer to releasing vehicles with higher levels of automated driving that can take over driving task completely from the driver. Advanced Driving Assistance Systems (ADAS) are setting new demands on the driver's interaction with the vehicle. One way to increase the desired behaviour is to ensure that the driver feels appropriately responsible while using the system. This master's thesis project focuses on two types of automated systems, one where they are responsible for the driving task, and one where they are not.

By conducting a second analysis of a previous research project conducted by Volvo Cars, this thesis project investigated how drivers with little experience in automated systems perceive responsibility in automated vehicles. Several interesting findings were made, and in combination with a review of relevant literature, a conceptual model of responsibility was created. An interview study which focused on frequent users of an automated system enabled a narrow focus on perceived responsibility and the connected factors proposed in the conceptual model. The results from the interview could then be used to validate the conceptual model. Furthermore, two generated HMI concepts investigated how responsibility could be communicated through symbols to the driver and how it could lead them to an appropriate feeling of responsibility.

From the study contextual information, individual factors and control were found to affect the driver's feeling of responsibility. Contextual information was found to be derived from the driving environment and the individual factors were found to be trust in automated driving and the experience and expectations of automated driving. Furthermore, different kinds of responsibilities were found to be connected to automated driving, e.g. the responsibility to keep people safe, the responsibility to monitor situations that the car is less trusted to handle. A design checklist was created based on the conceptual model to aid the development of automated systems where drivers feel appropriately responsible.

The two HMI concepts that were investigated enlighten the complexity of perceived responsibility in automated vehicles, and it could be concluded that a symbol on its own was not enough to communicate responsibility. It was also concluded that the drivers perceived responsibility in automated vehicles must be investigated further to be fully understood.

Keywords: Automated driving, Responsibility, Automotive, Control, Mode confusion

ACKNOWLEDGEMENTS

We would like to thank everyone who made this thesis possible. First, we would like to thank our supervisors Fjollë Novakazi and Mikael Johansson at Chalmers University of Technology, who supported and guided us throughout the project with their expertise in the research area. Their positive feedback gave us more energy when we needed it the most and we are very thankful for their support. We are also thankful for the feedback and discussions with our examiner, MariAnne Karlsson. In addition, we would like to thank our industrial supervisor, Annie Rydström, who helped us prepare our studies, provided us with information from the previous study and helped us finding participants internally from Volvo Cars. When mentioning the participants, we would also like to mention the people who took part in our interview study. Especially those who with short notice could participate, making our list of participants complete.

We would also like to thank our friends writing their master's theses at the UX department during the same time period, for their company during our lunches at PVP and our daily walks around the Torslanda premises.

Lastly, thanks to the people at Human-Centric Lab, who with their welcoming atmosphere provided us with their time and help and contributed to important and interesting discussions regarding our project topic, which we are much grateful for.

Gothenburg, June 10th, 2020.

Gustav Erhardsson

Linnéa Lidander

TERMINOLOGY

Automation level – The automation level refers to levels defined by SAE. The levels range between 0 and 5 of which degree a system automates the driving task and is defined by the amount of interaction needed from the driver.

Automated driving system ("system") – Refers to a group of functions that controls a part of, or the complete driving task.

Pilot Assist (PA) – Volvo Cars' level 2 automated driving system.

Objective responsibility – The responsibility of the driver and the system according to laws and the information in the driver's manual**.**

Subjective responsibility –What the driver feel that they are responsible for when using an automated system.

Perceived control – The driver's perception of the control of the driving task.

TABLE OF CONTENTS

CONTENTS

1. Introduction 1
1.1 Background 2
1.2 Aim 2
1.3 Demarcations 3
1.4 Project process 3
1.5 Report structure 5
2. Literature study 7
2.1 Automated vehicles 8
2.2 Responsibility, control & trust 10
3. Factors connected to responsibility 13
3.1 Introduction 14
3.2 Method 14
3.2 Findings 15
3.3 Perceived control and subjective responsibility 18
3.4 Summary and Implications 19
4. Subjective view of responsibility – a conceptual model 21
4.1 The subjective responsibility model 22
4.2 Summary and Implications 26
5. Development and evaluation of an HMI concept 27
5.1 Creating ideas 28
5.2 Evaluation 30
5.3 Final concept 31
6. Validating the model 33
6.1 Study design 34
6.2 Findings 35
7. A design checklist 41
8. Discussion 47
8.1 The choice of methods and its effects on the findings 48
8.2 Problems regarding responsibility in automated vehicles 48
8.3 Designing to communicate responsibility 50
8.4 The model of subjective responsibility 50
8.5 Ethical considerations 51
9. Conclusions 53
References 55

1. INTRODUCTION

This chapter provides important information such as background to automation and the problems that have been investigated by previous researchers. In addition, it provides an explanation of the aim of the project and its demarcations, along with a description of the project process and the structure of the report.

1.1 Background

New automated technology is constantly being developed and several manufacturers in the automotive industry are competing on the way towards the first commercial self-driving vehicle.

One motive for developing automated driving systems is traffic safety. According to the World Health Organisation (2018), creating safer vehicles is one of several means to decrease accidents in traffic worldwide. However, examples show that the technology used to create safer vehicles is not always fully ready to be introduced to the users. Automated technologies such as Advanced Driver Assistance Systems (ADAS), are putting drivers in unfamiliar situations which could lead to undesired effects. For example, in 2016 an accident involving an automated vehicle occurred and lead to fatal consequences (Tesla, 2016). The ADAS-system was designed to control parts of the driving task but the human driver was nevertheless responsible for the safe operation of the vehicle, more exactly, it was expected of the human to monitor the vehicle and the environment and take over in situations when the system was not operable (Banks, Plant & Stantone, 2018). And accidents like this have resulted in increased attention to the automated systems but also on human error. However, Banks et al. (2018) discuss that many investigations fail to explain why these types of accidents occur and conclude that to prevent and predict accidents in automated vehicles what is referred to as 'human error' must be viewed as a symptom rather than as a cause (Banks et al., 2018). Thus, many factors need to be considered and investigated to be able to design highly automated technologies that can be controlled and interacted with by the driver in a safe way, one of the factors being responsibility.

When it comes to responsibility and automated vehicles many research projects in the area have been focused on investigating causal responsibility. This is something that Agah Howard, Cabibihan, He and Salichs (2016) define as when someone is responsible for every event they caused to happen, this someone can be either a person or an automated vehicle. One example of research on causal responsibility is Awad et al. (2018) with their research on the driver's responsibility in accidents with automated cars and who is to be blamed when the control is shared between the human and the system.

However, few research projects have been conducted to investigate the *perception* of responsibility of automated systems even though there are indications that drivers feel less responsible in automated vehicles than in nonautomated vehicles e.g. by testing the technology beyond its limitations (Stumpf, 2018). Thus, it is of high importance to address driver's understanding of responsibility when using automated technologies and to do this before severe accidents happen and not afterwards. If the driver feels an appropriate level of responsibility during automated driving it is possible that the risk for accidents can be reduced assuming that people feeling responsible also will act more responsible. Furthermore, automated systems can differ in degree of automation and one and the same vehicle can have several systems available. This can make it even more difficult for the driver to know when they are responsible and when not. Therefore, this master's thesis project investigates the human driver's subjective perception of their responsibility in a car with multiple levels of automation.

1.2 Aim

This master's thesis project aimed to investigate drivers' subjective responsibility, meaning what they feel responsible for when driving with several levels of automation available. This project focused on level 2 and level 4 automation. Through researching drivers' subjective responsibility, the goal was to gain knowledge that can aid future development of automated vehicle systems and provide useful

insights to the development of features in level of automation 2 (LoA 2) as well as level of automation 4 (LoA 4). At the beginning of this thesis project, two research questions were formulated to define the scope of the project. The research questions were the following:

Research question 1: *Which factors affect the drivers' subjective responsibility when interacting with an automated vehicle that offers several levels of automation?*

Research question 2: *How can different design solutions support drivers understanding of their responsibility of the driving task in each automation level?*

The deliverable of the study is a conceptual model explaining the connection between factors affecting responsibility, and a list of design guidelines which can be used by designers and developers to support users of LoA 2 and LoA 4 vehicles in understanding their responsibility. In addition, an HMI concept is developed and evaluated to provide an answer to the second research question.

1.3 Demarcations

The thesis was limited to investigate the perception of responsibility during the usage of an automated vehicle and did not consider causal responsibility since much research has already been conducted on that topic in relation to automated driving.

Since designing and evaluating a solution and getting feedback from users were important for the thesis project, there was a limitation on which solutions were possible to consider. It was not an aim that the solution would be directly implementable in upcoming cars. The focus was to see how solutions could affect subjective responsibility, but how they would affect other parts of the interface has not been taken into consideration.

1.4 Project process

The overall approach for the project was based on the Design Thinking process. Design Thinking is often used by designers to handle unknown problems (Siang, 2020). Even though the focus of the project was known from the beginning, i.e. responsibility and design of the in-vehicle HMI, it was unknown which other factors that would have an impact on responsibility and where in the interaction between the driver and the automated system the actual problems could be found, as well as the extent of the problems. Design Thinking can be described as a non-linear process with a human-centred focus, working iteratively to empathize with the user and challenge designer's thoughts. It is also a process that is used to redefine problems and create solutions that can be tested by the user (Siang, 2020). For this thesis project, the focus was to seek the user's perspective. To make it easier to empathize with the users, ideas were tested and discussed with participants. In Figure 1, the overall process is presented involving the five stages from a design thinking perspective: empathize, define, ideate, prototype and test.

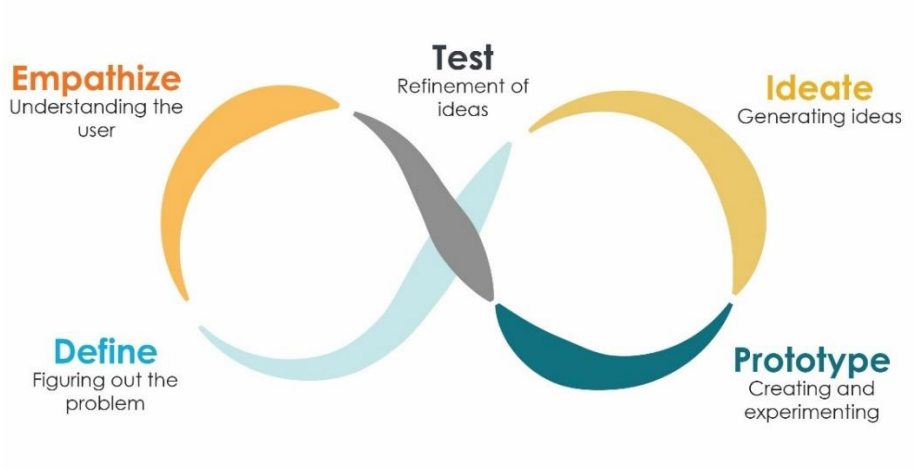


Figure 1, The Design Thinking process and the 5 stages throughout the project, adapted from Siang (2020)

Furthermore, the project can be divided into three different phases described in Figure 2. Each phase illustrates which of the stages in the design thinking process that was present in the phase. The main focus of this thesis was to empathize with the user and try to define the problems around responsibility in automated vehicles.

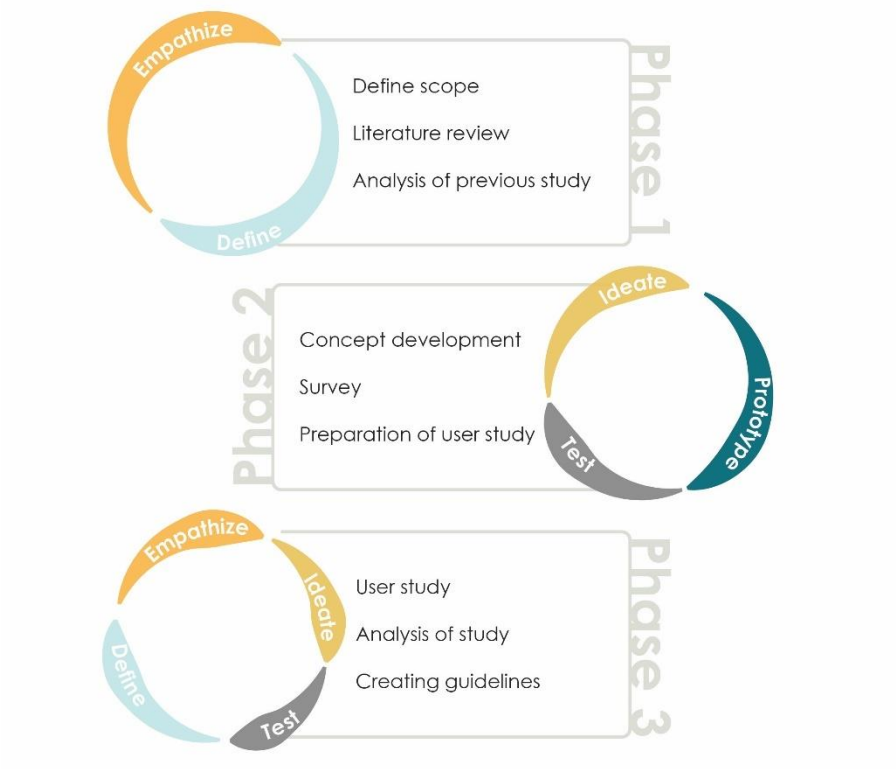


Figure 2, The project phases with their process focus

During phase one the goal was to define the scope of the study and explore the topic of subjective responsibility when using automated driving systems. A literature review was conducted to gain knowledge of previous research on the topics: responsibility, control and trust. It was also a way to gain a deeper knowledge of the usage of ADAS. In addition to the literature review, an analysis of a recent user study on automation, performed by Volvo Cars, was conducted. The literature review and the analysis of the user study were done in parallel, thus the literature could aid in generating ideas and

explaining assumptions found in the analysis. In summary, the first phase focused on defining the problem and empathize with the user to be able to ideate on a conceptual model on responsibility, linking the theory and the findings in the analysis. The conceptual model was evolved and developed throughout the whole project process.

When the literature and the analysis had been synthesized the project moved into phase two. This phase was focused on creating an interview study that could test the conceptual model and add important insights into the topic. Also, two HMI symbol concepts were created and evaluated in an online survey. One of the two concepts were tested further in the third phase as a part of the interview study to gain deeper knowledge about how one could communicate responsibility with the user.

The third phase involved the interview study with the aim to adapt and improve the model with the result from the study and finally summarize the results of the thesis with a design checklist on factors to consider when developing automated systems. Originally, the interview study was planned to include user tests where the participants got to experience level 2 and level 4 automation in real traffic, since it would be more accurate to the real experience. However, due to the Covid-19 pandemic, that plan was cancelled, and the interview study was held instead.

1.5 Report structure

The report is structured as follows:

Chapter 1: Introduction – This chapter provides a background to the project along with a description of the process used during the project.

Chapter 2: Literature study – This chapter contains a description of key concepts and a summary of literature relevant to the topic.

Chapter 3: Factors linked to responsibility – This chapter presents the data from a secondary analysis of a user study conducted in 2019 and the results it provided on the topic of subjective responsibility.

Chapter 4: Subjective view of responsibility - a conceptual model – The findings from chapter 2 and chapter 3 are used to present a conceptual model of subjective responsibility.

Chapter 5: Development and evaluation of an HMI concept – This chapter presents the development of two symbol concepts, supporting the users understanding of responsibility, that were evaluated by means of a survey.

Chapter 6: Validating the model – An interview study was conducted to validate the proposed conceptual model in chapter 4, and to get further insights into the topic.

Chapter 7: A design checklist – A tool that can be used as an aid when developing automated systems was created and is presented in this chapter.

Chapter 8: Discussion – This chapter discusses the most interesting findings along with what needs to be performed for further investigation.

Chapter 9: Conclusion – This chapter presents important conclusions from the results in the thesis.

2. LITERATURE STUDY

To understand the area in which the thesis was conducted, this chapter will introduce some background to the topic. It will provide definitions of concepts and terms used throughout the thesis along with findings from literature in the area of responsibility, control and trust.

2.1 Automated vehicles

To be able to understand responsibility in automated vehicles, the theory about how automation works and how automation is used today must be explained.

2.1.1 Levels of automation

Due to the development of automated systems in vehicles, six levels of automation have been defined by the Society of Automotive Engineers (SAE). The definitions of the levels serve as a framework for companies developing automated vehicles.

The levels range from no automation in level 0 up to full automation in level 5 (SAE International, 2018). Factors that define whether a system is low or high automation are amongst others, the human's responsibility and control over the system and how advanced the technology is.

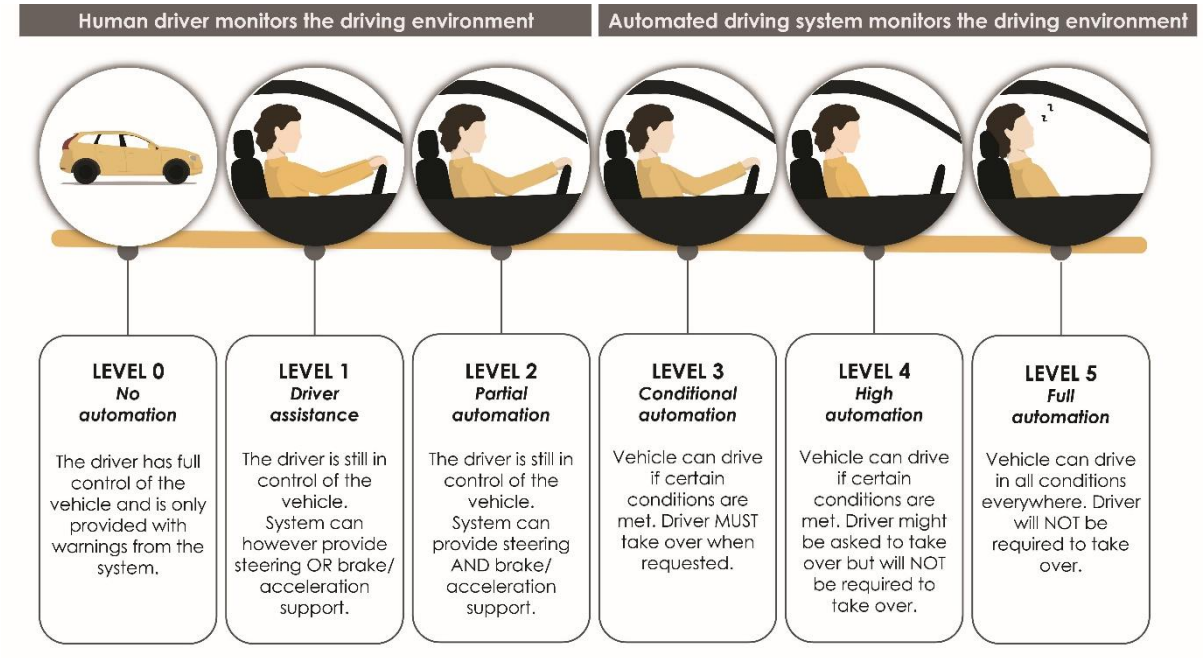


Figure 3, Adaption of the levels of automation according to SAE International (2018)

Cars that are 100 percent manually controlled by the driver are categorized as level 0, this also means that the driver has full responsibility of the driving task. Moving up to level 1, it is still the driver that is responsible for the driving task, but the support systems can assist with steering or brake/acceleration support, tasks which however must be supervised by the driver. In level 2 the driver is still fully responsible of the driving, but the system is described as *partially automated*. This means that it can provide steering and brake/acceleration support at the same time, but like in level 1, the driver must still supervise the system. Level 3 is called *conditional driving*. What differentiates level 3 from level 0, level 1 and level 2 is that the human in the car has no responsibility for the driving task when the system is engaged. This level covers automated systems that can be used when the right conditions are met but when they are not met the system will request the driver to take back control, due to that the system will not work in heavy rain etc.

