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Users' Understanding of their Role when Cooperating with a Semi-Automated Vehicle

Always Responsible but Sharing Control

Master's thesis in Industrial Design Engineering

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Gothenburg, Sweden 2021

MASTER'S THESIS 2021

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Abstract

When the development of semi-automated vehicles increases, as does the demand for efficient cooperation between user and automated system (AS). The common roles and responsibilities are being challenged. Throughout literature, apparent risks with faulty cooperation are often discussed. However, the knowledge of how the potential users will understand these challenged responsibilities is absent.

Therefore, the aim for this thesis project has been to investigate how users understand their responsibilities in a semi-AV (LoA 3) and then formulate user-centered guidelines that could create a foundation for future interface design developments in semi-AV.

This has been done by researching factors affecting responsibility, how these are understood by the user and how it should be designed in AS. The results showed that responsibility could not be shared, neither between humans nor humans and AS. Thus, the user should always have an understanding of constant responsibility, regardless of activated AS and therefore one could draw the conclusion that responsibility in the context of semi-automated vehicles is a non-problem.

However, factors related to responsibility e.g., control can be shared between user and AS. Since semi-automated vehicles are ever changing cooperation, the takeover requests (TOR) are a vital aspect to consider, since they require the user to always act responsible, regardless of if the AS is active or not. Therefore, the concept development aimed to create possible design solutions regarding TOR, by using different levels of system transparency. The final concept proposed an HMI design solution regarding the TORs information and how they should be conceptualized visually, to enable an efficient and safe cooperation between the user and the AS, during use of a semi-automated vehicle.

Keywords: Responsibility, control, semi-automated vehicles, LoA 3, Automated System, HMC, HMI, System Transparency

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I would like to express my deepest appreciation to all the people who made this master thesis project possible. I would like to express my sincere gratitude to professor MariAnne Karlsson at Chalmers University of Technology for giving me support and feedback that steered the report in the right direction. I would also like to thank my supervisor Fredrik Ekman at Chalmers University of Technology for all the insightful comments and suggestions. I would also like to thank my supervisor Alexander Gentner, Senior Specialist, UX research at Toyota Motor Europe for all the knowledge and insights. Also, a lot of thanks to Aurélien Badoil Senior Designer at Toyota Motor Europe and Carol Favart, General Manager at Toyota Motor Europe for their contribution to the workshop, which gave many interesting ideas.

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In this master's thesis project, and the first five chapters i.e., *Introduction*, *literature review*, *user study*, *searching for inspiration* and *guidelines* have been done together with Ida Geschwind. The rest of the thesis project, described in chapter 6 to chapter 9, i.e., *concept development*, *final concept*, *general discussion,* and *conclusion* has been written by the author, Cecilia Modigh.

Glossary

This glossary contains the explanations of words that have been used throughout the thesis.

Automation Bias
Refers to over relying on automation functions, placing too much trust in the automation when making decisions. This may cause degraded performance if following the automated aid's incorrect advice.

Automation Complacency
Can be explained by a lack of continuous assessments of the automation system states, due to over reliance. This may prevent the user from understanding when automation fails.

Control
Control, related to responsibility in human-machine systems, means to possess *the power to influence a situation*, i.e., control the proceedings or outcomes of an activity.

Human Machine Cooperation (HMC)
Human-Machine Cooperation has been interpreted as an interaction between human and machine, which share the same goal. Thus, a collaborative relationship between user and the AS. In this thesis project, this is considered as one of the most central concepts.

Human Machine Interface (HMI)
Human-machine interface can be described as a user interface or dashboard that connects the user to a machine, system or device. It is through the HMI that the user and the system can communicate and interact with each other.

Mental Model
Refers to a person's beliefs or assumptions about how the product or the systems works. A user's mental model is affected by different inputs such as mental models of other systems, expertise, previous experience, other users, shared cultural conventions, etc.

In-the-loop
Being in-the-loop can be explained as having the right type of information, while being part of a decision-making action. In the context of vehicles, the driver is in-the-loop when involved in the driving task and aware of the vehicle status and the road traffic situation, actively monitoring information, making decisions, and responding to requests.

Levels of Driving Automation (LoA)
Refers to a classification of different levels in automated vehicles, from level 0, with no automated systems (AS) at all (fully user operated vehicle), to level 5. In level 5 the vehicle is fully automated, without any need for any human assistance.

Situation Awareness (SA)

Refers to knowing what is going on around you at any given time. In order to achieve this, the user needs to see, understand and analyze the world around them in the context of what they are trying to do and then use this information to predict what might happen next.

System Transparency

Can be explained as a filter which determines how much or how little information that is going to be communicated to the user.

Take over Request (TOR)

Refers to a situation when the automated system reaches its operational limit, and the system is asking the user to take back control of the vehicle. In this situation the user has a limited amount of time in order to take over manual control of the vehicle, before the automated system deactivates.

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1. Introduction

The development of automated vehicles (AVs) has increased rapidly over the last years and is supposed to improve road safety, traffic flow, and reduce emissions (Center for Sustainable Systems, 2019; Fagnant & Kockelman, 2015; González et al., 2016; Milakis et al., 2017; Zheng et al., 2020; Papadoulis et al., 2019), while at the same time increasing accessibility to transportation, and thereby facilitating a more inclusive society (Hörl et al., 2016; Pettigrew, 2017).

However, with higher levels of automation, the demand for efficient cooperation between drivers/ users and AVs increases. According to Banks and Stanton (2017) the sharing of the driving task comes with challenges such as reduced situation awareness (SA), automation complacency and overreliance. To mitigate and avoid unsafe situations, it is important that factors related to the cooperation between users and AVs, among other things, are taken into consideration.

In an attempt to clarify the cooperative relationship between the user and the AV, SAE International (2018) updated their *Levels of Driving Automation* (LoA) scale. According to this scale, which ranges from LoA 0 to LoA 5, level 0 describes a fully manual drive, with no automated systems (AS), while level 5 is defined as driving with a fully automated driving system. The levels from LoA 1 to LoA 5 are characterized by cooperation between the user and the AS, meaning that the driving mode can change from manual to automation mode and back to manual mode again. Moving between these modes, the user and the AS need to communicate information through the human-machine interface (HMI).

However, Novakazi et al. (2020) argue that the SAE's description of the levels is not developed from a user perspective. Seppelt et al. (2018) agree that, in particular, SAE's midrange-LoAs create confusion about the role and responsibilities of the user. This may negatively influence how users understand the overall system, the automation function and their expected responsibility.

Considering that AVs, from LoA 1 until reaching LoA 5, entail cooperation between user and AS, (Biondi et al., 2019), the roles and responsibilities of driving an AV will be challenged (Banks & Stanton, 2017). To address these challenges, it is important that the design of the human-machine cooperation (HMC) and in turn human-machine interface (HMI) supports the users in maintaining an appropriate understanding of their responsibility.