The last two levels are level 4, *high driving automation*, and level 5, *full automation.* Here the driver does not have any responsibility for the driving task and the human can now be described as a passenger instead of a driver. Unlike in level 3, the systems will not require the driver to take over. In level 5 the car can drive during all conditions whereas level 4 is limited only to work when certain conditions are met, such as highway driving or traffic jams. If those conditions are not met, it is not possible to turn on the system. Figure 3 provides an overview of the relations and descriptions of the six levels of automation.

2.1.2 More on level 2 automation

Manufacturers have chosen many different names for level 2 features, but it is common that the word "pilot" is included in the name. For example, Volvo Cars named its system Pilot Assist (Volvo Cars, 2020), Tesla named it Autopilot (Tesla, 2020), whereas Nissan's system is called ProPilot (Nissan, 2020).

What is typical for the level 2 systems available on the market today is first that they are activated by the driver on their initiative. It is typically activated and deactivated in the same way - by pressing a button or a switch (Volvo Car Corporation (2019); Nissan Motor Corporation (2020)).

The feedback from the car to the driver is different icons displayed in the infotainment cluster behind the steering wheel. A study investigating users' understanding of level 2 symbols showed that a majority of the icons from the three manufacturers involved was illustrating a steering wheel to communicate that the automated system was active (Richardsson, Stanton, Revell & Kim, 2020). Also, both auditive and visual warning signs are provided if the driver releases their hands from the steering wheel for too long. A collection of infotainment clusters from four different manufacturers can be found in Figure 4.

Figure 4, Infotainment clusters from Nissan, Volvo & Tesla

2.1.3 More on level 4 & level 5 automation

Even though it is not possible to buy a level 4 automated vehicle yet there are examples of vehicles that are driving in level 4 and 5 automation today. One example is Waymo, Google's self-driving car project, which is testing self-driving vehicles on public roads across the US without anyone behind the steering wheel (Waymo, 2020).

Until it is possible to buy a level 4 automated vehicle, many problems need to be solved of which one is the legal aspects of automated driving. According to Vellinga (2020), legislators stand before many legal challenges when the absence of a human driver is a fact. It is discussed who will be assigned as the actual 'driver', i.e. who is taking decisions on the dynamic driving task and who is responsible for the performance of the dynamic driving task in such vehicles and whether it is possible to assign the car manufacturer or the software developer as the 'driver'. The user of the vehicle cannot be regarded as the driver since they do not perform the dynamic driving task (Vellinga, 2020). Volvo Car has, as an example, earlier stated that they will assume liability when their cars are driving in level 4 automation (Volvo Car Corporation, 2017). Thus, facts point towards a new unfamiliar driving situation where

responsibility is removed from the human driver and assigned to another entity. If the system is designed for the driver to not be responsible, it could lead to a bad user experience or the system being used incorrectly if the driver still feels responsible.

2.2 Responsibility, control & trust

There are many factors central to the content of the thesis that will benefit from being explained. A summary of some relevant literature related to responsibility is also presented.

2.2.1 Responsibility

Since this thesis investigates responsibility related to automated driving, it is important to have a clear image of what is meant by the term. Cambridge Dictionary (2020b) defines responsibility as "*Something that it is your job or duty to deal with*.", while Merriam-Webster (2020) defines responsibility as "*The quality or state of being responsible: such as moral, legal, or mental accountability*". In the context of driving, many laws and regulations define what you are supposed to do and how you are supposed to act. As a driver, you might not have the same perspective. Therefore, it is helpful to divide responsibility into *subjective* responsibility and *objective* responsibility. *Subjective* responsibility refers to the perceived responsibilities of the driver while objective responsibility is described in the instructions manual of, for example, a vehicle or from a legal point of view (Flemisch et al., 2011). Objective and subjective responsibility can describe the same thing if the driver has a correct view of responsibility. On the opposite, the subjective and the objective responsibility can differ if the driver's perception does not comply with the legal view. This thesis project is focussed on ***subjective responsibility which is defined as the driver's perceived moral, legal, and mental obligations that are present in the context of automated driving.***

2.2.2 Control

Control is another central term for this thesis and that is important to be able to distinguish from responsibility since they are often mixed up. The definition by Cambridge Dictionary (2020a) is *"The power to give orders, make decisions, and take responsibility for something."*. One could say that control is the ability to act on an assigned responsibility, e.g. prevent your kids from getting sunburnt by making them wear sunscreen since they are your responsibility to care for. Furthermore, control is described as *"the ability or power to decide or strongly influence the particular way in which something will happen or someone will behave, or the condition of having such ability."*(Cambridge Dictionary, 2020a). This is similar to how Flemisch et al. (2011) define control when applied to human-machine systems. They define control as *"To have control means to influence the situation so that it develops or keeps in a way preferred by the controlling entity."* (Flemisch et al., 2011).

In automated vehicles, part of the control of driving is transferred from the driver to the automated system. However, for a driver, it can be difficult to know how much control the automated driving system has over the driving task since it is a complex system. Therefore, it is important to distinguish actual control from the control that the driver perceives the automated driving system to have. Therefore, the term ***perceived control will be used throughout the thesis to refer to the driver's perception of the control of the driving, both by the driver and by the automated driving system.***

2.2.3 Explaining the evaluation of an individual's responsibility

Three key elements, *Prescriptions*, *Event* and *Identity*, are presented in the triangular model of responsibility (Figure 5). According to Schlenker, Britt, Pennington, Murphy & Doherty (1994), the elements are required to evaluate whether an individual can be held accountable or not in case of an accident. The strength of the linkages between the elements can be used to judge how responsible the individual is. The model considers the responsibility judged from an audience perspective and the

audience can be composed either by other people or oneself (Schlenker et al., 1994). The reflection upon the responsibility of oneself can be seen as subjective responsibility.

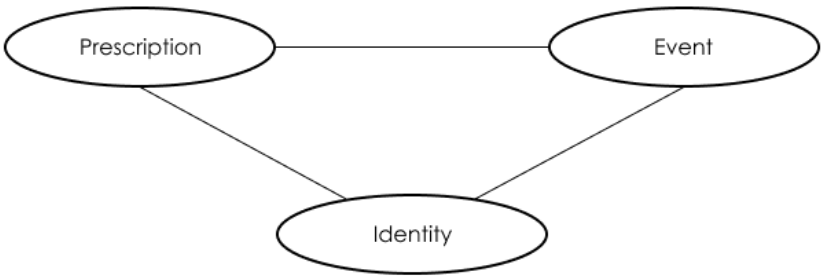


Figure 5, Adaption of the responsibility triangle (Schlenker et al., 1994)

Prescriptions are defined by Schlenker et al. (1994) as codes or rules of conduct. They handle implicit or explicit information about the goals of an activity, standards of how to act and the appropriate way to achieve them. Events are units of actions and consequences that can be viewed as coherent but can vary in size. It can be a small job task or a task that is performed for a long period of time. Together prescription and event make up the situational context. Finally, identity refers to the actor's roles, qualities and commitments related to the situation (Schlenker et al., 1994).

The link between prescription and event is used to evaluate to which extent clear prescriptions, e.g. rules laws and moral codes, exist and can be applied to an event to steer the behaviour of a person. Second, the link between prescriptions and identity is used to evaluate to what extent the prescriptions can be applied to the actor. It can be judged through the individual characteristics, role or convictions meaning that a professional driver might be held to a higher standard of driving than a non-professional driver in case of an accident. Lastly, the link between identity and event refers to the extent to which the actor can be associated with the event, e.g. by being part of a group connected to the event (Schlenker et al., 1994).

2.2.4 Linking control and responsibility

Based of examples of cooperative systems, four cornerstones of such systems are investigated in a model by Flemish et al. (2011). The cornerstones are *Ability, Authority, Control* and *Responsibility.* Ability means having the means or skill to act correctly. Authority can be broken down into control authority, i.e. having the power to do something (such as steering a car), and change authority, i.e. being able to change the control distribution (such as switching driving modes). Control means influencing the situation, so it stays or turns into the desired state.

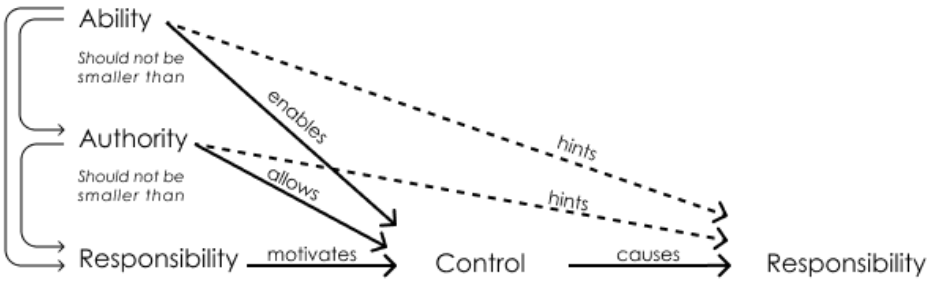


Figure 6, Relations between Ability, Authority, Responsibility and Control (Flemisch et al., 2011)

The cornerstones are highly connected, as seen in Figure 6. Without ability and authority, control is not possible, but subjective or objective responsibility is also required to motivate the driver to take control. Objective responsibility should not be assigned to the driver for control that they do not have the authority or ability to perform, responsibility should therefore be smaller than authority and ability. Authority should not be given to someone without this someone having sufficient ability. Having control causes the driver to be responsible for their action, for example, the driver cannot be seen as responsible for steering in a driving mode where the steering is handled by the automated system. Indirectly, the presence of ability and authority hints towards responsibility and the objective view can be used to debate whether the driver is responsible or not (Flemisch et al., 2011).

2.2.5 Trust

In a study conducted by Lamberti, Morra, Pratticó, La Rosa and Montuschi (2019), where it was found that information in the HMI affected trust, specifically information concerning why the system acted as it did. Another study provided an idea that the perception of the system performance in different situations influence the driver's trust in the system. Furthermore, trust can be seen as the result of a combination of the information provided in a situation (Ekman, Johansson, Bligård, Karlsson and Strömberg, 2019). How drivers build their trust is also discussed as a factor that will become an important issue in future vehicle automation, and a match between mental models and experience is believed to increase trust (Beggatio & Krems, 2013), which indicates that the opposite probably would lead a driver to no longer trust or rely on the system.

Earlier research also points out the problems with inappropriate reliance in automated systems and that trust is a factor affecting the performance of the driver (Lee & See, 2004). They also suggest that one should design for an appropriate level of trust and avoid greater trust than appropriate for the situation (Lee & See, 2004), something that Parasuraman, Sheridan and Wickens (2008) also discuss in terms of excessive trust which is believed to lead to misuse of the system.

2.2.6 Summary and implications

Not a lot of research into the specific topic of subjective responsibility in automated driving was found, which indicated a research gap in the area. However, related research provided some insights. From Schlenker et al. (1994), prescriptions and events could be of interest since the instructions and information provided about an automated system as well as the context of the use of the system can affect subjective responsibility. The identity is less important in the context of personal driving, and one can assume that users have a valid driver's license, making them have an equal responsible role on the road. Furthermore, there is a strong connection between control and responsibility (Flemisch et al., 2011). Subjective responsibility and perceived control were defined to be able to further investigate the driver's feelings when using automated systems. The driver needs to differentiate if they are responsible for the driving task when using a system in level 2 and level 4 automated driving, while from their perspective, both systems steer, accelerate and brake. Trust was also found to be common topic related to automation and the performance of the driver in automated systems. It was also found to be connected to experience, something that will be further investigated in this report.

3. FACTORS CONNECTED TO RESPONSIBILITY

This chapter will present the result of a second analysis of the existing data provided by a previous study. It will be used alongside the literature study to provide more insight into the topic of responsibility.

3.1 Introduction

A study on automated driving was conducted by Volvo Cars in California in 2019. The study was provided as a resource for this thesis project.

3.2 Method

3.2.1 Material

The Volvo Cars study was based on user tests where 19 participants drove with systems resembling level 2 and level 4 automated driving. Afterwards, interviews were held, and the participants were asked about their experience of the respective systems. The 19 participants had a valid driving license and previous experience of cruise control systems, which are used to keep a car at a set speed.

The system that simulated a level 2 experience offered lateral steering support by keeping the vehicle in between the lines on the road with the help of advanced lane-keeping support. It also offered longitudinal support by adjusting the speed of the vehicle to objects in front. Additionally, it was able to keep a set speed decided by the driver. This partial automation left the driver in full control of the vehicle and they could activate or deactivate the system at any time. It is also important to mention that the driver was fully responsible for the driving task. This was communicated through visual and auditory warnings, which were activated when the driver released their hands from the steering wheel and informed the driver to put their hands back on the wheel. If this information was ignored for ten seconds, it automatically led to a deactivation of the system and the vehicle went back into manual drive.

The system simulating level 4 experience was limited to use during a congested traffic situation. Compared to the partial driving automation in level 2, this system resembled a high driving automation system. Whenever a congested traffic situation occurred, the system could be activated. When the decision to activate the system was made, it took full control over the driving task. However, if the conditions no longer were met, the driver was asked to take over control. This was communicated by both visual and auditory information, giving the driver one minute to re-engage in the driving task. Unlike level 2, the driver is not responsible for the driving task when the level 4 system is activated, and they can do anything they want to since the mode does not demand any driver involvement, apart from activating and deactivating the system.

3.2.2 Analysis

In a first step, the interview manuscript used in the study was reviewed and the questions relevant to the topic of responsibility were selected. The questions deemed relevant were “Do you feel responsible at all times?” and “When were you responsible for the driving task?”, as well as follow up questions.

In a next step, the answers to these questions were analysed. The analysis was done with an inductive approach, going through the material without any predetermined hypothesis and grouping it in themes as these emerged (cf. Bernard, 2017). This method enabled factors connected to responsibility to be discovered. The material was processed in three iterations by both authors to decrease the misinterpretations or that relevant information was missed. The comments made by the participants were divided into factors making them feel responsible and things they felt responsible for. They were

also grouped based on similarity and if they motivated control or came as a consequence of control, as suggested by Flemisch et al. (2011).

3.2 Findings

From the secondary analysis of the provided material, several patterns were identified, and interesting insights were gained. As a result, many factors that affect responsibility and many kinds of responsibilities were found.

3.2.1 Subjective responsibility in level 2 and 4 automation

Based on the answers to the interview questions, the drivers' perception of whether the driver or the system was responsible for the driving task could be identified. The result for each automation level is presented in table 1.

Table 1. Whom the drivers felt was responsible during level 2 and level 4 automation, not all participants made comments

Automation level	Driver responsible	Driver somewhat responsible	System responsible
Level 2 (n=17)	13 (76%)	2 (12%)	2 (12%)
Level 4 (n=18)	10 (56%)	3 (17%)	5 (28%)

To be categorized as 'the driver responsible' or 'the system responsible', the participant had to express clearly if they or the system was responsible. If they expressed some kind of middle ground, they were categorized as 'driver somewhat responsible'. If considering the driver's manual, i.e. objectively, the driver is responsible in level 2 and the system would be responsible level 4. The preferred situation would be that the subjective responsibilities would match the objective, to reduce potential problems, but this was often not the case.

Table 2. The drivers' subjective responsibility referring to level 2 and level 4 automation

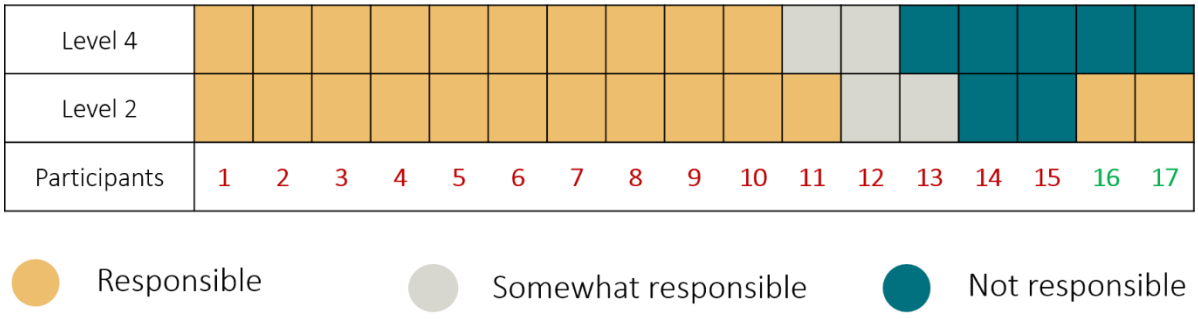


Table 2 presents an overview of the subjective responsibility as indicated by each participant in relation to both levels. Only two of the participants' subjective responsibility complied with the objective responsibility in both the level 2 and the level 4 system, meaning that they felt like they were responsible in level 2 and that the system was responsible in level 4. The majority of the participants felt responsible in both levels. This was often motivated by them having the ability to turn off the system and that they always feel responsible in the car, since they decided to drive the vehicle.

3.2.2 Factors that made participants feel responsible

From the analysis, several reasons to why the participants felt or did not feel responsible when driving with the two levels of automation were identified and summarized in Table 3.

Table 3. *Reasons why participants felt or did not feel responsible*

Level 2: Driver is responsible	
Why drivers feel responsible	**Why drivers feel like the system is responsible**
Driver having control Able to steer Able to brake Easy to turn off the system with the button Activation Being the driver Turned on the system Context High speed Having to keep their hands on the wheel Trust/experience Still learning the system Monitoring *"You have to watch over it."*	System having control The system seemed to steer well enough without help Not feeling like you have to worry about accelerating or braking Only feeling like you have to brake Expectations Expecting the system to have higher control: *"Why can't I release my hands from the wheel?"*
Level 4: System is responsible	
Why drivers feel responsible	**Why drivers feel like the system is responsible**
Activation and control Activating the system Able to turn the system off *"Because I am the driver"* Trust/experience Not knowing what will happen when the system is turned off Not knowing what the system will do or tell them to do Afraid of the system malfunctioning	System having control Feeling like they did not have to do anything Trust/experience Feeling trust by seeing the system work Having learned that the system tells you when you need to do something Context Cues from the interface that they were not responsible for the driving task.

When it comes to level 2 the participants gave multiple reasons for why they felt responsible. The main reasons were the feeling of still having control of the vehicle, e.g. in the sense of being able to steer or brake and performing the action of activating the system. Cues and information from the interface i.e. telling the participants to keep their hands on the steering wheel were also mentioned. What made the participants not feel responsible was the perception of the system controlling the driving task. In many cases the participants expressed trust towards the system since it seemed to perform well and therefore,

they felt less responsible. In addition, some participants expressed that their expectations for the system was that it could be held responsible.

In level 4, being able to activate the system and being able to turn the system off was again expressed as a reason for why participants felt responsible. Along with activation and control, participants felt responsible due to the lack of experience and trust in such systems. On the other hand, some participants expressed that they could trust the system after seeing it handle tasks such as steering, braking and accelerating. The participants also interpreted cues from the vehicle that made them feel less responsible. Thus, trust, experience, expectations and information were found to have a connection to the subjective view of responsibility.

3.2.3 Categories of subjective responsibility

The identified areas describing what participants expressed that they felt responsible for in the driving situation were categorized and are described in Table 4. Many of the responsibilities that were expressed are directly related to factors mentioned in Table 3, e.g. being able to steer results in a feeling of responsibility for steering.

Table 4. Categories of subjective responsibilities

Subjective Responsibility	Description
Motivators	
Legal responsibility	Feeling responsible to follow the law and requirements in the driver's manual.
Driver responsibility	A feeling of responsibility that derives from being the driver of the vehicle, having made the choice to drive the car and activate the system.
Safety responsibility	Feeling responsible to keep themselves and other people on the road safe.
Competence	
Skill responsibility	Feeling responsible to have a sufficient amount of skill to use the system.
Knowledge responsibility	Feeling responsible to have a sufficient amount of knowledge of the system.
Tasks	
Responsibility to follow instructions	Feeling responsible to follow instructions given by the car.
Responsibility for driving tasks	Feeling responsibility of one or multiple driving tasks (steering, braking, accelerating, etc.)

Subjective Responsibility	Description
Monitoring	
Responsibility to monitor the system	Feeling responsible to monitor the system to ensure it is working as intended.
Responsibility to monitor the driving environment	Feeling responsible to monitor the driving environment for situations the system is judged not to be able to handle.
Readiness responsibility	Feeling responsible to be ready when the system gives back the driving task.

The responsibilities were categorized into four groups, *Motivators, Competence, Tasks* and *Monitoring*. Motivators are linked to the moral views of the driver, such as how important it is to follow the law and keep people safe on the road. Another responsibility that was placed in the Motivators category is the responsibility that drivers feel by sitting in the driver's seat and having the ability to activate systems etc., called driver responsibility. Competence is the responsibility the driver feels to understand the system and to be able to use the system correctly. The last two categories are Tasks and Monitoring. What differentiates them is how the responsibility takes shape. Tasks are limited to actions that demand physical interaction with the system, whereas monitoring is a mental activity where you observe the behaviour of the system and the driving environment to find situations which the system can not handle.

In summary, from a user perspective there seem to be many different types of responsibilities, some more general like responsibility for safety, and some more specific, like feeling responsible for a specific driving task such as steering the car.

3.3 Perceived control and subjective responsibility

The illustration in Figure 7 provides an overview of how the participants perceived the system's control of the driving task and how it related to whom they felt was responsible.

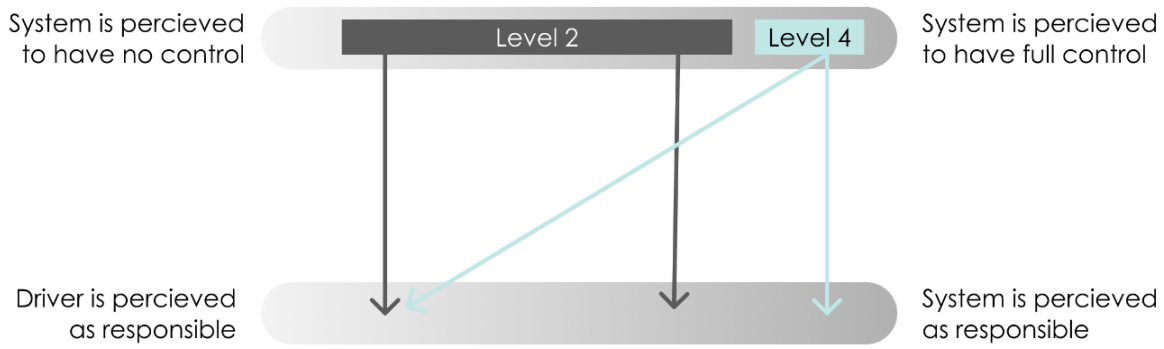


Figure 7. Illustration of how the perceived control affects subjective responsibility in level 2 and level 4 automation

As shown in Figure 7, the control of the driving task by the level 2 system was perceived in many ways by the participants. If the system was perceived to have a high degree control, the driver perceived themselves to be less responsible and vice versa, indicated by the first two vertical arrows. The

participants expressed that they interpreted the feedback from the system as it was controlling some of the driving task. It was, however, difficult to interpret how much of the driving task was handled by the system and how much control they were supposed to have. In level 4, most participants perceived the system to have high or full control over the driving. However, there was a big difference in the drivers' subjective responsibility. As illustrated by the diagonal arrow some drivers felt responsible even though the system was perceived to have high control, arguing that they always have the responsibility when driving and that they still had the control to turn off the system. Other drivers felt that the perceived high control of the driving task by the level 4 system made them not responsible.

3.4 Summary and Implications

In summary, the problem in level 2 seemed to be the variation of how drivers perceived the system to control the driving, ranging from low control to high control of the driving task leading to an unwanted variation of who is perceived as responsible, instead of all drivers feeling responsible. In level 4 it seemed like it was to let go of responsibility. The drivers felt responsible because they decided to use the system and because they could turn it off.

Reasons to why responsibility was felt in level 2 and level 4 were found and categories of subjective responsibilities were created: *Motivators, Competences, Tasks and Monitoring*. These could explain the perceived control in both level 2 and level 4. For example a driver who feels responsible to monitor the driving environment in level 4 even though the car is perceived to have high control, will more likely feel responsible in level 4, and a driver who feels little responsibility to follow instructions from the car in level 2, will more likely perceive the system as having enough control and thereby more likely feel that the system is responsible.

When comparing the results from the study with the results of Flemisch et al. (2011), similar result were found about responsibility motivating control and control causing the driver to feel responsibility. However, the participants talked less about authority, ability and control as different concepts and more about it as one concept of what they could control without distinguishing between the terms. While the distinction of the different concepts is important from a holistic perspective, with the focus on the drivers' subjective responsibility, authority, ability and control here can be grouped into one.

4. SUBJECTIVE VIEW OF RESPONSIBILITY – A CONCEPTUAL MODEL

In this chapter, a conceptual model of subjective responsibility is presented. It provides an overview of factors that affect subjective responsibility. The purpose of the conceptual model is also to explain where and why potential problems can arise that lead to the subjective responsibility being different than the objective responsibility. The model is meant to be used in the development of automated systems and HMI development to make it easier to design a system where the driver feels an appropriate amount of responsibility for the driving task for the system that is used. Apart from HMI development, the conceptual model could aid evaluation of systems before they enter the market through user research.

The foundation of the model was the literature study described in Chapter 2, and the results from the secondary analysis described in Chapter 3. Descriptions and connections between factors in the model were iteratively reviewed to make the entire model coherent. Observed situations with the participants from the study conducted by Volvo Cars were used to validate the model, and when inconsistencies emerged, adjustments were made.

4.1 The subjective responsibility model

Similar to how Flemisch et al. (2011) view responsibility, the conceptual model of responsibility (Figure 8) is built on the fact that responsibility motivates control and that the level of control, in turn, can cause a feeling of responsibility. The model is focused on the driver's subjective view and how the interpretation of information leads to a perception of with whom the responsibility lies.

The model consists of several building blocks. Firstly, there is a clear connection between responsibility and control. Responsibility can motivate the driver to take control of driving, such as steering, changing speed or turning off a system, but having control can also make the driver feel responsible. The responsibilities that were identified in the study described in Chapter 3 were divided into different groups depending on if they were considered to motivate control or if they were considered a consequence of control. Motivators and Competences were categorized as the general responsibilities motivating control whereas Tasks and Monitoring were categorized as more specific responsibilities derived from control. Responsibility and control make up three central building blocks in the model. Apart from control and identified responsibilities, there are two outer blocks connected to the central building blocks. I*ndividual factors* like trust, experience and expectations that affect the feeling of responsibility is one, and the *contextual information* when driving is another which also affects the driver's feeling of responsibility, as described in Chapter 3. The last building block is engagement, which is used to describe the driver's interaction with the system.

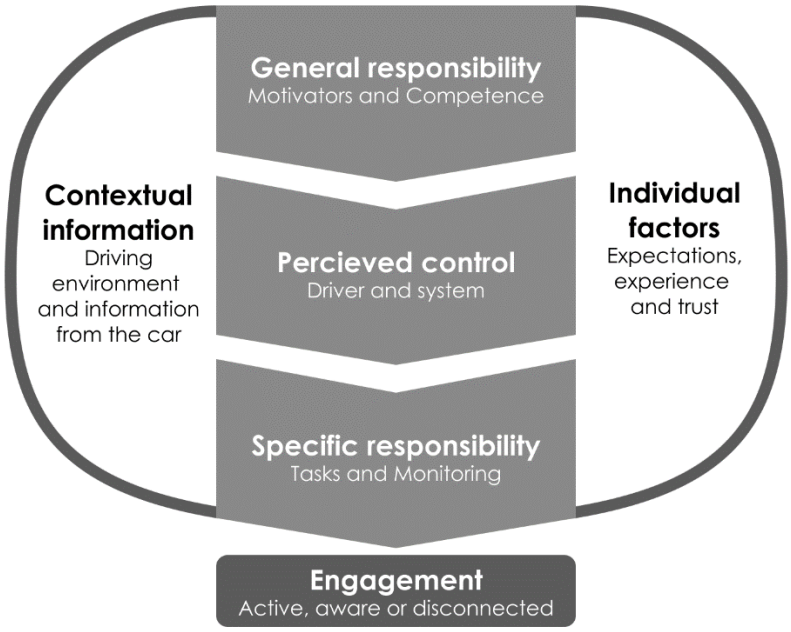


Figure 8. Conceptual model of responsibility

4.1.1 Contextual information

In the responsibility model, contextual information refers to information available to and interpreted by the driver the moment. It can be derived from car haptics, infotainment system, information cluster and/or the driving environment. The driving environment includes the environment inside the car, such as if there are passengers, as well as the external environment, such as other road users, traffic density, weather and road conditions.

Furthermore, information can be either implicit or explicit. Explicit information is clear and easy to interpret by the driver, e.g. the system prompting "steer the car". Implicit information leaves room for interpretations, e.g. resistance in the steering wheel or interpretations of symbols. Contextual information can affect what kinds of, and how much responsibility the driver feels. For example, driving at higher speeds can make the driver feel more responsible for driving safely. It is also a factor in how the control of the driving task is perceived e.g. through haptics or information in the instrument panel. Information that is unclear or incomplete seems to increase the driver's feeling of responsibility, such as if a driver is unsure of what a message from the car means.

4.1.2 Individual factors

On the other side of the model are individual factors. Based on the results from the previous study trust, experience and expectations were identified as factors affecting the feeling of responsibility. Trust in the automated system enables the driver to hand over responsibility to the system. Through experience with the system the driver can build trust. Experience can also enable the driver to better evaluate what they feel responsible for. Expectations can be derived from mental models of the driver and it can be described as a view that a person has over how something works. News articles or talking to friends about automated systems, also affect subjective responsibility, e.g., thinking that an automated system will work flawlessly and take full control of the driving task, resulting in going into a situation feeling less responsible. The users experience and expectations in different levels can indirectly affect each other, e.g. if a user has the experience of feeling little responsibility in a level 2 system, a higher automated system might enhance that feeling.

4.1.3 General responsibilities

In General responsibilities one can find different areas of responsibilities that are derived from the moral believes and mental models of the driving situation. Based on the subjective responsibilities identified in the Volvo Cars study, each driver feels an individual level of responsibility to follow the laws and behave safely in the traffic environment along with a feeling of responsibility that derives from being the driver, here called Motivators. The driver also feels the responsibility to have the right knowledge on how to, and skill to, use the car, such as knowing the limitations of the system and being skilled in judging that a situation is outside the system's capabilities, together called Competences. The Motivators and Competences can encourage the driver to take more or less control of the driving situation depending on how strongly they are felt by the driver.

4.1.4 Perceived control

As is mentioned in the literature study, section 2.2.2, control is the power to take decisions and influence behaviour. To be able to make decisions, the driver estimates the amount of control that they possess and the control that the system possesses. So, based on contextual information, the individual factors, Motivators and Competence, the situation results in perceived system control and perceived driver control. Together they make up to the combined perceived control. The driver will also have a lower limit for the amount of control present in the driving situation, affected by the previously mentioned factors in the model such as contextual information.

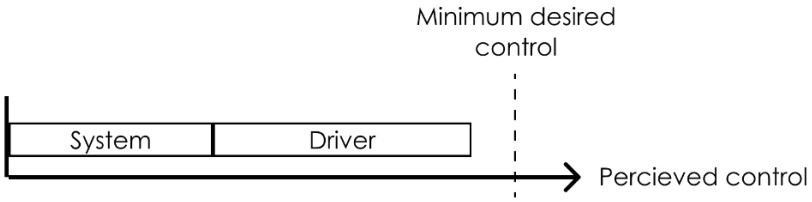


Figure 9. Illustration where the perceived control of a situation is not enough for the driver

Figure 9 presents an illustration of how control is perceived by the driver when the minimum desired control is not reached. The bar represents the amount of control the driver perceives the system and themselves to have of the driving task and the dotted line represent the minimum desired control the driver wants to be present in the driving situation. A driver that is unfamiliar with an automated driving system might have a higher minimum desired control because of low trust in the system, while a driver that is familiar with a system and trusts it might have a lower minimum desired control. If the minimum desired control is not met, the driver feels like there is a lack of control and might either try to compensate by increasing their control of the driving by exercising the control they have at hand, such as steering or braking, or by paying more attention to the driving environment. If there is a large deficit of perceived control compared to the minimum desired control, the driver might change or turn off the system to end up in a situation where the driver feels like there is enough control of the driving task, either by the driver, the system or both .

4.1.5 Specific responsibilities

The previous parts of the model, i.e. contextual information, individual factors, general responsibilities and control, affect how responsible the driver feels for certain driving tasks or for monitoring the system. Tasks are defined as interactions with the car such as steering, braking, or accelerating but also turning on or off the system. Monitoring is defined as evaluating the performance of the system or the surrounding driving environment without physically interacting with the system, to judge whether an intervention is needed.

4.1.6 Engagement

The last part of the conceptual model is a level of engagement from the driver, depending on how responsible the driver feels. The level of engagement ranges from a high level of engagement to no engagement present. *Active* is the highest level of engagement and can be described as being constantly focused on the driving environment and interacting with the car by steering and or braking, etc. This behaviour is much likely due to a high feeling of responsibility. *Aware* is the next engagement level where the driver is interpreting cues in the surrounding, but not actively controlling the driving, e.g. being aware of that the car will hand over the driving task at some point. Lastly, we have the level where no engagement from the driver is present, called *Disconnected*. This means that the driver is in a condition with reduced ability to take in stimuli and information from the system, e.g. while paying all their attention to their smartphone. In contrast to Active engagement, this behaviour derives from not feeling any responsibility for the driving task.

4.1.7 How the parts of the model are connected

Contextual information and the individual factors are connected to both responsibility and control in the model. The responsibilities can differ a lot depending on contextual information and individual factors. One might for example not feel as responsible for safety when parking a car or when trusting the system. The same applies to control. One might perceive a higher control due to car haptics or having had a lot of experience with the system. Lastly, contextual information, such as a warning signal, or individual factors, such as lack of trust might make you feel more responsible.

4.1.8 Mismatches: Identifying problems with the help of the model

Automated driving systems come with different definitions of what is objective responsibility and it is desired that the driver's subjective responsibility matches the objective responsibility. For example, a level 2 automated system is designed for the driver to be responsible for the driving, while a level 4 automated system is designed for the driver not to be responsible for the driving while using the system. In considering any part of the model, problems can arise that leads to a mismatch between the objective and subjective responsibility.

If very little responsibility is felt for Motivators and Competences the driver will most likely be satisfied with low perceived control, which in turn can result in accidents e.g. if the driver does not feel like they need to have the right knowledge to use the level 2 system, they might be satisfied with the car handling the steering leading to a misuse of the system. If on the other hand, a very high amount of responsibility is felt, it could lead to the desired control being very high which can make the driver seek more control of the driving task than the system was intended for.

If the desired perceived control is not reached in a situation, the driver will most likely not feel at ease with the situation. So, if the perceived control of the driving, by either the system or the driver, is higher than the actual control the driver might let go of control and thus responsibility, even though they should not. The opposite scenario is that if the perceived control is lower than the actual control, the driver might feel responsible and seek control even though it is not needed.

The same reasoning can be applied for Tasks and Monitoring. If the driver feels a little responsibility for Tasks and Monitoring responsibilities, they might move into a lower engagement than desired and if the driver feels a lot of responsibility for Task and Monitoring responsibilities, they might move into a higher engagement than desired.