1.1 Automated Vehicles

The automated vehicle is a vehicle that uses connectivity, sensors, and several systems to drive with limited or no human assistance. Depending on the degree of complexity, the vehicle is classified according to SAE International's level of automation. The classification aims to create a universal understanding of how these vehicles differ. This taxonomy is continuously updated.

1.1.1 Levels of Automation and Associated Problems

The classification of different levels in AVs ranges from level 0 with no ASs at all, i.e., a fully user operated vehicle, to level 5. In level 5 the vehicle is fully automated, without any need for human assistance. This can be seen in figure 1.1.

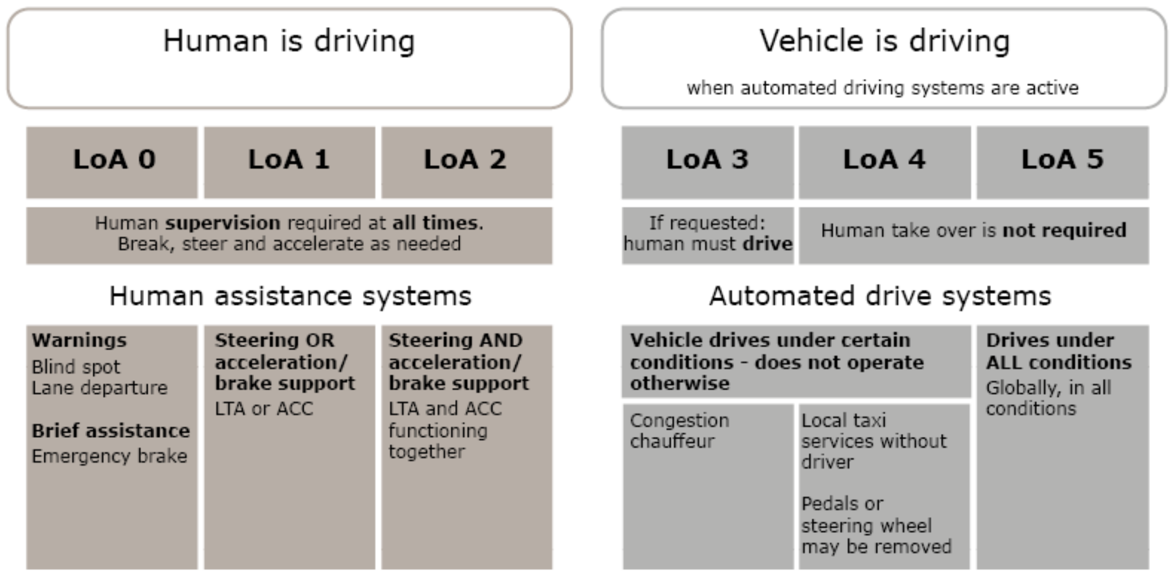

Figure 1.1 Levels of Automation according to SAE (2019).
(Author's own copyright.)

The most distinctive difference in the levels of automation is, according to SAE (2019), between LoA 2 and LoA 3. Up till LoA 2, the *human is driving* - even though the driver's feet can be removed from the pedals and steering can be handed over to the vehicle. In semi-AVs, LoA 3, "the vehicle is driving", i.e., the *human is no longer driving – if the* AS is activated. However, the user is still expected to take over when the vehicle encounters surroundings in which the AS does not function appropriately. Take over requests (TOR) will appear during the journey when the conditions for AS are not met.

These specific transitions between user and AS provide difficulties for users to understand their responsibilities. A formal outline of the user's role and responsibilities throughout the varying automation levels, could facilitate these human-machine transitions. However, this information is lacking in the SAE taxonomy, as well as in similar classifications (Banks, Eriksson, O'Donoghue & Stanton, 2018).

The absence of clear definitions regarding human and automation responsibilities has proven it difficult to implement the SAE taxonomies in the design process. Kaber (2018) argues that the existing definitions of LOAs have made presumptions of human behavior with automation and that it is difficult to define a set of rules that yields an accurate assessment of automation. Nevertheless, as long as there is a user involved in the automation results, the user's role and responsibilities must be considered.

1.1.2 Responsibility – A Key Concept

Responsibility is a construct that is defined in different ways and the differences depend on for example different cultures, and therein ethical approaches. According to the Oxford Dictionary, "Responsibility" (2020) is defined as *''a moral obligation to behave correctly'', ''the state or fact of having a duty to deal with something'' or ''the state or fact of being accountable or to blame for something''.* To further understand these differences, responsibility in itself is here explained through emotivism, consequentialism followed by deontologism and lastly virtue ethics (figure 1.2).

Emotivism claims that ethical sentences do not express propositions, but rather emotional attitudes, which means that moral statements are meaningless as they only express our emotions about the issue ("Emotivism", 2020). Therefore, according to this theory, responsibility can be interpreted as *we do not have any responsibility*. **Consequentialism**, on the other hand, predicts consequences of actions in terms of good or bad. If the consequences are good, the act itself is good ("Consequentialism", 2020). Then, responsibility is interpreted as *having the responsibility to maximize happiness and to minimize suffering*.

In contrast to consequentialism, **deontologism** focuses on whether the action itself is right or wrong, through a set of rules ("Deontology", 2020). Seen from the perspective of deontologism, *responsibility is something we all have, society would not work without it.* Still focusing on actions, **virtue ethics** highlights that good actions are those leading to something good and emphasizes human duties ("Virtue-ethics", 2020). Then, according to virtue ethics, *responsibility is something we all have and to renounce our responsibilities go against our nature*.

Emotivism	*"We do not have any responsibility."*
Consequentialism	*"We have a responsibility to maximize happiness, and minimize suffering."*
Deontologism	*"Responsibility is something we all have, the society would not work without it."*
Virtue ethics	*"Responsibility is something we all have and to renounce our responsibilities goes against our nature."*

Figure 1. 2: Responsibility explained by different philosophical approaches.

Aristotle (1984), who is associated with virtue ethics, provided specific conditions which needed to be fulfilled for responsibility to be applied. First, the user needs to be in control of the action and second, the user needs to have an understanding of the complete situation, i.e., situation awareness. Included in the situation are others who can be affected by the actions. Thus, responsibility is relational (Gardner, 2003; Coeckelbergh, 2016).

In the context of human-machine systems, such as AVs, the responsibility of an action is allocated when defining how a system should be used. This motivates appropriate actions and enables accountability evaluation of any consequences for those same actions (Flemisch, 2012). The allocation could be implemented already in the development process, by the developers. Coeckelbergh (2016) combines this with the terms of control, understanding and relation in the same context:

> "(1) she is in control of the car, that is, she is driving and not someone else, and she knows what she is doing with respect to operating the car and knowing the environment — this enables her to respond to it, and thus to drive "responsibly" in this sense. However, (2) she also needs to perceive, and experience, that she is related to others to whom she should act responsibly."
> (Coeckelbergh, 2016, p. 752).