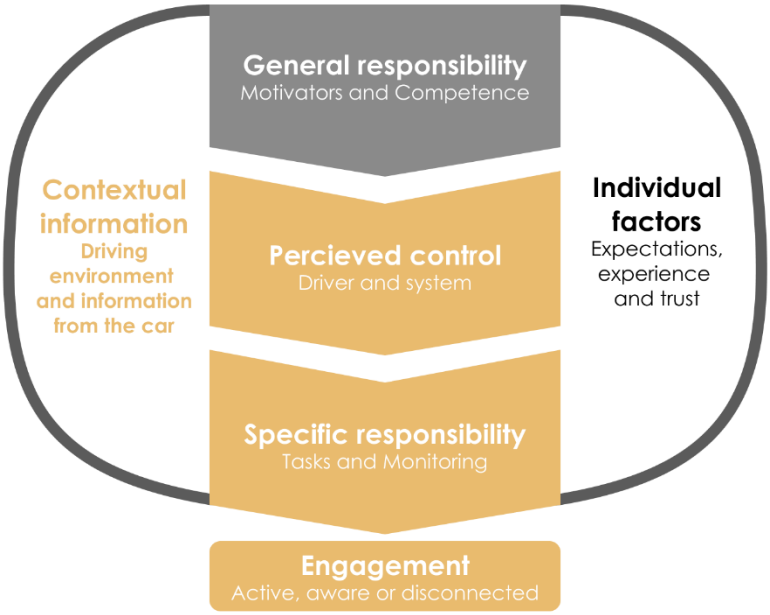


Figure 10. An example of a mismatch that originates from contextual information

Mismatches can also appear from contextual information and individual factors. If the provided information is interpreted in the wrong way or if information that is needed is missing, this can lead to a mismatch. For example, as illustrated by Figure 10, if a driver thinks the system can take on responsibility in a specific driving condition when it actually cannot, it will lead to a mismatch in the perceived control. That will make the driver feel less responsible e.g. for steering and will in turn lead to the wrong engagement from the driver. Taking the individual factors into consideration, mismatches can also occur if the drivers' expectations for the system are higher or lower than its actual performance or if previous experiences of automated systems (or the lack thereof) has created an incorrect understanding of the system.

4.2 Summary and Implications

A conceptual model was created based on literature and findings from a second analysis of data from the study conducted by Volvo Cars. It considers different factors that was believed to affect responsibility and is an attempt to explain how subjective responsibility works in automated vehicles.

As the first research question can be considered as answered through the factors in the conceptual model, the next step was to investigate how an HMI concept could be used to affect the drivers' subjective responsibility. After that, the step would be to validate the model further by testing the concept with users, to make sure that the structure and the components are present even with users that are experienced with automated systems. It will also be important to explore how the model can be used when designing automated systems.

5. DEVELOPMENT AND EVALUATION OF AN HMI CONCEPT

The model presented in the previous chapter answered the first research question. It was found that a vast majority of the participants in the Volvo Cars study did not feel responsibility in a way that complied with the objective responsibility when using level 2 and level 4 automation, indicating that changes have to be made to the experience. To investigate the second research question "*How can different design solutions support drivers understanding of their responsibility of the driving task in each automation level?"*, a concept for how one could communicate control and responsibility through the in-vehicle HMI, and work with implicit and explicit information was developed and evaluated.The concept was developed in parallel with the conceptual model and was thereby not directly founded in the model and its building blocks. The quotes in this chapter are the exact words written in English by participants in a survey study.

5.1 Creating ideas

The methods used to create the ideas for the HMI are presented here, along with two concepts that could be investigated further. The methods included one brainstorming session followed by braindrawing sessions.

5.1.1 Brainstorming

By brainstorming freely around how one can get the driver to feel the desired level of responsibility, the first ideas were developed. Brainstorming is a commonly used method for ideation that provides an informal approach to problem-solving and encourage crazy ideas. It can be conducted in a group or individually to avoid influencing each other's creativity flow (Mindtools, 2020a). This was utilized during the ideation session to first create ideas without influencing one another and then taking the ideas developed in the first brainstorming session as inspiration to develop new ideas.

5.1.2 Braindrawing

Some of the ideas were iterated further through a couple of braindrawing sessions. Braindrawing is a visual brainstorming method used to ideate around visual ideas such as icons and layouts. The focus while using this method is to get several ideas that can be used to give input for further development of the design (Kidd, Ekhteraei & Wilson, 2011).

The braindrawing sessions were about five minutes long and a timer was set to keep the timeframe. At the end of each session, the ideas were discussed, before moving on to the next session. The first drawing session was focused on symbols and icons and what they could look like in general since that is how the HMI is used today, followed by sessions based on how one could communicate control, responsibility and work with implicit and explicit information.

Figure 11. Braindrawing session

5.1.3 Selection of Ideas and proposed concepts

The ideation methods resulted in many different ideas. Some were more elaborate than others, such as changing the resistance in the steering wheel, working with auditory information from the car or to disconnect the driver from the external environment in level 4 by covering all windows with curtains.

Because of the setup of the master thesis project, there were some design factors that were considered when choosing ideas to develop further. It was desired that the concept could be tested in a car, (even if it was not possible due to covid-19), in a way that was credible for the participants, and the allocated time created limitations for doing modifications of the interior of a car. It was also desired that the solution should be a part of the system and not be an external solution such as a demonstration in order to improve the preconditions for all users to feel responsible, or not responsible, at the right times. This resulted in the two main areas for ideas being auditory and visual solutions. Based on the comments in the Volvo Cars study, there seemed to be problems in understanding the existing visual parts of the system, like symbols, compared to auditory signals, and therefore, the ideas ended up revolving around visual solutions.

Two of the visual concepts were developed further and evaluated with users to help decide which to move forward with. The concepts were chosen due to their consistency in showing comparable information through each level and due to their difference to the solutions used today, which only indicates that the system is on and not the driver's role. Each concept was based on having a dynamic symbol that changed with the level of automated driving.

Concept 1 showed who was the responsible actor in the drive mode by using explicit information such as text, A1 for level 0 and level 2 when the driver is responsible and B1 for level 4 when the system is responsible (Figure 12).

The second concept showed the control division of the driving task between the driver and the system, providing more implicit information than concept 1. It consisted of three different versions of a symbol, A2, B2 & C2 for level 0, 2 and 4 (Figure 12). Version A2 is intended to show that the driver is in full control, B2 that the driver is in full control but assisted by the system and C2 that the car is in full control of the driving but that the driver has the option to take some control.

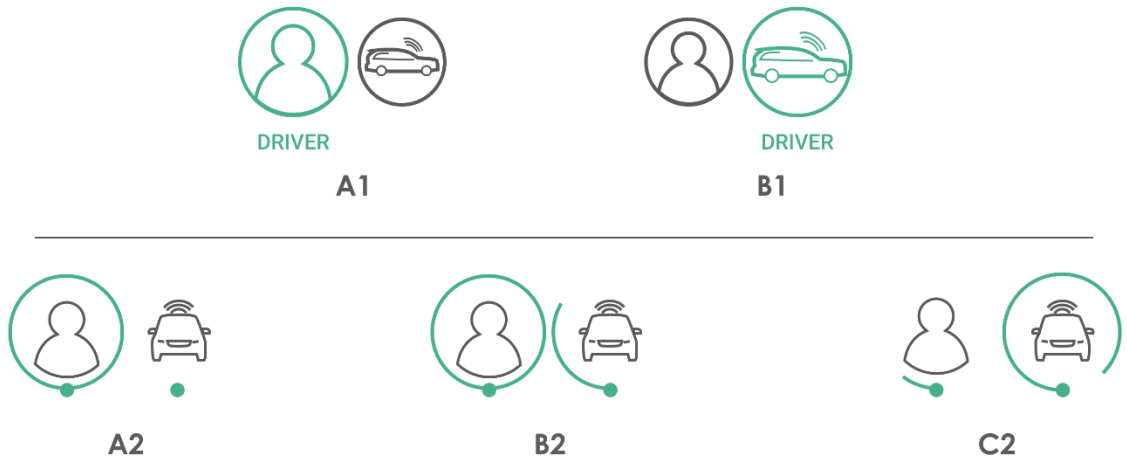


Figure 12. Concept 1 and concept 2, HMI symbols for automated driving

5.2 Evaluation

An evaluation of the developed concepts was conducted with help of an online survey. The results from the study was then used as a basis for choosing one concept to evaluate further.

5.2.1 Study design

The survey was shared on social media platforms such as Facebook and LinkedIn to reach a large number of respondents. To gain as many respondents as possible, the survey was anonymous and took about five minutes to complete.

It was divided into two sections, one for each concept, and along with each concept, a scenario was described to provide the respondent with the right context. The scenario was the same for both concepts and was described as following:

> ***Scenario:*** *Imagine that you are driving your car and that there is a symbol showing in the information cluster behind the steering wheel. Depending on which systems you are using and how much assistance you get from the car, the symbol will take different shapes.*

For each concept the respondents were provided with four statements, "I am currently in charge of the driving", "I only have to monitor the car", "I can release my hands from the steering wheel" and "I can lay back and relax". For each statement, they were asked to indicate which of the versions A or B (or C) that they thought matched the statement by filling in tick-box answers. It was possible to tick more than one version for each statement and there was also one option saying that none of the symbols could represent the statement. At the end of each session, it was also possible to write additional thoughts about how the symbols were interpreted. This possibility was added to gain deeper qualitative data with insights and thoughts about the symbols and their meaning. The complete survey design can be found in Appendix 1.

5.2.2 Results

The survey received 101 responses in total, of which 34 participants also wrote additional thoughts about the first concept and 29 about the second concept.

Quantitative result

A summary of the quantitative data for the survey can be found in Appendix 2, Figure 13 provides the result from two of the statements in the survey.

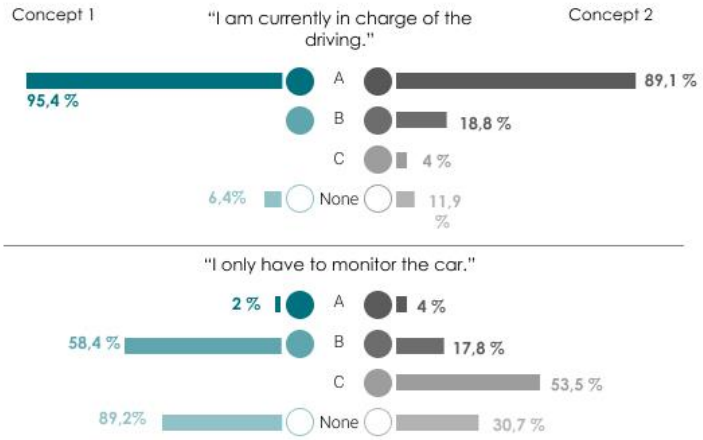


Figure 13. Quantitative survey results for concept 1 and 2

For concept 1, the respondents understood that symbol A1 meant that the driver was in charge of the driving. The statement was chosen with the intent of meaning having control and authority of the driving task, and to be more easily interpreted than control. The interpretation of symbol B1 was that they were

not in charge, but it was unclear to what extent since the answers to the last three statements almost had an even distribution between option B1 and None. For concept 2, it was also clear that symbol A2 meant that the driver was in charge of the driving. Symbol B2 was less clear and was mostly selected to be in line with the statements "I am currently in charge of the driving" and "I only have to monitor the car". The interpretation of symbol C2 was that they only had to monitor the car. Many respondents interpreted it as being okay to release the steering wheel, but only 9% interpreted it as they could lay back and relax. To summarize, both concepts seemed to be difficult to interpret, in particular the B1 and B2 symbols and the C2 symbol.

Qualitative result

For concept 1, many respondents had comments on graphical elements such as the size of the text and symbols, but also on the space between the symbols and the colour. The word "driver" under the symbols was the most commented factor, when placed under symbol B1 many felt that it was too associated with a human driver to refer to the system being responsible.

"Feels like this has 2 modes. Driver is in complete control and car is totally autonomous."

"While symbol A may tell me that the human driver should do the driving task, symbol B says to me that the driving task has been transferred to the car and the car can do it autonomously."

"A bit unclear what my role is in the different conditions."

In relation to concept 2 many respondents expressed that they were confused by the circle around the symbols, especially in symbol B2 where, for example, respondents thought that both circles were supposed to add up to 100%. In response this concept most comments referred to the circle and how they interpreted the meaning of it.

"Longer line feels like more control on that symbol."

"As long as there is some green line by the person symbol, I assume that my brain is needed at least a little."

"Leaves more room for interpretation than the other figures."

"Looks like part is handled by the car, part by the driver. Question is -what parts? The symbols don't convey that."

5.3 Final concept

Concept 2, showing the control distribution between the system and the driver was selected for further work. This concept provided unique information about all automated levels while also being consistent in presenting the information in the same way in all levels, supporting the drivers in understanding that there is a difference between the levels, while Concept 1 did not differ between level 0 and level 2 since the driver is responsible at both. This was thought to confuse the driver more than support them in forming a clear perception of responsibility in relation those levels, and possibly making the driver less able to reflect on responsibility since the symbol does not change. Thus, the information might be ignored when moving into level 4.

Even though the concept was developed separately from the conceptual model it is built on the idea of working with factors such as contextual information and control. The concept provided information about how much control the system had over the driving task, which was difficult for participants to judge in the previous study conducted by Volvo Cars. Therefore, when compared to the conceptual model, the concept provides contextual information to help the driver judge the control of the driving,

which makes the driver feel appropriately responsible for Tasks and Monitoring responsibilities, which leads to an appropriate engagement with the system.

Some modifications were made to concept 2 based on the feedback, mainly by removing the dot which caused some confusion. The adjusted concept with symbols for control distribution is presented in Figure 14.

Figure 14. Selected concept including minor graphical adjustments

6. VALIDATING THE MODEL

While the results from the literature study and the analysis of the Volvo Cars study provided a lot of information about subjective responsibility in relation to different automation levels and lead to the subjective responsibility model, more research was needed to validate the model. Furthermore, getting insights from experienced users of level 2 automation could provide insights into how subjective responsibility may change with time and how strong different responsibilities are felt. The symbol concept illustrating the control distribution was also evaluated further.

6.1 Study design

The study was based on interviews divided into two parts, in which one enabled the participants to interact with elements in the interview through a digital tool. The participants were screened before the interview and an analysis was conducted after the interviews.

6.1.1 Interview

An interview was seen as a method that could provide insights from regular users of level 2 automation and validating parts of the conceptual model. A few days before the interview, the participants were asked to reflect on their usage of and experience with their level 2 automation system. The interviews were conducted over Skype and in line with GDPR standards.

The first part was an interview based on structured questions making it possible to easier compare the participants' answers (cf. Research Methodology, 2019), and to answer questions that had emerged in the previous stages of the project, mainly regarding the parts included in the conceptual model e.g. trust, experience and control. Probing and follow-up questions were used when there was potential for the participant to elaborate their answer (cf. Mindtools, 2020b). This part of the interview took approximately 15 minutes and the manuscript used for the interview can be found in Appendix 3.

The second part of the interview was an interactive part conducted through the website Mural which provided “a workspace for visual collaboration” (Mural, 2020). It had multiple purposes of which one was that it enabled the collection of quantitative data as the participant filled in scales. The interactive segments also enabled the participant to express deeper insights (cf. Visser, Stappers Van der Lugt & Sanders 2005), which was something that was of high importance to the study. The main part of the interactive part was when participants were asked to rank how strongly they felt different responsibilities, while also describing their thoughts. The chosen HMI concept from the previous study (described in Chapter 5) was also presented to the participants to enable deeper probing questions about interpretations. This part of the interview took approximately 30 minutes and the summary of all tasks and the structure of the interactive part can be found together with the interview guide in Appendix 3.

Three pilot interviews were conducted before the actual interviews. The pilot interviews were an important step to evaluate the interview questions and make sure people understood the questions correctly. It also served as a way of evaluating the tools used for the interviews and get an idea of how long the interviews would be. Based on these interviews, certain questions were reformulated, and minor changes were made to the structure of the study design. The results of the pilot tests have not been included with the result of the interview study.

6.1.2 Participants

The participants were recruited partly internally from Volvo Cars and partly from a social media group for people working in technical professions or with a genuine interest for technology. The participants were screened to get participants with different ages, gender and annual driving distances. To ensure that the participant had enough experience, having a car with a level 2 automated system as well as at least 5000 km driven per year were requirements for inclusion. This was important to get participants that were familiar with level 2 systems and to see if there was a difference in subjective responsibility compared to the less experienced users of automated systems (as in the previous study conducted by

Volvo Cars). Of the 10 participants, eight had Volvo cars and the other two had cars from the brands Škoda and Nissan. Four of the participants were females in the age span between 25 and 45, and six were males in the age span between 25 and 65.

6.1.3 Analysis

The data from the interview study was transcribed and summarized. Both steps served as a way of getting to know the data and to get insights on how to approach the analysis. After this, a deductive approach was used to analyse the data (cf. Streefkerk, 2019) to follow up on the literature about subjective responsibility. The deductive analysis was based on the assumption that the identified factors included in the conceptual model were connected and that they could affect subjective responsibility. The deductive analysis was done in the following steps: before coding the data in the program NVivo 12, a plan of how the data could be analysed was decided. The plan included a list consisting of questions which the data could answer and in which parts of the interviews the answers could be found. After coding each question that was used in the interview, e.g. *"Do you feel like you can trust the car when using the system?"*, the material was coded once more according to the new questions in the analysis document, e.g. *"What effect does trust have on responsibility/control?"*.

6.2 Findings

From the analysis, some interesting findings were made. The findings concerned primarily responsibility and control, but also individual factors, trust, expectations and experience. As the participants in the study were interviewed in English, the quotes in this chapter are the direct words from the participants.

6.2.1 Responsibility

When asked about what is meant by responsibility, the participants described it as something that could either be self-motivated or coming from an external source. Control, decisions and actions were also common topics. One participant said: "*A must, not always a choice, even though I love my job and I love my kid, it is not always I want to do it, but I do it anyway because I need to*", indicating that there sometimes can be conflicting motives present to act upon responsibility.

In the interactive part of the interview, the participants were asked to rate their feeling of their responsibility when driving themselves in a level 0 system, second with their car's level 2 automation system and lastly when imagining a level 4 system. The mean ratings can be found in Figure 15. A more detailed overview of the ratings can be found in Appendix 4.

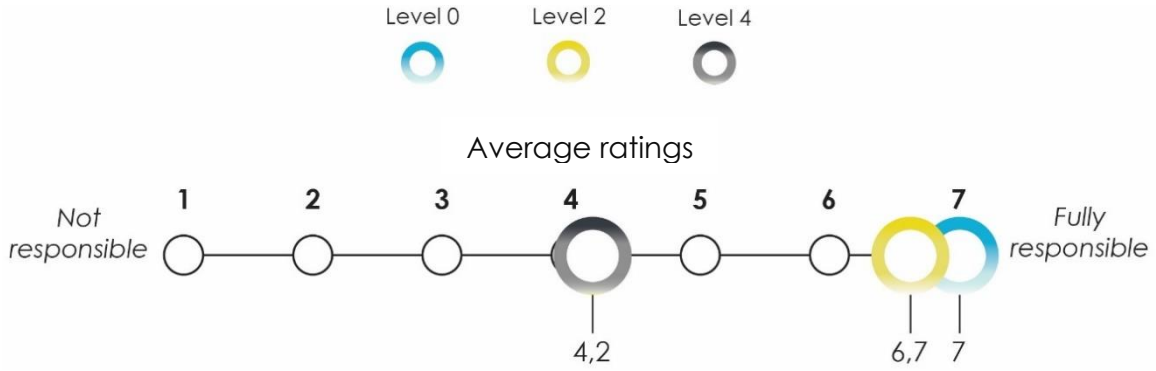


Figure 15. Mean ratings of the participants feeling of their responsibility (n = 10)

Driving with an automation level 0 and level 2, the participants felt more or less fully responsible. Almost the same reasons for feeling responsible were mentioned in relation to both levels, mainly being the driver and having control. For level 4 the answers were quite varied, some participants rating their

own responsibility high by saying that it would be difficult to let go of control, while others rating it low saying it would be easy to let go of control. In addition, some said that they would be responsible because they chose to use the system. The amount of control that the driver had of the driving while using the system was said to affect how responsible they would feel. Another topic that was mentioned making drivers feel less responsible was legal agreements, i.e. the car manufacturer taking responsibility for any potential accidents if they were to occur during the use of a level 4 system.

As another task, the participants were asked to place responsibilities that were found in the analysis of the previous study along a line, ranging from least feeling of responsibility to most feeling of responsibility. This was made in two steps to assure that participants did not get overwhelmed with information. The first step involved Motivators and Competences whereas the second step only involved Tasks and Monitoring. Motivators and Competence were written down on orange post-its and Tasks and Monitoring were placed on yellow post-its. In total there were 9 post-its and the mean ratings of those can be found in Figure 16. A seven-step scale was assumed and each post it was given a rating between 1 and 7 based on the position on the line.

Figure 16. Mean ratings of different responsibilities in a level 2 system (n = 10)

The mean ratings showed that the drivers felt more responsible for supervising the system than for controlling the car. When commenting the instructions received from the car, such as keeping their hands on the wheel, it was frequently mentioned that it was viewed as advice that they could either follow or dismiss since they felt like they were responsible for the driving. Laws and regulations were seen as partly handled by the system, e.g. the system keeping the speed, and thereby participants felt little responsibility for that motivator. *"To keep people safe"* and *"Be the driver and be responsible for the car at all times"* were rated highest of the *Motivator* responsibilities. Regarding responsibility for knowledge, participants mentioned that the system is quite intuitive and that their previous experience of level 1 systems makes it easier to use the level 2 system. When discussing skill, e.g. the ability to judge the surroundings and act fast, some participants expressed that you should drive according to your skill and if you do not have enough skill you should not drive. It was also mentioned that automated systems could decrease the skill needed to drive, such as keeping a constant speed on the highway and thereby decrease the responsibility to have enough skill to drive the car.

In addition to the provided responsibilities that were placed along a line, some participants wrote down additional responsibilities that they felt responsible for, they are represented in Figure 17. Some of those responsibilities were feeling responsible to use the system, to know the limitations of the system and to be responsible towards the passengers inside the car. How the responsibilities written by the participants were placed along the line ranging from least feeling of responsibility to most feeling of responsibility can be found in Appendix 5.

Figure 17. Additional things participants felt responsible for

As stated earlier in the report, the subjective responsibility when driving is considered to depend on many factors. The ones that were mentioned in the interviews are summarized in Table 5 together with the categories proposed in the conceptual responsibility model. The table includes both factors that make people feel responsible and things that people feel responsibility for.

Table 5. Mentioned factors and areas and their connection to the categories in the responsibility model.

Connections to the model		**Mentioned factors and areas from the interview study**
Information	Driving environment	If there are both automated and human drivers on the same road
Motivators and Competences	Laws and regulations	Regulations If the car company takes legal responsibility in high-level automation driving Descriptions in the manual
	Being the driver	Personal decision to use the system Personal decision to drive on the road Always responsible for the car
	Safety	Fear of hurting someone People inside the car Use the system to increase safety Inability to effect how other drivers behave
	Knowledge	Knowing the limitations of the system
Control	Driver control	The drivers control of the driving Feeling that you lack control
	System control	Perceived control of the driving by the system What situations you have learned that the driving system can't handle. If the system is verified to work

Tasks and Monitoring	Responsibility to monitor the driving environment	Not to be distracted from the road by using mobile phone etc.

6.2.2 Control

The participants were asked to rate how much control of driving they felt that they had, that the system had, and that both combined had when driving with their level 2 system. The mean ratings can be found in Figure 18 and a more detailed overview of the result can be found in Appendix 6.

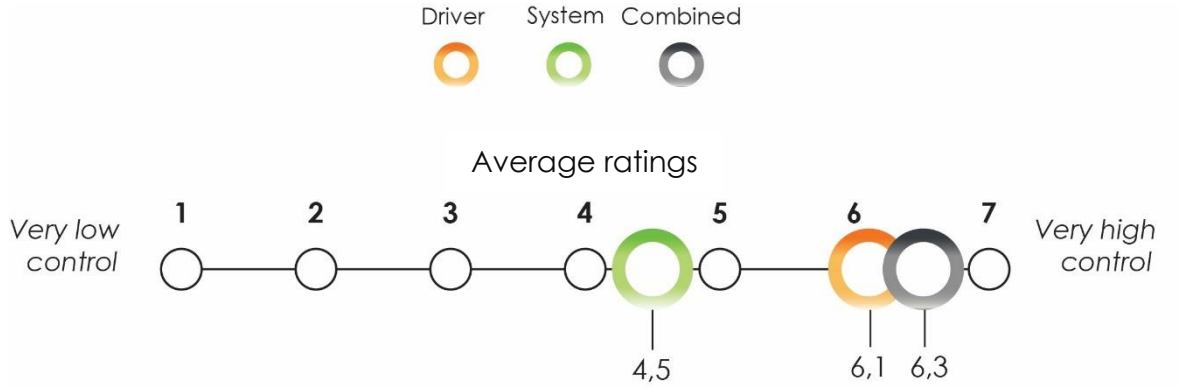


Figure 18. Mean ratings of the participants feeling of control while using level 2 systems (n = 10)

All participants perceived their control as quite high and motivated it with their ability to still interact and control the car if they want to. The answers regarding the system's control were more varied. When participants talked about the system's control, they talked about it either as being high when the conditions of the road are good or as low when the conditions are bad. They also mentioned using the system only when they feel comfortable with the system being activated.

"I am still trying to control the car even if I am using Pilot Assist"

"I trust the technology when I have it on, so I feel like it has control".

"It is like driving with a 16 or 17 -year old practice driver, it is very late and take decisions on narrow things just 20 meters in front of the car"

When talking about combined control, which received a high mean rating (=6.3), participants often saw the car and themselves as two entities complementing each other. Of those participants who placed their ratings in the middle of the scale, one saw it as the system and them having enough control together whereas another talked about the need to supervise the system and was not satisfied with the combined control.

"I see it as we complement each other, it wouldn't be as good if I did it by myself, but it wouldn't be as good if the car did it by itself either."

"And the combined control is of course very high because I have a very high control I believe."

In addition, two participants mentioned that the control would be rated higher when driving without the level 2 system, compared to driving with the level 2 system activated.

"Performance of the total car carriage? Worse than me driving it myself for sure."

"If you're activating all the security devices the car is really stuck to the lane, meaning it is really difficult to move out of the line. Of course, you need to use the turning lights and such but in situations that you really don't have time […] and you need a really quick reaction."

Apart from the rating of control, the control distribution HMI concept was shown to the participants, Figure 19. By revealing each pair of icons one by one and explaining in which automated level they would be active, participants could talk about their interpretations.

Figure 19. Control distribution concept for level 0, level 2 and level 4 systems

After revealing the symbols for level 0 and level 2, about half of the participants reasoned that it had to do with the car aiding the driver. When the control symbol for level 4 was shown everyone described it as the car being autonomous and that the driver should complement the car in some way. The participants did not think the symbols would affect their feeling of responsibility to any large extent and they were hesitant to whether it would help them understand unfamiliar systems, indicating that symbols by themselves might not be the best way to communicate responsibility or that they need to be complemented with something else.

6.2.3 Individual factors

The individual factors trust, experience and expectations were also topics addressed in the interview, and they were found to be much related to each other. In the interview study, half of the participants felt that they could trust their level 2 system, while the other half felt that they could not trust it. Participants who felt like they could not trust the system mentioned situations where they knew the system did not work or that they felt like the performance of the system was not high enough to be trusted. The participant who felt like they could trust the system mentioned the situations where they knew it worked well. When participants talked about trust, they also mentioned control and that if the system control was perceived as low in a situation, they tended to take over driving by turning off the system. One participant who expressed 100% trust in the system said:

"If my anticipation was that it was going to brake, and it didn't, I think I would blame the car actually."

Another participant said:

"I don't think you should trust it 100%, just as much as you cannot trust another human being 100%, either when it comes to reaction or crisis situations"

Both statements indicate that trust is somewhat connected to responsibility and control. Concerning trust, people also mentioned their experience as a factor for building trust. In the interview, participants expressed that they through usage have learned the limitations of the system and in which contexts it performs well.

Most participants described that they had expectations before they used the level 2 automation system. One participant expressed expectation for the system being intuitive enough to be used directly without looking up information about the system. Six participants felt like their expectations were met due to

low expectations on the technology and due to the performance of the system being perceived as higher than expected. Two participants stated that their expectations were not met and explained that communication from the system was lacking because it did not inform them well enough when the system deactivated itself because of unclear road markings, and that they could not trust the system because of that. Expectations were also expressed as something that you build up with experience in different systems, such as experience in lower levels of automation affecting the view of how a system of a higher level will work.

6.2.4 Summary and implications

The results of this interview study validate the conceptual model to some extent, meaning that the structure of the model remains. However, new factors that make people feel responsible were found. The responsibility to use automated systems to improve safety and the responsibility to know the limitations of the system were introduced to the categories Motivators and Competences in the conceptual responsibility model and are placed under the subcategories, Safety responsibility and Knowledge responsibility. Another important finding was that the responsibility for knowledge and skill was found to decrease with the usage of automated systems. It was also concluded that there is a difference in how strong responsibilities are felt dependent on users' experience with the system, e.g. participants in the interview study felt little responsibility for the right skill and knowledge to use the level 2 system. When it came to the perceived combined control, participants were found to talk about themselves and the car as two entities, something that could be used to explain the driver's understanding of automated systems. This view hints that they are ready to give full control to the car in level 2 and that they do not understand that the level 2 system is supposed to work as an aid.

In addition, the interview study gave insights about using symbols to communicate responsibility. When the concept was presented it gave indications that more than a symbol is needed to affect drivers' felt responsibility.

The next step in the project was to use the results from the activities in the project together with the model to come up with a design tool that could aid future development of automated systems.

7. A DESIGN CHECKLIST

This chapter presents a design checklist that is based on the conceptual model and the results from the empirical studies. It was created with the intention to be used as a tool aiding the development of automated driving systems. The checklist raises important questions to reflect upon and factors to consider from each part of the conceptual model to increase the probability that the system is designed to make the driver feel appropriately responsible compared to the laws, possible legal agreements between the car company and the driver and the driver's manual when using the automated system.

The design checklist can be used after an early draft has been created of how the system should work. It is desired that the checklist is used early to ensure that the necessary adjustments to the design of the system can be done before parts of the design have been finalized. It can also be used to evaluate existing automated driving systems.

The design checklist was created to be possible to use without reading this master's thesis. Thus, it enables an accessible way to get an understanding of drivers' subjective responsibility when using automated systems. The first step is a description of the system and then it consists of several questions to be answered and reflected upon.

DESIGN CHECKLIST – DRIVER RESPONSIBILITY WHEN USING AUTOMATED SYSTEMS

The checklist has been created based on two user studies regarding responsibility when using automated systems and the different parts in the checklist concern the parts in a conceptual model of responsibility, created as a part of a master's thesis. The model includes the following factors: contextual information, individual factors, general responsibilities, control and specific responsibilities. They are all factors that affect how responsible drivers feel in the driving context.

The checklist starts with a description of the system and is then based on YES or NO questions that are supposed to raise reflection related to the factors and their effect on the use of the system, making sure that all factors concerning subjective responsibility is considered when designing the system. Some questions are more critical than others depending on the description of the system. If questions are answered with a YES, they can be considered as reflected upon. However, if the system is found to lack in any of the questions in the checklist, or if the questions haven't been discussed, it is important to reflect on the question to ensure a good interaction between the human and the system. If all questions have been reflected upon, it is more likely that the driver will feel appropriately responsible when using the system.

Description of the system

It is important to be aware of what level of automation the system will be and what behaviour is desired by the driver to ensure that the system is designed to be used in a safe and pleasant way. Thereby these questions have been created to aid developers when answering the questions in the checklist.

- In which context is the system supposed to be used.
- What conditions are required for the system to be used?
- Is the human driver objectively responsible when the system is in use? By objective responsible is meant the responsibility according to the law.
- What behaviour of the driver is desired when the system is used, i.e. can they disengage completely, or do they have to monitor or control to some extent?

Contextual information

Contextual information is defined as information available to and interpreted by the driver in the moment. It can be derived from the driving environment as well as car haptics and information in the infotainment cluster. The information from the car can be instructions from the system as well as information on how and when to use the system. The information outside the car can for example be the traffic density and the speed. The contextual information is used by the driver to understand the driver's role.

Infotainment and haptics

- Is the provided information clear and precise about the driver's role in the car? For example, is it clear that the driver needs to keep the hands on the steering wheel?
- Is there no implicit information that can be interpreted to conflict with the explicit information about the driver's role in the car, for example, haptics and visual information conveying different messages?

- Is the system intuitive to use and is all necessary information provided while the system is active?
- Is the system designed so that it is unlikely that information is misinterpreted by the driver?

Driving environment

- Has it been considered that drivers feel more responsible at higher speeds and traffic densities?
- Has it been considered that drivers feel more responsible with passengers present?
- If the system is designed to be used in certain situations and not others, and has it been considered how that is communicated to the driver?

Individual factors

Expectations, experience and trust are individual factors that can affect subjective responsibility and they are important to consider when designing automated systems. Drivers' expectations towards a system is found to affect their experience with the system, especially when the system does not live up to the expectations. It is also believed that the experience in other systems can affect how the driver will use the new system. Lastly, over trust and distrust are found to affect driver's interaction with the system and might in a worst-case lead to misuse of the system or that the system is not used at all. Having used a system that works flawlessly during a longer period can lead to over trust.

Expectations

- Does the system consider drivers with low/high expectations on the system?

Experience

- Does the system consider drivers without any previous experience in automated systems?
- Does the system consider drivers with experience in higher automated systems?

Trust

- Does the system aid the driver to not feel too little or too much trust?
- Does the system consider that the driver might start to over trust the system after extended use without problems and that measurements to counter this might be needed?

General responsibility

The general responsibilities can motivate the driver to take control. They consist of the responsibility for safety, to follow laws and regulations and the responsibility that derives from being the driver e.g. turning on the system and being placed in the driver's seat. They also concern the responsibility to have the right skill and knowledge to drive the car and use the system. Drivers often feel responsible to keep people safe, but they also feel responsible from the fact that they turn on the system or because they are placed in the driver's seat where they are used to have responsibility over the driving. Drivers also tend to feel little responsibility to know how to use the system in a correct way, such as when/when not to use it. If the system is below level 3 automation it might be desired to make the driver feel more responsible and above level 3 automation it might be desired to make the driver feel less responsible.

- Is the system designed to consider that the driver feels responsible for people's safety?
- Is the system designed to consider that the driver feels more responsible when turning on the system?
- Is the system designed to consider that the driver feels more responsible when placed in the driver's seat?
- Is the system designed to consider that the driver feels little responsibility to know how to use the system correctly?

Perceived control

Perceived control was found to be a factor that affects subjective responsibility a lot. Perceived control refers to the driver's perception of their control of the driving and is affected by contextual information, individual factors and general responsibilities. If the perceived control by the system is not enough, the driver is more likely to take back the control by deactivating the system, and the more control the driver has, the more responsible they will feel.

- Has the system been designed to communicate how much control the system has, and how much control the driver should have of the driving task?
- Has it been considered that the more control the driver has, the more responsible they will feel, including having the control to turn off the system?

S**pecific responsibilities**

The specific responsibilities are derived from the driver having control but are also affected by contextual information, individual factors and general responsibilities. They involve different driving tasks and monitoring activities. These specific responsibilities have a direct impact on the behaviour of the driver when using the system. When "the desired level of responsibility" is used in the questions, it refers to the desired behaviour of the driver described in the beginning of the checklist. It is important that the driver feels responsible for those things, but also that the driver does not feel excessive responsibility, which can affect driving safety and experience negatively.

- Is the system designed to make the driver feel a desired level of responsibility to follow instructions from the system?
- Is the system designed to make the driver feel a desired level of responsibility to monitor the traffic environment?
- Is the system designed to make the driver feel a desired level of responsibility to monitor the system?
- Is the system designed to make the driver feel responsible for the desired driving tasks by the driver when using the system?
- Is the driver likely to feel responsible to take over control from the system when the conditions for the system to work are no longer met?

8. DISCUSSION

This part of the report discusses the methods and important findings in the thesis project. It also discusses and highlights what needs to be investigated further. Also, ethical topics related to the thesis are addressed.

8.1 The choice of methods and its effects on the findings

The thesis explores a wide range of factors and information to be able to make general and more reliable conclusions about subjective responsibility in automated vehicles. One important aspect when conducting user research is the participants involved. In the Volvo Cars study, the participants had limited experience in automated systems while the participants in the interview study were regular users of a level 2 system. This enabled the collection of insights about how subjective responsibility might change with experience.

Another very important factor is the context of use. In the Volvo Cars study, the participants got to experience a simulated level 4 automation in a real traffic situation, whereas the participants in the interview study could only get descriptions of the level 4 system. By experiencing the simulated level 4 automation, the participants in the Volvo Cars study could likely provide more detailed and more valid descriptions of their feelings of responsibility than the participants in the interview study. And this should be considered when interpreting the results.

Another effect of having participants with experience of the level 2 system but not driving in conjunction to the interview, was that their discussions were less focused on the lower part of the model involving Tasks, Monitoring and Engagement. Thus, it can be discussed if the interview study could validate the entire conceptual model. A study in a real car could help to validate information factors such as car haptics and the driving environment as well as possibly providing additional views on responsibility. The interview study did not include drivers with experience of level 4 system, and thereby the model is validated from the level 2 automation perspective.

This thesis project was conducted with a focus on drivers and their thoughts and explanations. Another approach would be to focus on the behaviour of the drivers when driving, to get further insights into how drivers react in different situations and to what extent undesirable actions are performed in different automated systems. However, this approach would not provide information on why the driver acted as they did. A combination of the two approaches would probably result in a more accurate and insightful result.

Another important aspect to discuss is that this master's thesis project does not consider all factors that were found in the studied literature, such as ability and authority proposed by Flemish et al. (2011). Since the focus in the thesis has been to investigate empirical results from user studies more than literature there could be other factors that would be important to consider when talking about responsibility in automated vehicles. Investigating psychological factors and aspects could for example bring deeper understanding of driver's perception of responsibility.

8.2 Problems regarding responsibility in automated vehicles

Based on the literature study and results from the empirical studies, it is clear that there is a problem as the subjective responsibility of the driver does not conform with the objective responsibility when using automated systems. This could be discussed as a factor having serious consequences unless it is not considered in the design of the systems.