However, when applying this to AVs, especially semi-AVs (i.e., LoA 3), issues with allocating responsibility appear, the most prominent being whether the AS meets all conditions for it to be assigned responsibility.

1.2 Aim and Research questions

The primary aim of the master thesis project is to investigate how users understand their responsibilities in a semi-AV (LoA 3). The secondary aim is to use the generated knowledge in order to formulate user-centered HMC guidelines that will create a foundation for future design developments regarding the HMI, which could facilitate the cooperation between the user and the AS in a semi-AV.

AIM

*The **primary** aim of the master thesis project is to investigate how users understand their responsibilities in a semi-AV (LoA 3).*

*The **secondary** aim is to use the generated knowledge in order to formulate user-centered HMC guidelines that will create a foundation for future design developments regarding the HMI, which could facilitate the cooperation between the user and the AS in a semi-AV.*

Three research questions support the aim and provide direction for the work. These are found in figure 1.3.

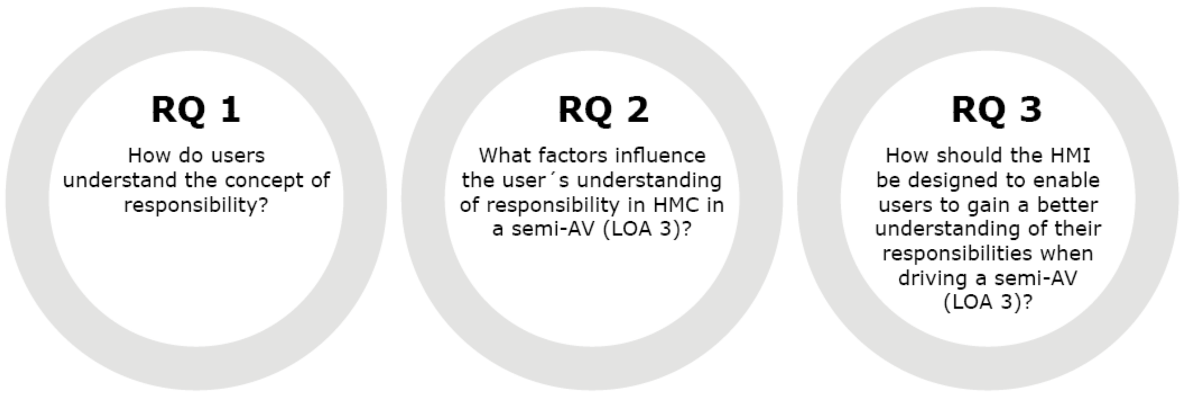

Figure 1. 3: The three research questions posed.

1.3 Delimitations

The intention of this thesis project is to investigate how users understand the concept of responsibility with focus on semi-AVs (LoA 3). Therefore, the concept of responsibility was explored in broad terms, to create a holistic view.

Regarding the level of automation considered as most relevant, LoA 3 according to the SAE standard (2018) was in focus. LoA 3 and higher levels of automation are still undergoing technical research as well as subject to possible traffic law changes, such as who is to be held responsible for accidents or special AV driving licenses (Ilková, 2017). Therefore, vehicles in LoA 2, which are already available on the market, were also considered. This level has interactions, such as control transitions between user and AS, similar to that of LoA 3, which can enable comparisons of understood responsibility.

This thesis project focuses on the countries and cultures that are connected to the term ‘Western world’, since there are major differences in usage and preferred design of the vehicles in other cultures (Shafi et al., 2019; Haider, personal communication, February 19, 2020). These differences have an impact on the experience of the vehicle, and it is, therefore, difficult to assess.

The outcome of the project is an incorporation of users’ understanding of responsibility, an understanding of which factors that influence their understanding and user-centered guidelines which aim to facilitate future design developments regarding the HMI, and in turn the HMC between the user and the AS. However, this means that the concepts investigated only are explorative, rather than fully functioning mockups.

Due to circumstances regarding Covid-19, applying force majeure, all data had to be collected with social distancing. The user study is therefore based on scenario-based expectations, rather than on actual use experiences.

1.4 Process

This thesis project was conducted through a process, figure 1.4, grounded in a literature review, a user study, activities searching for inspiration, concept development and lastly design of a final concept. The methods were user-centered and chosen based on their assumed possibilities to find clues as to how users understand their responsibilities and what the influencing factors are. All activities that have been performed, have contributed to answering the research questions. Nevertheless, it was only the user study that provided direct input to the primary aim. However, this could not have been achieved without the understanding that was generated through the other activities.

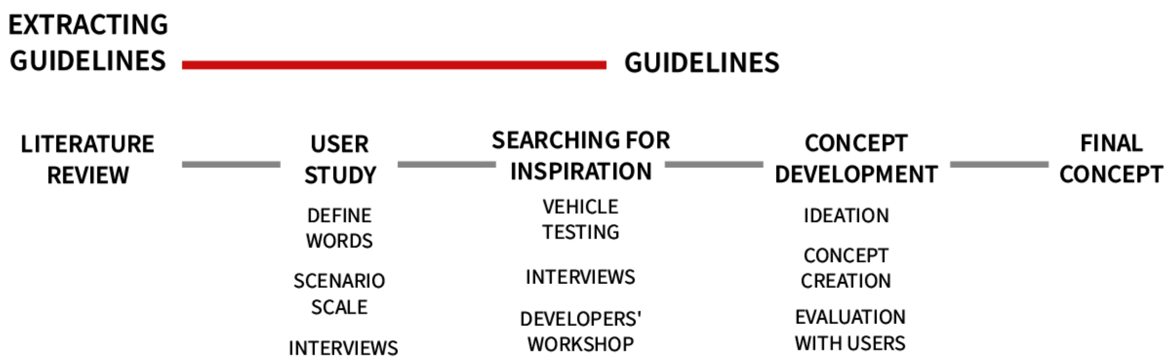

Figure 1. 4: Scheme of activities performed to reach the primary aim.

The first phase, the literature review, was completed in order to discover the subject and to enhance the understanding of the cooperation needed in semi-AVs (LoA 3) (RQ1; RQ2). This was done via a structured process consisting of five steps; define, search, select, analyze and present.

A user study was conducted in the second phase and aimed to grasp how users understand their responsibilities in semi-AVs (LoA 3) (RQ1; RQ2). The user study was centered around the insights gathered from the literature review. The initial plan was having the users test semi-AVs (LoA 2), to generate user experience-based results. However, the user study was the most suffering activity due to the social distancing guidance which followed the outbreak of Covid-19. The user study was therefore based on scenario-based expectations. Thus, the results provided to fulfil the primary aim of the thesis, were only based on expectations.