For level 2, it seems like it is initially difficult to understand to what extent a system is assisting the driver. With time and experience, it seems like it becomes clearer for the drivers that they are

responsible due to the increased knowledge about the limitations of the system. However, there are indications that the feeling of responsibility is lower after gaining knowledge about in which situations the system consistently works well, such as a part of a commute, and that the trust in the system increases. The driver might start exhibiting unsafe behaviour like releasing the steering wheel for longer periods of time. One might wonder why drivers act like this and why they feel less responsible. The answer might be in how a level 2 system makes the driver feel more responsible to monitor the driving instead of actively controlling the car. In a level 2 system part of the control is given to the system even though the driver still has control. It might not be clear to the driver what control they have, and when a task that used to be the driver's is assigned to the system it can be discussed to result in compensating behaviour such as monitoring the driving. The responsibility to monitor the driving could also have connections to not trusting the system to work on its own.

In level 4 automation, almost all driver perceived the system's control to be high, but some felt responsible while others did not. It is possible that drivers are unfamiliar with this new situation and will adapt to over time hand over responsibility to the system. Their mental model when driving is most likely that they are always responsible and, depending on how deeply rooted that mental model is, it might take a longer time to adopt a new mental model. It could be important to consider these effects when designing for level 4 automation, meaning that an intuitive system could aid the drivers' understanding of the level 4 system and adapting to the new driving situation faster. If people feel responsible it is presumable that they will take over driving in situations when they guess that the system will perform poorly, even though the system could have handled the task better than the driver. This is a potential problem which could be the result of drivers feeling responsible in level 4 automation nevertheless what the handbook says, something that needs to be investigated further. Thus, it could be important that systems in higher automation are designed to make the driver trust the system fully since the responsibility is fully assigned to the system. However, in lower levels of automation, such as level 2, where over-trust is a problem, it could be more important to find measurements towards over-trusting drivers.

From the Volvo Cars study, there are indications that drivers perceive the driving situation in level 2 as them and the car being two different entities working together, a view that can be used to describe the problems. As the objective responsibility is assigned to the driver it is desirable that the driver still feels like they are the driver and that the system is enhancing their driving skills rather than doing the driving for them. Thus, perceiving two entities would not be desired until automation reaches level 4 when the driver no longer is responsible during the usage of the system. Why the driver has this view could be explained by the performance of the level 2 system. The driver perceives the control by the system as high enough to be a separate entity in control of the driving. This was confirmed in the interview study, where there were tendencies to talk about the system as a separate entity. Designing the experience of using a level 2 system to feel like you are one entity could be a way to avoid low feelings of responsibility e.g. by the system adjusting the steering only when the driver is steering, something that should be investigated further.

It is evident that trust has a big impact on responsibility and that it can both enhance and reduce the level of responsibility felt. Half of the participants, who were regular users of a level 2 system, said they trusted it. These people mention situations where they can trust it whereas the other half mention situations where they cannot trust it. One explanation could be that it is a "the glass is half full or half empty" situation and that the drivers have had similar experiences with the system, but it affects them differently. Trust also seems to be strongly connected to expectations. Expectations were seen as something that exist before use, but the study also indicates that it is something that can be built up with time, e.g. if you see the system work in a situation it could make you expect or trust it to always work in that situation and in similar situations.

8.3 Designing to communicate responsibility

The results of the survey and the interview study enlighten the complexity of subjective responsibility, and the attempt to communicate this through a symbol in the HMI was not altogether positive. Both concepts received feedback that they did not communicate the interaction needed from the driver, pointing towards a need from the driver about the clarity regarding their role in the car. The fact that people need more information about their task inside the car also enlightens the idea that the human driver is driven to search for cues indicating what they should do and strengthens the previously discussed idea concerning people's ability to let go of responsibility in a context where they are used to have responsibility.

The question is if it is possible to communicate the driver's responsibility when using an automated driving system solely through a symbol. To some extent, it seems to be possible to affect the driver's subjective responsibility by communicating related factors such as control. Thus, it could be argued that control could be communicated and used to indirectly affect subjective responsibility. However, as the discussion above clarifies that it is hard to communicate something as abstract as responsibility. It must be further investigated how other kinds of information can be used to complement a symbol. Nevertheless, since contextual information affects subjective responsibility, symbols should be evaluated in the proper use context, something that was not possible in this project.

While one way could be to use control to target responsibility, another way could be to utilize the things people feel responsible for. From the ratings of responsibilities, it is evident that the experienced users of level 2 systems feel more responsible to e.g. monitor the car and keep people safe than they do for performing driving tasks. Thus, it could be of interest to investigate how information about how the system handles such areas affect the feeling of responsibility. It is possible that a system that is designed to communicate how it handles safety e.g. showing the human driver everything that the system "sees", could lower the responsibility to keep people safe and could be used in higher levels of automation. It could also have the opposite effect, making the driver feel responsible to monitor the thing that the system "sees" for problems that might occur.

8.4 The model of subjective responsibility

The model was created based on literature and user research explaining factors affecting how and for what drivers feel responsible, that in turn can affect the driver's behaviour when driving with automated systems. Since the focus is responsibility, it can give the impression that responsibility is the most important factor behind how the driver behaves. However, there seem to be multiple, interconnecting factors like trust and expectations that affect the final behaviour to a large extent. Which factor that has the largest impact is difficult to say based on the result in this thesis, however, it seems like it can vary depending on the situation, the driver and the design of the system.

Another important insight about the model is that it only brings to light identified factors that have been mentioned by participants in the respective studies. Responsibility is a complex feeling and sometimes the answers were along the lines of "I just feel responsible", which the participant had a hard time explaining. This could mean that responsibility is more subconscious, and that there could be more factors that should be included in the model but that these were not identified through the methods used for the thesis. How strong responsibilities are felt can probably differ considerably between individuals, i.e. something that is more important to one individual might be less important to another. This is something that adds to the complexity of the topic of subjective responsibility.

The literature, mainly the cornerstone model by Flemisch et al. (2011) effected the conceptual model. While the conceptual model partly resembles the cornerstone model in the relation between responsibility and control, it is grounded in the user research and the factors found that affected

responsibility were all identified in the user studies. The literature mostly affected how the different factors were connected in the conceptual model.

The purpose of the model is to support the development of automated driving system with a user experience in which the driver feels an appropriate amount of responsibility. However, many of the identified factors cannot be controlled or influenced directly, such as context or expectations, which are affected by many external sources. We propose though that they can be influenced indirectly and affect how the driver will feel about them. This could, for example, be through the description of the systems or presenting information while the system is in use.

The division of the degrees of engagement can also be discussed. The definitions created in this thesis are quite broad, and during the use of a specific system, a specific behaviour might be desirable. For example, in level 4 systems, one might want the driver to feel free to write a message on their phone, but not to take a nap. During the design of a system, it would probably be a good idea to clearly define the engagement that is desirable in relation to the specific system.

The model and the design checklist could be used in many stages of the development of automated systems. It can be used to identify when the drivers might benefit from an intervention to increase or decrease the subjective responsibility. It could also be used as a foundation for user research in automation.

8.5 Ethical considerations

One can discuss how transparent the design of an automated system should be to the human driver. It can be seen as unethical to design systems where the human driver is responsible when the design of the system goes against what makes people feel responsible, e.g. letting the system steer the car when the driver still has the responsibility to steer. Level 2 systems are especially troublesome and the way the system is built provides a lot of information that the human can interpret as that they are not responsible, such as the system being able to control the car for long periods of time with minimum control from the driver. Furthermore, such systems often allow the human to let go of their responsibility for a short period of time since no direct consequences are in place e.g. allowing the driver to release the steering wheel for 15 seconds. This allowance can be discussed to enhance the feeling that it is okay to let go of responsibility. It can then be discussed how the human driver will feel if an accident occurred, would they blame the car since it was unclear that they were responsible while using the system? One could argue that it is not enough for the car manufacturers to explain in the driver's manual that the driver is responsible while using a system. Instead, they could increase their efforts in designing the system so that it leads to an appropriate level of subjective responsibility.

9. CONCLUSIONS

Based on the results in this thesis project, it can be concluded that subjective responsibility is a complex topic that differs depending on the individual and contextual situation. That does not make it less important and it is evident that it has effects on the users' experience in automated vehicles and the behaviour they practice in using such systems. Thus, it is important to design the systems with the factors in mind that affect subjective responsibility. Not only since they have an impact on the engagement with the system, but also since there are ethical aspects that matter in the usage of automated systems.

It can also be concluded that the topic of subjective responsibility is not fully solved in this thesis and that it needs further research to be understood fully. To be able to create safer vehicles, the responsibility issues must be solved. A driver who knows their role in the car is more likely to behave safely than a driver who is less aware of their role. The design checklist presented in Chapter 7 can be used by developers of automated systems, as a first step to address the issue regarding subjective responsibility and to prevent potential problems regarding responsibility. As the topic is further analysed, the checklist can be improved and thus serve as a common way to work with automated systems.

The first research question "*Which factors affect the drivers' subjective responsibility when interacting with an automated vehicle that offers several levels of automation?"* was answered with the conceptual model of responsibility, in which control, contextual information from the car and the driving environment, and the individual factors trust, experience and expectations, were found to affect responsibility. Furthermore, four categories of responsibilities were found and used to create the model, namely Motivators, Competences, Tasks, and Monitoring.

The second research question "*How can different design solutions support drivers understanding of their responsibility of the driving task in each automation level?*", was in a part answered through the development of an HMI consisting of symbols communicating the distribution of control between system and driver, which was evaluated in a survey and an interview study with users of level 2 systems. It was concluded that it was important that the symbols had to be both clear and precise in their message to the human driver, and that symbols are only one of many factors that influence drivers' feeling of responsibility. Of the factors included in the conceptual model, control and contextual information from the car served as main factors used as an inspiration to development of the HMI concepts.

The design of the system affects the driver's actions in relation to both level 2 and level 4 automation. The cooperation between the driver and the vehicle must not be forgotten in higher levels of automation even though less interaction is needed from the driver. In the end, it is all about two entities working together and the design of the HMI is setting the frame for the actions.

REFERENCES

Agah, A., Howard, A. M., Cabibihan, J.-J., He, H., & Salichs, M. A. (2016). *Social Robotics*: *8th International Conference, ICSR 2016.* Kansas City: Springer.

Awad, E., Levinea, S., Kleiman-Weinerb, M., Dsouzaa, S., Tenenbaumb, J. B., Shariffd, A., . . . Rahwana, I. (2018). Blaming humans in autonomous vehicle accidents: Shared responsibility across levels of automation. Retrieved from https://arxiv.org/abs/1803.07170

Banks, V. A., Plant, K. L., & Stantone, N. A. (2018). Driver error or designer error: Using the Perceptual Cycle Model to explore the circumstances surrounding the fatal Tesla crash on 7th May 2016. *Elsevier, Vol. 108*, pp. 278-285. doi:10.1016/j.ssci.2017.12.023

Beggatio, M., & Krems, J. F. (2013). The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information. *Elsevier, Vol. 18*, pp. 47-57. doi:10.1016/j.trf.2012.12.006

Bernard, H. R. (2017). *Research methods in anthropology: Qualitative and quantitative approaches*. Lanham, Maryland: Rowman & Littlefield.

Cambridge Dictionary. (2020a). Meaning of control in English. Retrieved from https://dictionary.cambridge.org/dictionary/english/control

Cambridge Dictionary. (2020b). Meaning of responsibility in English. Retrieved from https://dictionary.cambridge.org/dictionary/english/responsibility

Ekman, F., Johansson, M., Bligård, L.-O., Karlsson, M., & Strömberg, H. (2019). Exploring automated vehicle driving styles as a source of trust information. *Elsevier, Vol. 65*, pp. 268-279. doi: 10.1016/j.trf.2019.07.026

Flemisch, F., Heesen, M., Hesse, T., Kelsch, J., Schieben, A., & Beller, J. (2011). Towards a dynamic balance between humans and automation: authority, ability, responsibility and control in shared and cooperative control situations. *Cognition, Technology & Work, Vol.14, no. 1*, pp. 3-18. doi:10.1007/s10111-011-0191-6

Kidd, A., Ekhteraei, S., & Wilson, C. (2011). *Braindrawing.* Retrieved from https://www.usabilitybok.org/braindrawing

Lamberti, F., Morra, L., Pratticó, F. G., La Rosa, S., & Montuschi, P. (2019). Building Trust in Autonomous Vehicles: Role of Virtual Reality Driving Simulators in HMI Design. *IEEE Transactions on Vehicular Technology, Vol. 68, no. 10*, pp. 9438-9450. doi:10.1109/TVT.2019.2933601

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate relianc. *Human factors, Vol. 46, no. 1*, pp 50-80.

Merriam-Webster. (2020). Responsibility. Retrieved from https://www.merriam-webster.com/dictionary/responsibility

Mindtools. (2020a). Brainstorming: Generating Many Radical, Creative Ideas. Retrieved from https://www.mindtools.com/brainstm.html

Mindtools. (2020b). Questioning techniques. Retrieved from https://www.mindtools.com/pages/article/newTMC_88.htm

Mural. (2020). Retrieved from https://www.mural.co/

Nissan. (2020). Nissan Intelilgent Mobillity. Retrieved from https://www.nissan.se/fordon/fordon-utbud/qashqai/intelligent-mobility.html

Nissan Motor Corporation. (2020). ProPILOT. Retrieved from https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/propilot.html

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2008). Situation Awareness, Mental Workload, and Trust in Automation: Viable, Empirically Supported Cognitive Engineering Constructs. *Journal of Cognitive Engineering and decision making*, *Vol. 2*, pp 140-160. doi: 10.1518/155534308X284417

Research Methodology. (2019). Interviews. Retrieved from https://research-methodology.net/research-methods/qualitative-research/interviews/

Richardsson, J., Stanton, N., Revell, K., & Kim, J. (2020). Signs Symbols & Displays in Automated Vehicles: A focus group study. *Springer Nature Switzerland AG 2020*, pp 980-985. doi: 10.1007/978-3-030-39512-4_149

Royal Literary Fund. (2020). Literature reviews. Retrieved from https://www.rlf.org.uk/resources/what-is-a-literature-review/

SAE International. (2018). J3016. In. Surface vehicle recommended practice. Retrieved from https://www.sae.org/

Schlenker, B. R., Britt, T. W., Pennington, J., Murphy, R., & Doherty, K. (1994). The triangle model of responsibility. *Psychol Rev, Vol. 101, no. 4*, pp 632-652. doi:10.1037/0033-295x.101.4.632

Siang, T. Y. (2020). What is Design Thinking? Retrieved from https://dl.acm.org/doi/pdf/10.1145/2799250.2799288?casa_token=FUu1LIiIN0AAAAAA:PXcYiB8VGVBYH6CuhSHnElBSXM4QQbCAnBrCefoMba2bJ3RViFug2oodOMaX3SwdpTPu_hbIRaxr-Zs

Streefkerk, R. (2019). Inductive vs. deductive reasoning. Retrieved from https://www.scribbr.com/methodology/inductive-deductive-reasoning/

Stumpf, R. (2018). People keep comming up with ways to fool Tesla's Auto Pilot: Drivers have been low-tech hacking Tesla's Autopilot in order to drive hands-free. Retrieved from https://www.thedrive.com/sheetmetal/18168/people-keep-coming-up-with-ways-to-fool-teslas-autopilot

Tesla. (2016). A tragic loss. Retrieved from https://www.tesla.com/blog/tragic-loss

Tesla. (2020). Future of Driving. Retrieved from https://www.tesla.com/autopilot?redirect=no

Waymo. (2020). We're buliding the Worlds Most Experienced Driver. Retrieved from https://waymo.com/

Vellinga, N. (2020). *Legal Aspects of Automated Driving: On Drivers, Producers, and Public Authorities.* [Groningen]: University of Groningen. Retrieved from https://doi.org/10.33612/diss.112916838

Visser, F. S., Stappers, P. J., Van der Lugt, R., & Sanders, E. B. (2005). Contextmapping: experiences from practice. *CoDesign, Vol. 1, no. 2*, pp 119-149.

Volvo Car Corporation. (2017). Volvo Cars CEO urges governments and car industry to share safety-related traffic data. Retrieved from https://www.media.volvocars.com/global/en-gb/media/pressreleases/207164/volvo-cars-ceo-urges-governments-and-car-industry-to-share-safety-related-traffic-data?fbclid=IwAR07obSGnqKmGW6kw_eZ236B87hSU1-vJh4NL5DaFxzvvt8A54eSKT5wNXQ

Volvo Car Corporation. (2019). Pilot Assist och Körfältsassistans. Retrieved from https://www.volvocars.com/se/support/topics/anvanda-din-bil/bra-att-veta/pilot-assist-och-korfaltsassistans

Volvo Cars. (2020). Intellisafe assist, Pilot Assist. Retrieved from https://www.volvocars.com/intl/why-volvo/human-innovation/future-of-driving/safety/intellisafe-assist

World Health Organisation. (2018). Global status report on road safety 2018: summary. Geneva: World Health Organization; 2018 (WHO/NMH/NVI/18.20). Licence: CC BY-NC-SA 3.0 IGO). Retrieved from https://apps.who.int/iris/bitstream/handle/10665/277370/WHO-NMH-NVI-18.20-eng.pdf?ua=1

APPENDIX

1. SURVEY DESIGN
2. QUANTITATIVE RESULT FROM SURVEY STUDY
3. INTERVIEW MANUSCRIPT AND STRUCTURE OF THE INTERACTIVE PART
4. RESPONSIBILITY SCALE
5. RATED RESPONSIBILITIES AND NEW RESPONSIBILITIES
6. CONTROL SCALE

Appendix 1, Survey design

Survey about symbols in cars

Hi,
we are enrolled in the programme Industrial Design Engineering at Chalmers University of Technology and currently writing our Master Thesis at Volvo cars, investigating how drivers perceive their responsibility when engaging with Automated Driver Assistance Systems.

For this aim we are conducting different studies, one of them being this short survey. We want to ask you, to give us written feedback on 5 different symbols, we aim to include in the car as part of a concept.

The survey is anonymous and all data will be handled confidential. It will not take you longer than 5 minutes and Your input would be very valuable and aiding us in preparing our next study.

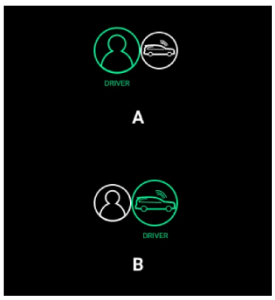
Thank You for your time!
Linnéa & Gustav

Avsnitt 2 av 4

Concept 1

Scenario: Imagine that you are driving your car and that there is a symbol showing in the information cluster behind the steering wheel. Depending on which functions you are using and how much assistance you get from the car, the symbol will take different shapes.