In order to search for some inspiration regarding the design of the HMI (RQ3), a benchmark and a workshop were conducted in the third phase. The benchmark consisted of two parts, where the first involved a test drive two different vehicles, and then evaluate these and their HMI designs according to NHTSA (National Highway Traffic Safety Administration) guidelines (see table 4.1, page 44). This activity enabled a comparison between the two vehicles regarding the HMC as well as the HMI. This part, however, should have been complemented with the test of a third vehicle, considered as being one of the ‘leaders’ in semi-AVs. Due to the circumstances of Covid-19, this opportunity was missed out.

A workshop with developers working with semi-AVs was then held. This provided more insights of how to work with HMI to affect the users' understanding of responsibility and other relevant factors such as control and authority (RQ1; RQ2; RQ3). This resulted in the idea of interviewing users or operators of other types of semi-AVs, i.e., aircrafts and trains, which have been around for longer than cars. The purpose was to see if there was any inspiration to be find.

Throughout these three phases, guidelines have been extracted and summarized after each and every phase. The guidelines are described in a chapter, *Guidelines*.

These guidelines were then used in the next project phase, concept development (RQ3). The concept development phase started with an ideation session by using the methods brainwriting and prototyping. Thirteen guidelines were selected from the guidelines and were used as inspiration to generate concepts regarding control transitions. After some ideation, one concept representing how the TORs look in vehicles today was created, as a baseline, and four different alternative TOR design solutions emerged. These concepts were then evaluated by users and based on the results from the evaluation, a final concept was created. This was the last phase in the process.

2. Literature Review

The literature review was conducted in order to create a baseline for the research to follow. This, in terms of understanding the subject of responsibility in conjunction with semi-AVs. The chapter is organized as follows: The specific aim and method of creating a structured literature review are described. This is followed by the elements that have been researched, all with a connection to responsibility. Lastly, the discovered themes are discussed with implications that have been considered throughout the rest of the thesis project.

2.1 Aim

The literature review aimed to create an understanding of how responsibility appears within the context of AVs, foremost LoA 3. The aim also covers the understanding of HMC and HMI between users and AS used in semi-AVs.

2.2 Method

Grounded Theory was used as the method for the review as proposed by Wolfvinkel and colleagues (2013) due to the need for a structured process while maneuvering the broad field of research. The method consisted of five steps, which were conducted as follows.

2.2.1 Define

The foundation of this method lies within this first step of the process. This is where all relevant topics are defined, as well as the search terms used. The topics overlap each other but are listed anyhow in order to prevent any information loss. The search topics chosen for this thesis were:

- Responsibility
- Automated Vehicles
  - LoA 2 & LoA 3
- Human- Machine Interface (HMI)
- Human- Machine Cooperation (HMC)

2.2.2 Search

The aforementioned topics, and relevant search terms; *responsibility*, *automated vehicles (LoA 2 & LoA 3)*, *human-machine-interface* and *human-machine-cooperation*, were used to find relevant academic articles and publications. This was done primarily through the internet, using Google scholar and Chalmers online library to find recently published material.

2.2.3 Select

Articles were first selected based on title and abstract. If the article was considered relevant, the references were checked to find further publications that could enrich the sample quality (cf. Wolfsvinkel, et al., 2013).

2.2.4 Analyze

The selected articles were analyzed by highlighting keywords and key sentences. These highlights were gathered, printed and used to create an affinity diagram (figure 2.1).

2.2.5 Present

The final step was to present all discoveries. Even though the process was conducted based on the defined themes and terms, the final result included several additional topics.

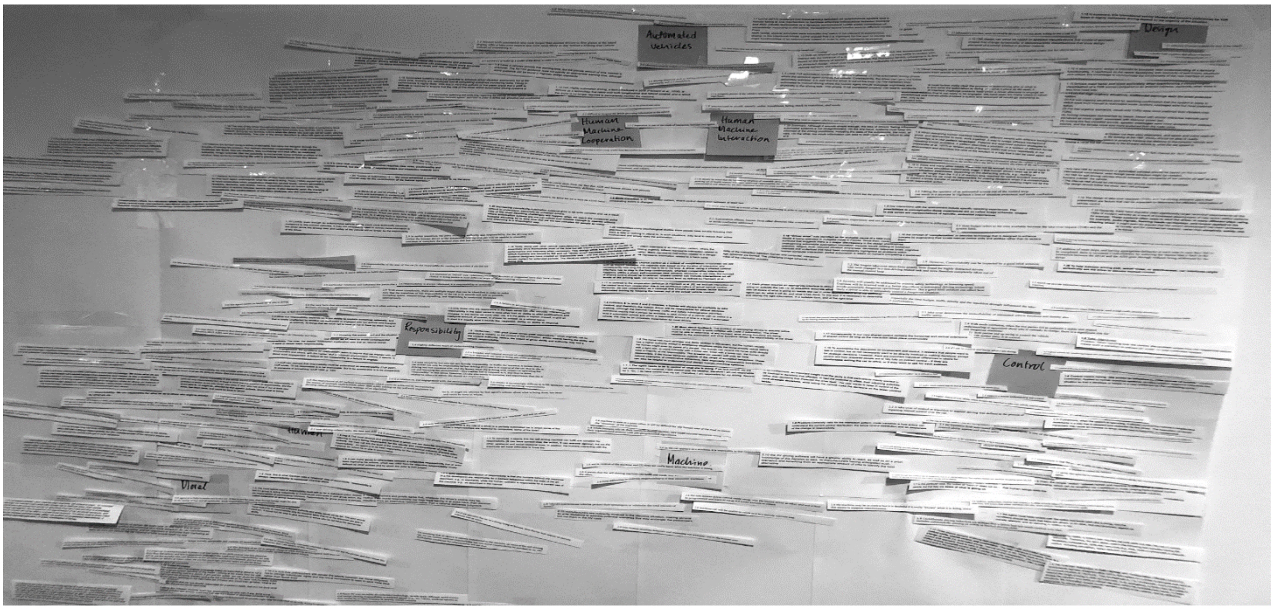

Figure 2.1: The last step of the literature study, an affinity diagram entailing the identified themes

2.3 Results

The concept of responsibility, in the context of semi-AVs, has been found to contain several different aspects that need to be taken into account in order to be able to understand the concept, and how all the different factors relate to each other.

2.3.1 Factors Influencing Responsibility

The construct of responsibility can be defined in various ways and individual factors i.e., knowledge and/or culture can affect how the word responsibility is understood, in this case how a user of a semi-AV might understand responsibility. To deepen the understanding of how these constructs may vary, responsibility is in the following text explained through the lens of an ethical approach to virtue ethics, followed by topics that are considered related to responsibility.

In the *Nicomachean Ethics*, associated with virtue ethics, Aristotle (1984) provides a specific description of what responsibility is. According to this description, responsibility can only be assigned if the two following conditions are fulfilled; First, the user needs to be in *control* of the action, and second, the user needs to have an understanding of the action (see figure 2.2). If the user lacks control or understanding, responsibility cannot be applied. Having an understanding, however, does not only refer to understanding the action itself, but to the whole situation, i.e., to have situation awareness (SA). Included here are not only things, such as artifacts or nature, but other human beings as well. Thus, responsibility is relational to those that could be affected by the actions (Gardner, 2003; Coeckelbergh, 2016).

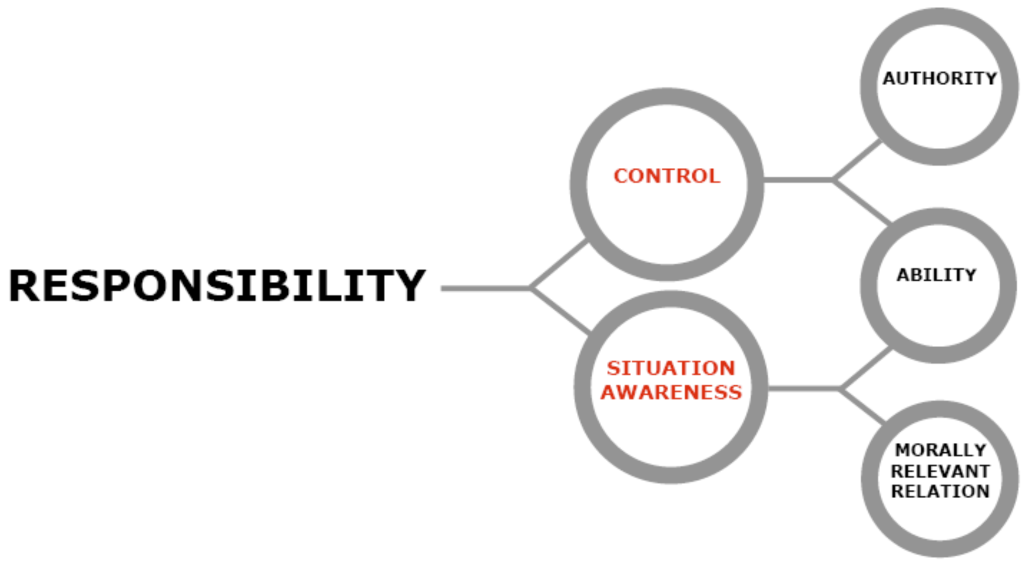

Figure 2.2: The two conditions for responsibility.

However, when applying this to AVs, especially semi-AVs, issues with allocating responsibility appear, the most prominent being whether the AS meets all criteria, for it to be assigned responsibility. Similarly, the human cannot be assigned responsibility if this information is missing, due to not having complete situation awareness.

Flemisch et al. (2012) argue that responsibility must be considered together with authority, control and ability to create a context in which to understand human-machine cooperation (HMC). Below is a description of these elements and their connection to responsibility. In the context of responsibility, the term relation is also relevant as noted earlier, and therefore explained. Behind control lies the aspect of ability and authority, while situation awareness is depending on ability and a relation relevant to the situation.

2.3.1.1 Authority

Related to responsibility, authority can be defined as what the user is *allowed to control*, in a human-machine system (Flemisch et al., 2012). In a cooperative driving situation, the authority is divided between the user and the AS, since transfer of full authority to the user or the system are often more difficult to perform. These can cause errors in HMC, such as protracted time intervals required for full transfer, misinterpretation of responsibility and loss of situation awareness (Bhardwaj et al, 2020).

2.3.1.2 Control

Control, related to responsibility in human-machine systems, means to possess *the power to influence a situation*, i.e., control the proceedings or outcomes of an activity (Flemisch et al, 2012). In the context of semi-AVs, the concept of control has a central role; mainly related to shared control, which is important in cooperative driving (Walch, Colley and Weber, 2019). In this type of driving, where manual and automated driving are combined, transitions in control are inevitable.

In order for the user to have control, the user must have situation awareness. This means that the user must be aware of what is happening both inside and outside the vehicle (Debernard et al., 2016). However, Strömberg et al. (2019) state that even though humans want to <u>feel</u> in control, they do not necessarily want to <u>be</u> involved in making decisions, except for when it comes to strategic decisions. Important to consider are also individual differences in interpretations of control (Strömberg et al., 2019).

The feeling of being in control is dependent on rituals and routines, where these rituals are incorporated in the everyday usage of the vehicle. The vehicle itself creates a familiar and safe construction surrounding the users, but when the AS is activated, the familiar routines change, which leads to that the user can experience a sense of losing control (Eckoldt et al., 2012).

It is important to understand that the control transitions involve collaboration between the user and the AS, especially in vehicles with a LoA 3 as these control transitions are initiated either by the user, or by the AS. This itself requires clarity of who is in control, such as a scheme for uniting users and AS that withstands unexpected situations, errors and similar (Bhardwaj et al, 2020). It is also important to communicate resumption of control in order to be able to avoid conflicts between the user and the AS which in turn can prevent road accidents (Mirnig, Stadler & Tscheligi, 2020). The human-machine-interface (HMI) plays an important role since it enables communication between the user and the AS which is needed in order for user and AS to be able to cooperate.

2.3.1.3 Ability

Ability can be defined as having the skills or means to understand a situation and thereby perform an appropriate action. The same applies in human-machine systems (Flemisch et al.

2012). In the contexts of AS, ability can be described as *being able to collect information and thereby act accordingly* (Pacaux-Lemoine et al., 2015).

The user has a superior ability of perceiving and judging situations, by generalizing information from other types of experiences (Bhardwaj et al., 2020). This is assisted by the user's ability to shape a mental model, which is a description of how the system works according to the user. A user's mental model is based, not on facts, but on beliefs i.e., what the user knows or thinks they know about a system and is affected by different inputs such as mental models of other systems, expertise, previous experience, other users, shared cultural conventions, etc. (Hartson and Pyla, 2012).

2.3.1.4 Moral

While driving a semi-AV, with the human as primary driver, the actions that the human makes are taken with consideration to morally relevant aspects that can be extracted from the specific traffic situation. Morally relevant aspects include taking others (e.g., other road users) into account. This means that responsibility can only be exercised if there is a known, important relation to others involved in the situation. Keeping in mind that semi-AVs entail cooperation between user and AS, the moral reasoning might be possible to reserve for the user, while being the primary or secondary driver. That is, even though the AS is assigned as the primary driver, the user assists with the moral assessments, practicing responsibility (Coeckelbergh, 2016).