These are the first symbols. Please choose wich combination/combinations you think fits best with the statements below!



I am currently in charge of the driving. *

- [ ] A
- [ ] B
- [ ] None of the above

I only have to monitor the car. *

- [ ] A
- [ ] B
- [ ] None of the above

I can release my hands from the steering wheel *

- [ ] A
- [ ] B
- [ ] None of the above

I can lay back and relax. *

- [ ] A
- [ ] B
- [ ] None of the above

Additional toughts about how you interpret the symbols

Lång svarstext

Concept 2

Scenario: Imagine that you are driving your car and that there is a symbol showing in the information cluster behind the steering wheel. Depending on which functions you are using and how much assistance you get from the car, the symbol will take different shapes.

Please choose wich combination/combinations you think fits best with the statements below!

I am currently in charge of the driving. *

- [ ] A
- [ ] B
- [ ] C
- [ ] None of the above

I only have to monitor the car. *

- [ ] A
- [ ] B
- [ ] C
- [ ] None of the above

I can release my hands from the steering wheel *

- [ ] A
- [ ] B
- [ ] C
- [ ] None of the above

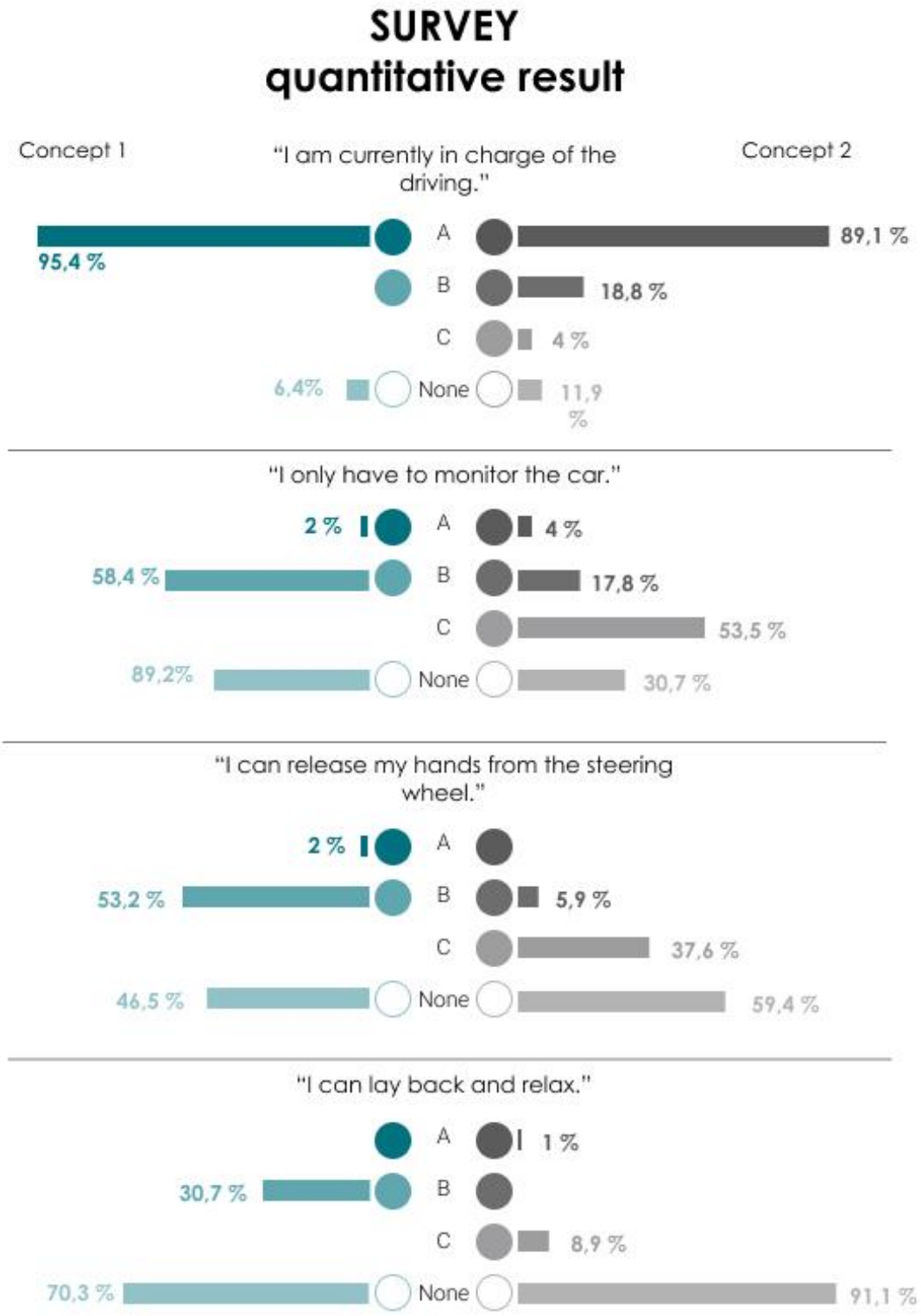
I can lay back and relax. *

- [ ] A
- [ ] B
- [ ] C
- [ ] None of the above

Additional toughts about how you interpret the symbols

Lång svarstext

Appendix 2, Quantitative result from survey study



Appendix 3, Interview manuscript and structure of the interactive part

Information before interview (e-mail)

Hello and thank you for your interest in our study!

If you are going to drive before the interview, we encourage you to use automated features with speed, distance and lane assistance such as Pilot Assist and try to think over how you use them, in which context and how the function makes you feel. We would also like you to reflect about your first interactions with these features.

Looking forward hearing about your experiences!

/Linnéa & Gustav

Interview, part 1 (15 min)

Introduction

"Hi, thank you for letting us have this interview with you! I will soon start the recording, and I will ask you if that is okay once it has started so we have that recorded. (**Start recording)** Now I have started recording, are you okay with that? Good. So, as you already know we are looking into the issue of responsibility in automated vehicles. More specifically for this interview we look at features that keeps the speed and distance to the car in front and assist with steering. In Volvo's case Pilot Assist. This interview will focus on your experiences with such functions. Try to answer the questions as good as you can by explaining your thoughts in detail and remember that this is not a test and there is no right or wrong way to answer to the questions, because we are interested into your opinions and experiences.

As you know we are going to go through an interactive part in the last stage of the interview. I will send a link to you when we come to that part.

- Do you have any questions before we start?

---

1. Introduction questions

1.1 Before we start talking about automated vehicles, I would like you to describe a situation where you feel responsibility! What does the term responsibility mean to you? It doesn't have to be car related.

- What is it in that situation that makes you responsible?
- Why are you accountable in that case?

1.2 We asked you to reflect a little on how you feel about PA, can you tell me about your expectations you had towards the function before you used it the first time?

- Where your expectations met by Pilot Assist?
- Where did you get these expectations?

1.3 How did you know how to use the function?

- Did you feel that you had the right knowledge, when you started using Pilot assist?
- Did you have to look up how to use It or ask someone else?

2. Pilot Assist/interaction

2.1 When do you typically use Pilot Assist and how do you know when to use it/when not to use it?

2.2 Does your driving behavior change when you use the function compared when you drive yourself?

- Is there a difference in how you steer? Why?
- Is there a difference in what you pay attention to? Why?

2.3 Do you feel that Pilot Assist allows you to do things that you regularly don't do when you drive yourself?

- In what way?
- Do you feel like you can do more advanced adjustments on the center screen? (Like changing the GPS)
- Does it enable you to use your phone?

2.4 Do you feel like you can trust the car when driving in Pilot assist?

- What makes you trust or distrust the car?
- Why/Why not?

3. Responsibility

3.1 Would you say that you feel responsible when using PA?

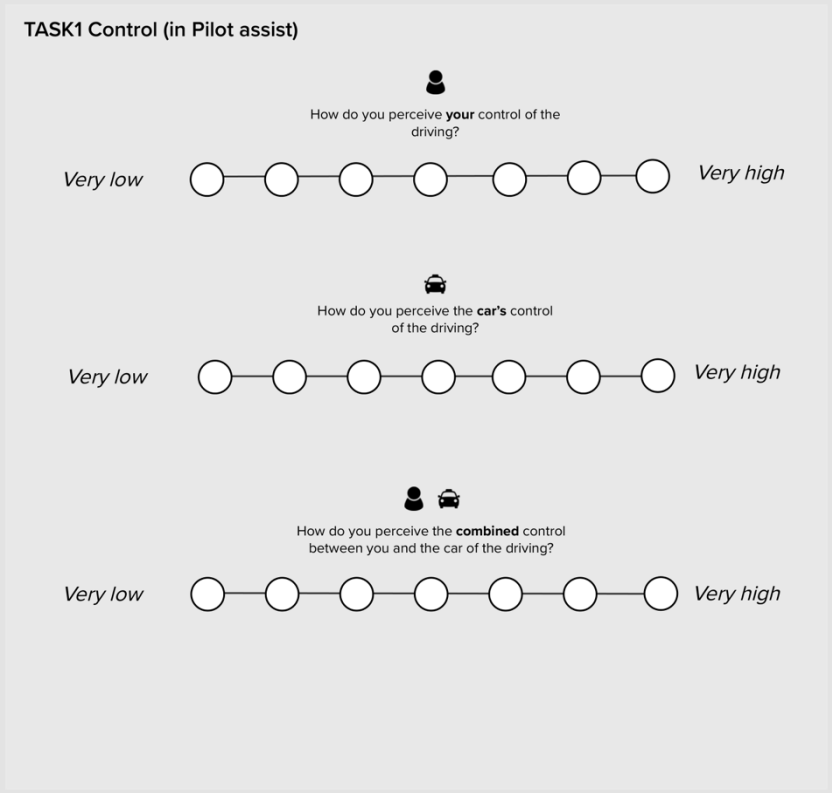
- In what way do you feel responsible/what are you responsible over?
- Why/ why not?
- Is there anything else?

Interview, part 2, (Interactive), (30 min)

Control & responsibility in different modes (Quantitative data) (5 min)

Now we are moving in to the more interactive part of the interview. We will use a website called Mural, where you will interact with a few different tasks. You will not need an account for this, but you will get an invitation from me in the chat here! I will be able to follow your screen inside Mural, but the screen will not be recorded. You are also anonymous in this document. Here is the link! You need to close a few pop-ups but it should be no problem getting started!

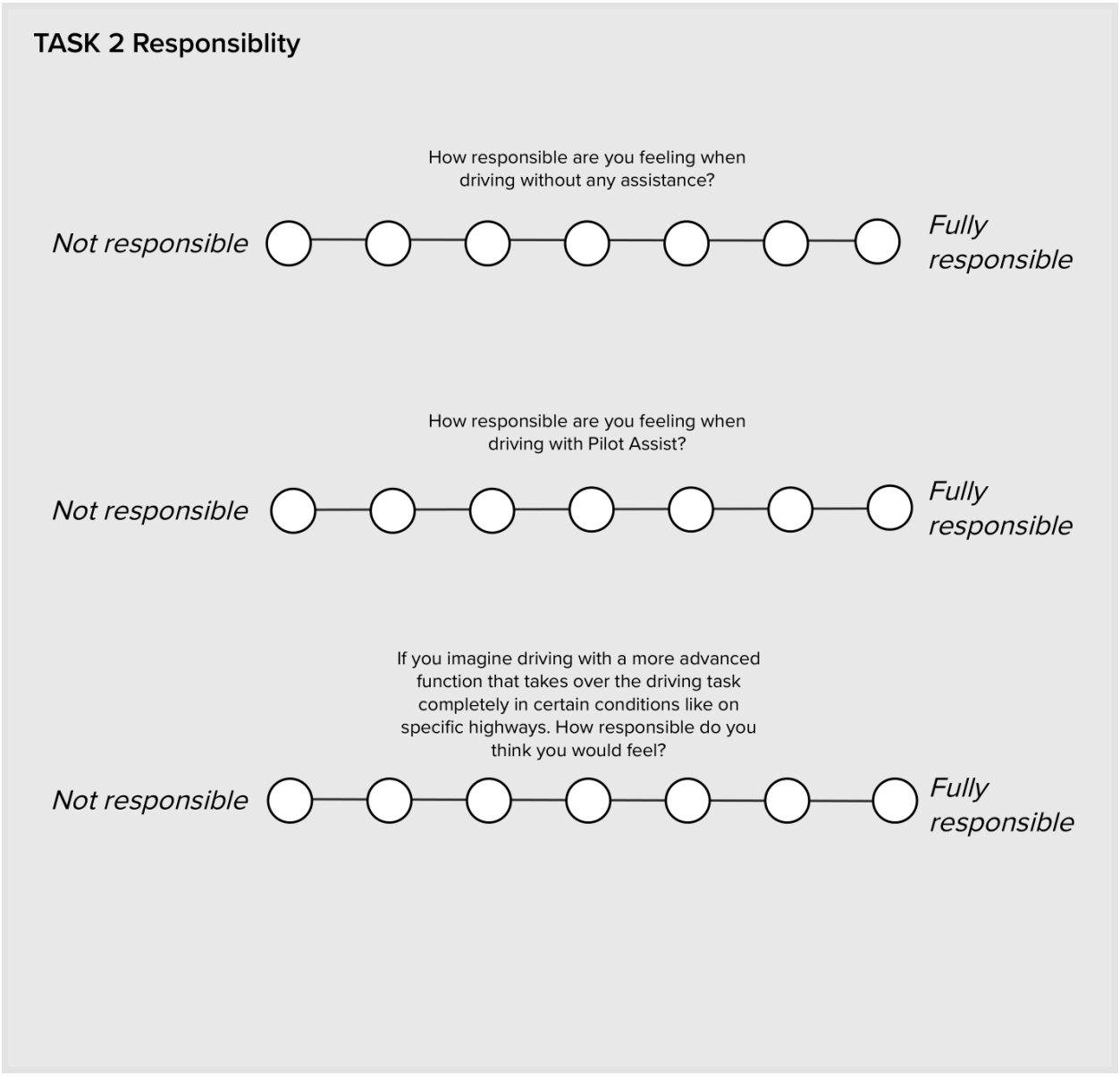
TASK 1: First, we are going to task 1. You are going to rate your feeling of control when driving in Pilot Assist. Please think aloud and guide me through your thoughts while you fill in the questions. In mural, use the pen to fill in the dots. You access the pen tool on the left side of the screen.



- **Why do you rate like this?**
- **Is there any situation where this changes?**

TASK 2: We can now move on to the next step which you can find if you press and drag over the document. It is a new table which we want you to fill in! Here you will rate how responsible you feel when you drive by yourself, in Pilot Assist, and in an automated function that takes over the driving task completely in certain situations, like on specific highways. Please guide me through your thoughts.

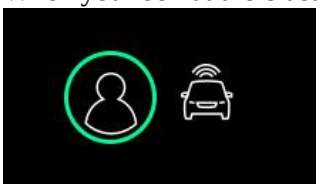
- **What is it that makes you feel responsible?**
- **What is it that makes you feel not responsible?**



Symbol (10 min)

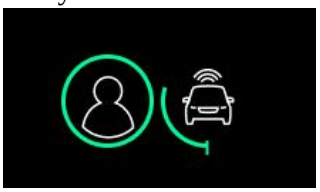
TASK 3: *In this stage we will show symbols(A,B,C) to the respondent together with some contextual information (Scenario). They will first try to describe their initial response to the symbols Then we will ask questions about control and responsibility.*

A. Manual drive: Imagine that you turn on the engine of the car and that you start driving the car. When you look at the cluster information behind the steering wheel you notice this symbol.



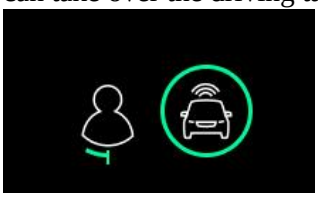
- **How do you interpret the symbol?**
    - What does it mean?

B. Pilot assist: Now imagine that you turned on a driving mode like the Pilot Assist function and the symbol behind the steering wheel has changed to this.



- **How do you interpret the symbol?**
    - What does it mean?

C. Auto Pilot: Now we activate a more advanced function than Pilot Assist, which sometimes can take over the driving task.



-
    - **How do you interpret the symbol?** What does it mean?

Now look at all three symbols:

- **What does the symbols tell you about who is in control of the driving?**
- **What do you think, would they influence your feeling of responsibility between the modes?**
- **What do you think, would it make you feel more or less responsible for the driving?**
- **Do you think these symbols would help you understand a function that you were not familiar with?**

Responsibilities (10 min)

TASK 4: *In this segment we want the participants to tell us about what they think about responsibility when they use Pilot Assist and test if the identified responsibilities from the previous study are correct and how important each factor is. We also want to see if there are other factors that were not identified.*

The next part is about different kinds of responsibilities that one might feel that surrounds driving. Here we have 5 examples (Safety, Legal, Being the driver, Competence and Knowledge). I would like you to rank them in the order which you feel them strongest when you drive in Pilot Assist by placing them in the box. Try to think how you feel about these when using Pilot Assist. If you feel like something is missing, you can add factors on the empty post-it!

1. MOTIVATORS & COMPETENCES

- Why did you rank them as you did?
- Why do you feel a high responsibility for ……?
- And why do you feel low responsibility for……?
- Without re-arranging the post-it notes, could you reflect over situations where your ranking might change?

Now you have some other factors (Driving tasks, follow instructions, malfunction avoidance, readiness) here and we want you to do the same thing as you did with those we had before:

2. TASKS & MONITORING (show these after motivators & competences)

- Why did you rank them as you did?
- Why do you feel a high responsibility for ……?
- And why do you feel low responsibility for……?
- Without re-arranging the post-it notes, could you reflect over situations where your ranking might change?