2.3.1.5 Relation

Responsibility is relational. To have a relation can be explained as to always act responsible towards someone else. Responsibility can only be exercised if there is a known, relevant relation to those affected by the actions. This relation can be to other humans, or the relation can be between user and AS (Coeckelbergh, 2016).

2.3.2 Semi-Automated Vehicles, HMC and HMI

In a semi-AV, there are three modes involved during the drive: the manual mode, the automation mode and the manual mode. First the user drives without any AS activated which means that it is the user that has all control over the vehicle. In order to change from manual mode to automation mode there is a transition, and when the AS is activated, the AS controls the vehicle. This implies that the user can perform some secondary activities. In this situation, the user is out-of-the-loop, i.e., does not have any physical control over the vehicle and/or lack of situation monitoring. The third mode is the manual mode again, which means that there is a transition from automated to manual driving mode. Here, the user needs to re-engage physically and cognitively in the driving task. Due to the user being out-of-the-loop when using the automation mode, the underlying risk of accidents, due to failures in mode transition, must be considered.

2.3.2.1 Theoretical Shared Responsibility

The distribution of responsibility differs between the developers of the AS and the user who uses the AS. Developers are responsible for ensuring that the AS behaves properly, i.e., as described in the user manual, while the user is responsible for a correct use of the AS, e.g., as described in the user manual (Flemisch, 2012). Additionally, ASs of semi-AVs continuously assess risks in order to minimize accidents. This implies that an AS needs to be making ethical choices autonomously, either via pre-programmed instructions, a machine learning approach or through a combination of the two (Goodall, 2014).

Other important aspects to consider are automation complacency and automation bias. Automation complacency refers to the lack of sufficient check-ups of the state of the system, complicating the recognition of automation failure. Automation bias refers to the tendency to over rely on automation, letting the system influence decision making. Both of these aspects could cause major errors in HMC if the automation fails (Yamani & Horrey, 2018) and, in turn, affect the user's understanding of responsibility.

2.3.2.2 Human Machine Cooperation (HMC)

Cooperation can be defined as an interaction between two agents who share the same goal (Pacaux-Lemoine, et al., 2015). In the context of semi-AVs, there is a collaborative relationship between user and the AS.

According to Baltzer (2019), successful cooperation is characterized by a consistent, commonly accepted result which in this context is generated by the user and the AS. If there is no collaboration, this can either lead to no results at all, or to two contradicting results. A positive aspect of HMC is that it can help to balance the workload between the user and the AS. The sharing of workload is directly connected to the allocation of functions and roles between the user and the AS.

2.3.2.3 Human Machine Interface (HMI)

A human-machine interface (HMI) can be described as a user interface that connects the user to a machine, system or device. It is through the HMI that the user and the system can communicate and interact with each other. This can involve input by modalities such as speech, touch, gestures and similar from the user to the system and visual or haptic output from the system to the user (Ballav & Ghosh, 2017).

Visual displays (and hence the visual mode), are the primary and most widely used solution for in-vehicle interfaces. Two types of visual displays are head-down display (HDD) and head-up display (HUD). HDD has the advantage of not blocking the view of the real word for the user, whereas a HUD makes it possible for the driver to take advantage of the necessary information while watching the external environment (Morra et al., 2019).

Several studies have also shown that display configurations with more centralized information, like HDD and HUD, result in better driving- and task performance than the spread out display configuration, e.g., infotainment displays (Normark, Tretten & Gärling, 2017). Another study claimed that in a LoA 3, where the user can engage in non-driving-related activities, one can mount the in-vehicle displays in other positions than the ones that are used for manual or automated driving. However, the authors also highlighted the risk that the driver requires more time to access information if it is moved away from the user's line of sight (O'Regan & Levy-Schoen, 2013). Yet other studies have found that it is more difficult to distinguish colors and frequency of blinking stimuli when they are presented in the periphery (Young, 2003; Jacob & Karn, 2003).

Since the HMI enables communication between the user and the AS, it can facilitate control allocations and increase the understanding of what is expected of the user. HMI can also create situation awareness, since it can help the user to know what is going on around them. This can in turn facilitate the users' ability to understand their responsibilities and how they should act while driving (with) a semi-AV.

In the automotive industry, the major changes to the vehicles have not been in terms of the physical design of the vehicle but instead in HMI systems. When HMI elements was introduced, new challenges emerged regarding the interaction between the user and AS (Ballav & Ghosh, 2017).

When designing an HMI, attention must be taken into account, since it allows the user to focus on the relevant information to what they are doing. Attention involves our auditory and/or visual senses and depending on how the information is displayed, it is either easy or difficult for the user to interpret and understand (Preece, Rogers & Sharp, 2015). According to Preece, Rogers and Sharp (2015) and Cooper (2014) there are therefore some design implications that need to be considered when designing a user interface.

It is important that the information regarding the AS's status, abilities and limitations are salient, so that the AS and the user understand each other. In order to achieve this, it is recommended to use techniques like positions, colors, size, underlining, ordering of items, sequencing of different information, and spacing of items. The user needs to understand what is important in the interface and how the different items are related. The most important element can be larger and have a greater contrast in value, hue and saturation for example. Another important thing is to avoid cluttering the interface with too much information, something that especially applies to the use of color, sound and graphics. A more cluttered interface can increase the user's cognitive load which affects the overall experience and can instead increase the risk that the user will be distracted and annoyed. When designing an interface, it is advised to keep it simple and use a minimal set of both visual and functional elements.

2.3.2.4 System Transparency

The term system transparency is relevant to address in this context since it is important that the user has an understanding of the behavior of the AS, in order to achieve good cooperation between the user and the AS. According to Preece, Rogers and Sharp (2015), system transparency can enable the user to easily understand how a system works and intuitive ways of interacting with the system. Fleischmann and Wallace (2005) describe transparency as "*an essential tool for preserving the autonomy of users and empowering them relative to model builders*" (p.93). The authors argue that when a user can have the ability to 'see' into the system, the system and the user share important information which in turn allow the user to make informed decisions based on all available information.

Lyons (2013) states that transparency is a mechanism to facilitate effective interaction between users and AS. In order to achieve this, the user needs to understand the intent or purpose of the AS, the system's actions and goals, why it acts the way it does and how the system makes decisions. The AS needs to have the capability to understand the dynamics of its surrounding environment which for example can be geographic variance (i.e., terrain), weather conditions, potential for hostility, and temporal constraints within a particular environment. This is important since the HMI communicates information from the AS to the user. The user and the AS also need to understand the division of labor for a given task or set of tasks, in order to prevent confusion. Therefore, it is important to communicate cues regarding the division of labor and to give clear communication in order to create efficient human-machine cooperation (Lyons, 2013).

Take-over request (TORs) is for example one important aspect that needs to be communicated. In an article about how users can understand their AVs and how one can use HMI principles to solve associated challenges, Carsten and Martens (2019) stated that in a semi-AV (LoA 3), where the user's attention is temporarily not required, the user should always receive a timely warning to take back control to avoid automation surprises. It is also important that the AS informs the user that it cannot cope and why and provide a countdown to the required takeover. This should be communicated by the HMI by using an appropriate level of system transparency.

2.4 Summary and Implications

The literature study assisted in creating a holistic understanding of responsibility related to AS. The different themes with connected keywords created patterns that explained the context and the interaction between these keywords. The context of AS and responsibility became easier to understand when other relevant and necessary parts were addressed, such as for example control and relation.

From the literature review, partial answers have been provided to two of the research questions formulated in *chapter 1.2.1*. The answers are summarized in 2.4.1 and 2.4.2. However, the literature did not provide any input to the overall aim of the thesis project, as this regards how users, themselves, understand their responsibilities. However, the answers have created a firm ground for the following research to build upon.

2.4.1 Factors Influencing Understood Responsibility

The literature review clarified the difficulties associated with assigning responsibility to a machine, in this case the semi-AVs. Artifacts do not (yet) have any moral reasoning, which appears to be a key issue with responsibility allocation. This means that the user is still central in semi-AVs (LoA 3). The question is whether the user is aware and understands the AS's status, limitations and abilities, which is needed to correctly be assigned responsibility. This implies that it is important with good HMC, where the user has a correct understanding of their responsibility, which in turn requires a good interaction between the human and the AS via well designed HMIs.

The most prominent discovery that clearly emerged was the importance of HMC and HMI in semi-AVs, especially in LoA 3. The HMI is a part of HMC, since HMI is an important part to enable cooperation. With that said, HMC should be considered as central, with several of the human aspects involved, therein responsibility and morals. Thus, until the level of automation reaches LoA 4, the user is still crucial. Figure 2.3 shows a scheme of how these factors influencing responsibility are related and linked to each other.

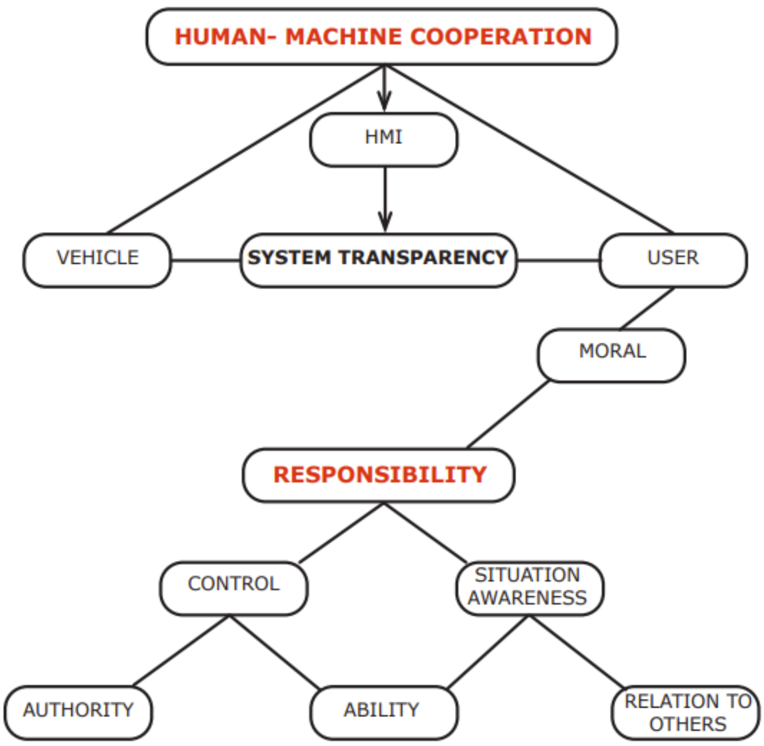

Figure 2.3: Scheme of how responsibility influencing factors are related.

The core concept of responsibility describes the responsibility of the user. Few references mentioned responsibility in connection with machines or vehicles. However, control which is considered to be a part of responsibility, appeared more clearly in relation to both user and AS. This led to the conclusion that control may be shared between user and AS, but responsibility may not. As the concept of responsibility consists of ethical and moral reflections, which are lacking in the AS (at least as of today), the conclusion appears reasonable. This implies that control allocation is an aspect that influences the users' understanding of their responsibilities.

Control allocation itself is not static when it comes to semi-AVs. As semi-automated driving is ever changing cooperation, the control transitions are a vital aspect to consider. This was clearly noted in the literature as well. These control transitions, or TORs, require the user to always act responsible regardless of if the AS is activated or not. In order to do so, the user needs to be aware of the AS's status, limitations and abilities. System transparency is therefore important since it decides how much information that is communicated between the user and the AS. This can in turn help the user create an understanding of how the AS works, as well as being in control and having situational awareness. All these factors are important when understanding responsibility (see figure 2.4).

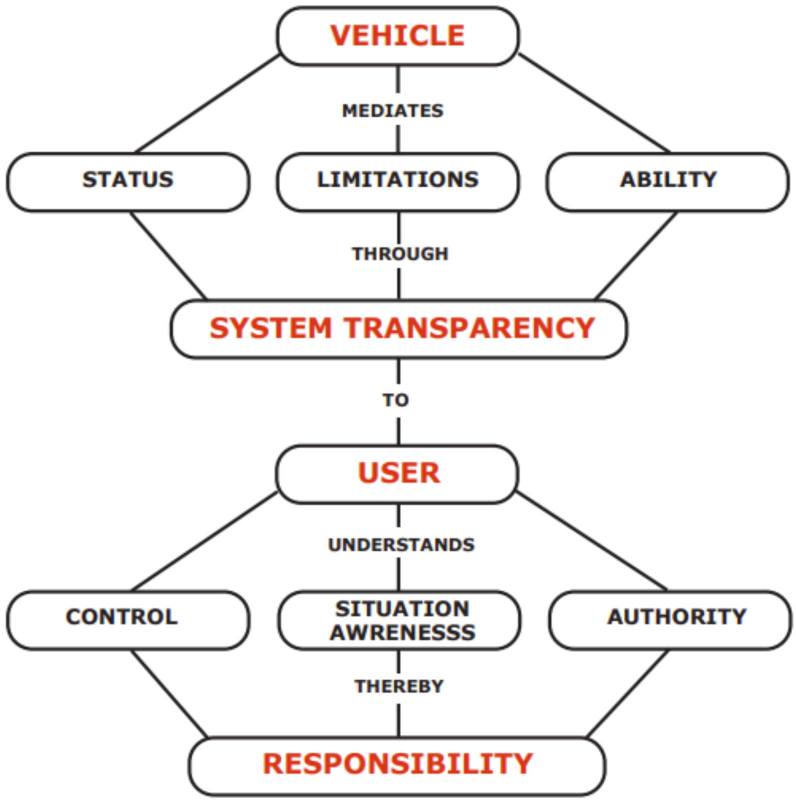

Figure 2.4: Vehicle - user interaction through system transparency

2.4.2 How Should this be Incorporated in the HMI?

In semi-AVs, the cooperation between user and AS entails challenges that can be solved with an appropriate HMI. Since the responsibility is fully assigned to the user (in LoA3), the focus is directed to control allocation and the need for the HMI to clearly communicate the control distribution between the user and the AS.

HMC is defined as having a shared goal, accepted by both user and AS. This goal needs to be clear and understood, in order for the cooperation to be successful, resulting in a singular outcome, accepted by both parts.

According to the literature review, the users' primary responsibility in terms of cooperation lies with a correct use of the AS, i.e., those intended by the designers of the AS and described in the user manual. For this to be possible, the user first needs to have the ability to understand and use the AS adequately. This is where the HMI should be used to facilitate a correct understanding of the AS, and in the end of the constant responsibilities.

Based on the material from the literature review, one can draw the conclusion that responsibility in the context of semi-AV LoA 3 is a non-problem. In this level of automation, responsibility cannot lie with the AS. However, since control is considered to be a part of responsibility, the challenge is more directed towards the distribution of control and that no confusion is created during this cooperation, as this can lead to problems regarding the user's understanding of responsibility. Therefore, the HMI needs to be appropriately designed and communicate the right type of information at the right time, to enable an efficient cooperation between the user and the AS.

2.4.3 Extracted HMC-guidelines from the Literature Review

The following HMC-guidelines have been extracted from the chapter 2, *literature review*.

- The HMI should clarify that the user has the "final" responsibility to act adequately while using a semi-AV
- The HMI should provide adequate system transparency
- The HMI should clarify the shared cooperative goal, AS ↔ user
- The HMI should communicate limitations, AS → user
- The HMI should communicate intentions, AS → user
- The HMI should clarify who is in control, AS ↔ user
- The HMI should clarify who has authority, AS ↔ user
- The HMI should communicate correct information at the right time, in an appropriate form (i.e., feedback)
- The HMI should use multisensory interaction
- The HMI should meet user's existing mental models
- The HMI should keep the user in-the-loop when AS is activated
- The HMI should counteract different automation related misunderstandings
- Minimize information repetition on the vehicles' displays
- Developers should consider how users differ when it comes to their understanding of semi-AVs

2.4.4 Research questions

In terms of the research questions, the literature study contributed in part to answering research question two and question three (figure 2.5). However, the gathered knowledge was vital for even continuing the project. Placing this knowledge into the world of users, the next phase in the project was to answer research question 1. This is described in the next chapter, *User study*.

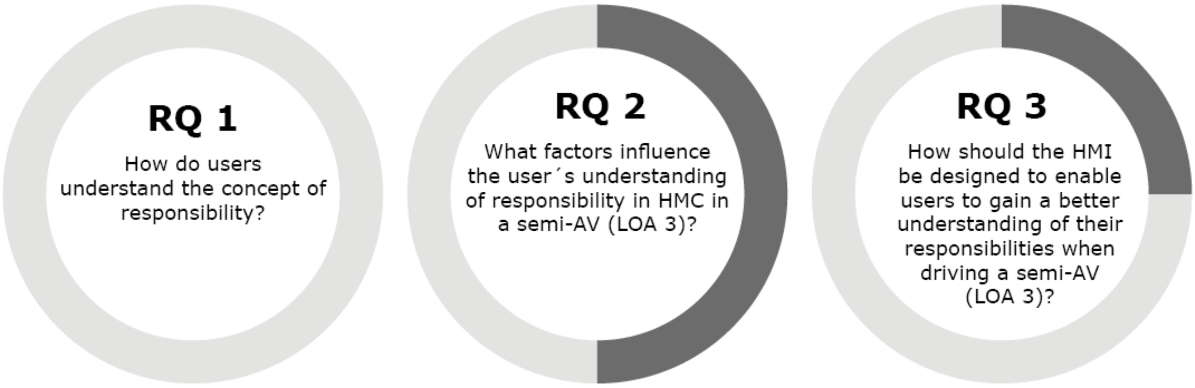

Figure 2.5: Progress towards answering research questions.

3. User Study

With the implications extracted from the literature in mind, users' understanding of responsibility was investigated in a user study.

3.1 Aim

Fundamentally, the user study aimed to answer research question 1; *How do users understand the concept of responsibility?* and to compare the results with findings from the literature. More in particular, the intention was to find out if the users had the same understanding of responsibility, as that proposed in literature, i.e., that responsibility cannot be shared between users and AS. Further, the intention was to see if the users could apply the term responsibility and related terms to the context of a semi-AV, and how this might differ from the interpretations suggested in the literature. The study further intended to investigate if the users would place situation awareness as a central factor, influencing the users’ understanding of responsibility, as the literature did.

3.2 Methods

3.2.1 Scenario Based User Involvement

The method of involving potential users when investigating their expectations of responsibility in semi-AVs focused on scenarios. The scenarios were based on different traffic events, which occurred when driving a manual vehicle and a vehicle with an automated system activated. However, the first step was to clarify how the participants understood the concept of responsibility, wherein relevant terms discovered through the literature were included.

3.2.1.1 Participants

Given that the intended target group involves different types of users, the participants for user study should reflect this variation. Therefore, age, driving experience and gender were relevant factors to consider while choosing the participants.

There were 12 participants in the user study, 5 women and 7 men with an age distribution between 23 and 71 years (mean =42). There were 5 participants who have had a driver's license for 30 years or more while the remaining varied from 3 to 16 years. Driver experience, based on the participants’ own judgment, ranged from medium to high experience; 3 were professional drivers. There were no novice users. The participants' technology interest varied from ‘little’ to ‘highly’ interested in (new) technology.

3.2.2 Procedure

3.2.2.1 Booklet

The first step in the user study consisted of posting an envelope containing instructions as well as two different task bundles - booklets. All participants received the same content. The purpose was to firstly have the participants get familiar with the subject of responsibility and AVs. Sending out the material by mail made it possible for the participant to complete the tasks and familiarize themselves with the material and the subject over a longer period of time, rather than all of it in one seating. Secondly, the booklet task was created to receive an understanding of how the participants understood the constructs relevant to responsibility (*see chapter 2.3.1*); i.e., ability, authority, control, relation and how these were shared (or not) between user and AS.