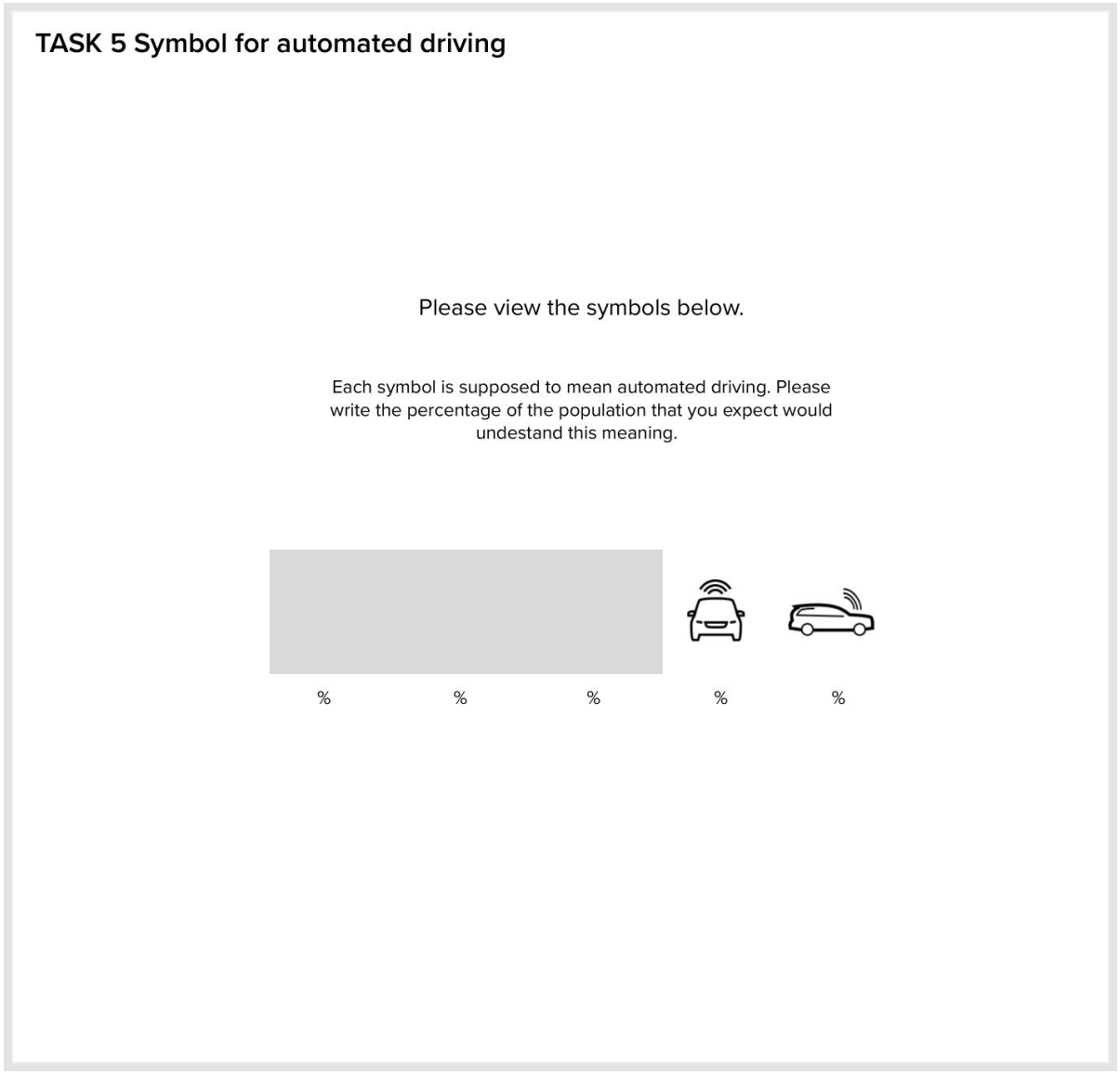
Sum up:

- Is there any situation where they change? (Driving situation or outside PA?)
- Is there any type of responsibility that we are missing among these?

Symbols for automated vehicles (5 min)

This segment compares our symbols (the two to the right) with some proposed ISO standard symbols for automated driving system. The method of asking which percentage of the population would understand the meaning of the symbol comes from the ISO standard 9186.

TASK 5: Finally, we want you to look at some last symbols. You can think about the percentage among the population that have a driver's licence.



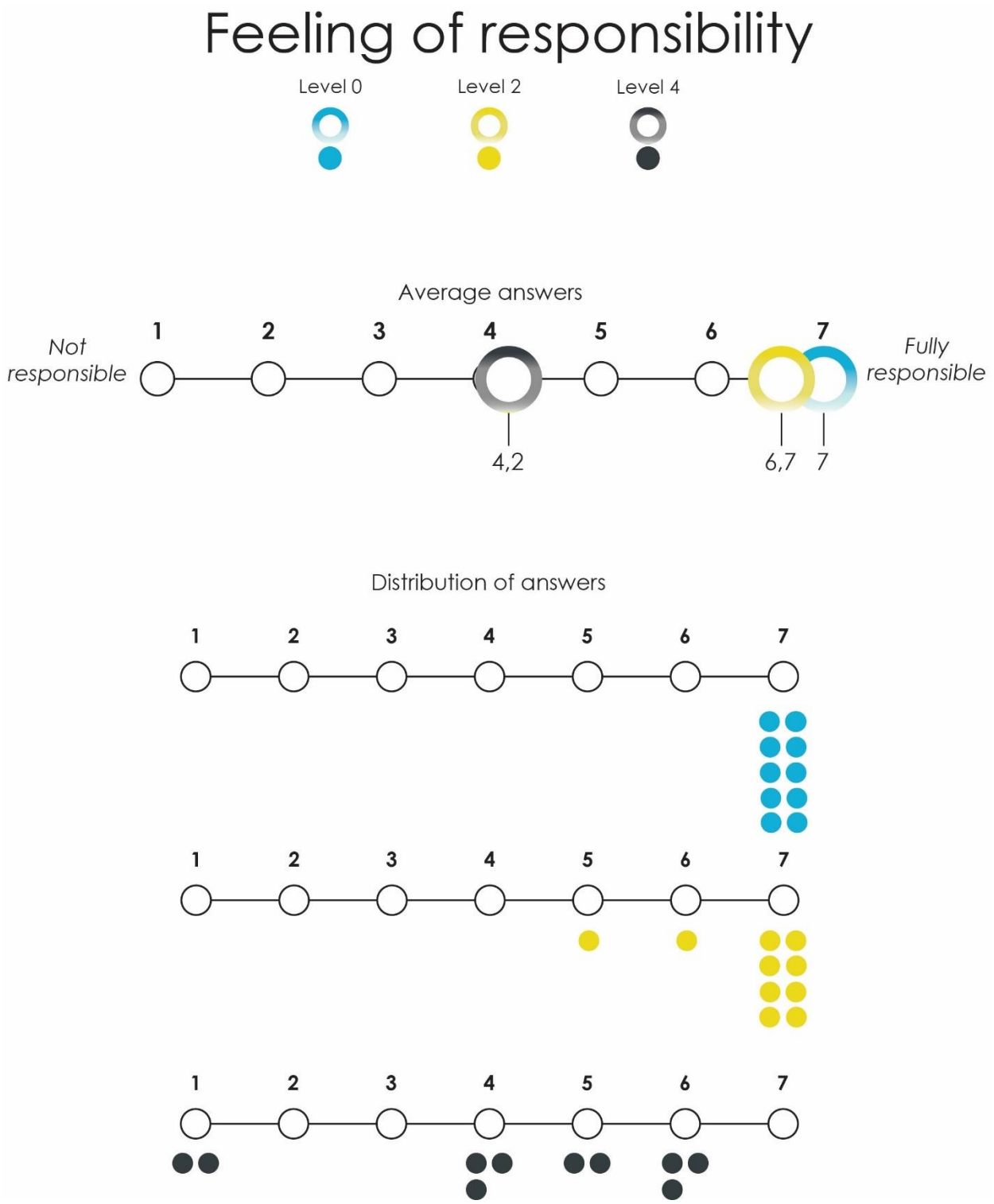
-Why did you rate them as you did?

-Would the steering wheel work as the symbol for the car in task 3?

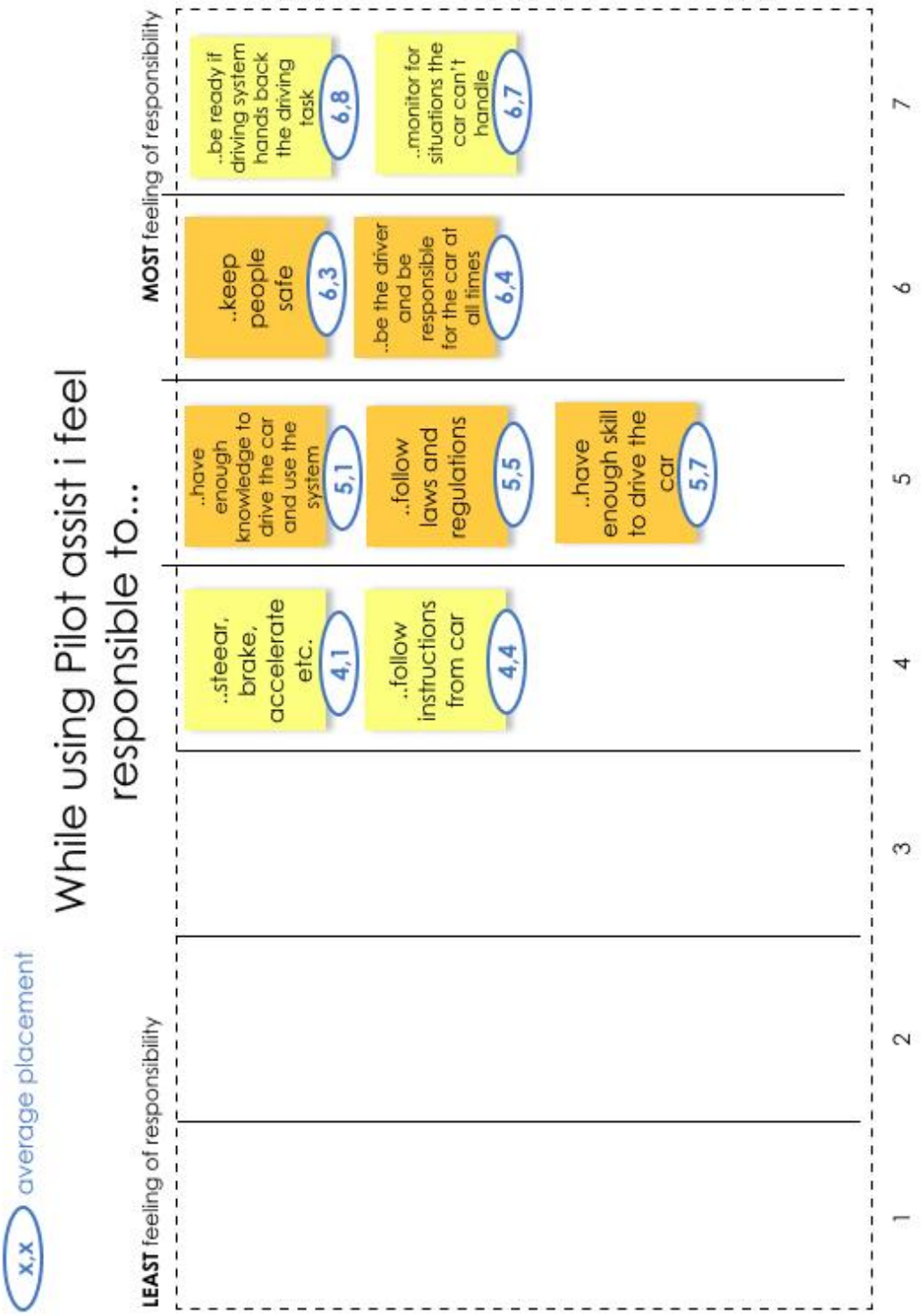
That was all! Thank you for participating!

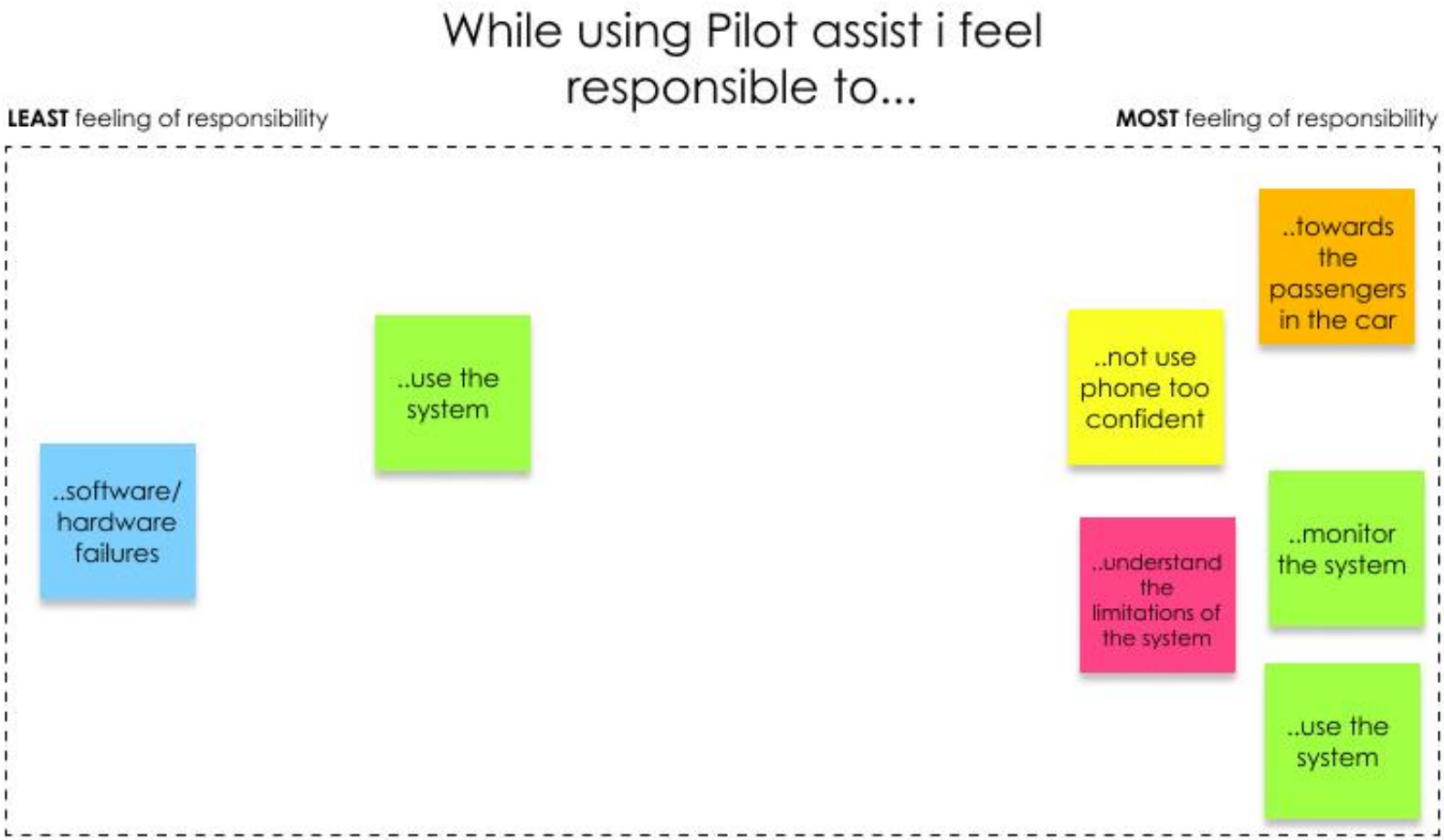
- Do you have any questions before we end?

Appendix 4, Responsibility Scale

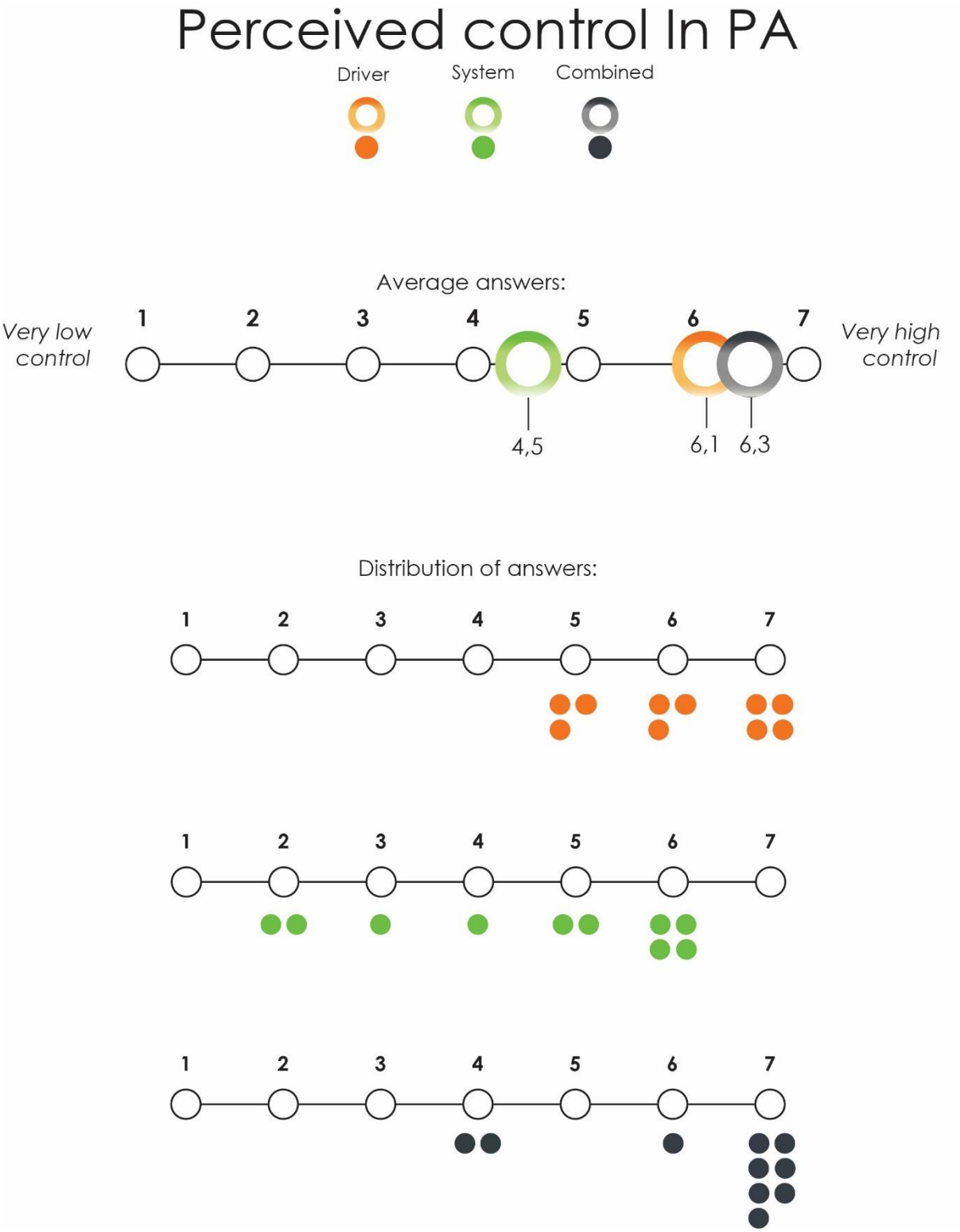


Appendix 5, Rated responsibilities & new responsibilities




While using Pilot assist i feel responsible to...
LEAST feeling of responsibility
MOST feeling of responsibility
..towards the passengers in the car
..use the system
..not use phone too confident
..software/ hardware failures
..understand the limitations of the system
..monitor the system
..use the system

Appendix 6, Control Scale



DEPARTMENT OF INDUSTRIAL AND
MATERIAL SIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY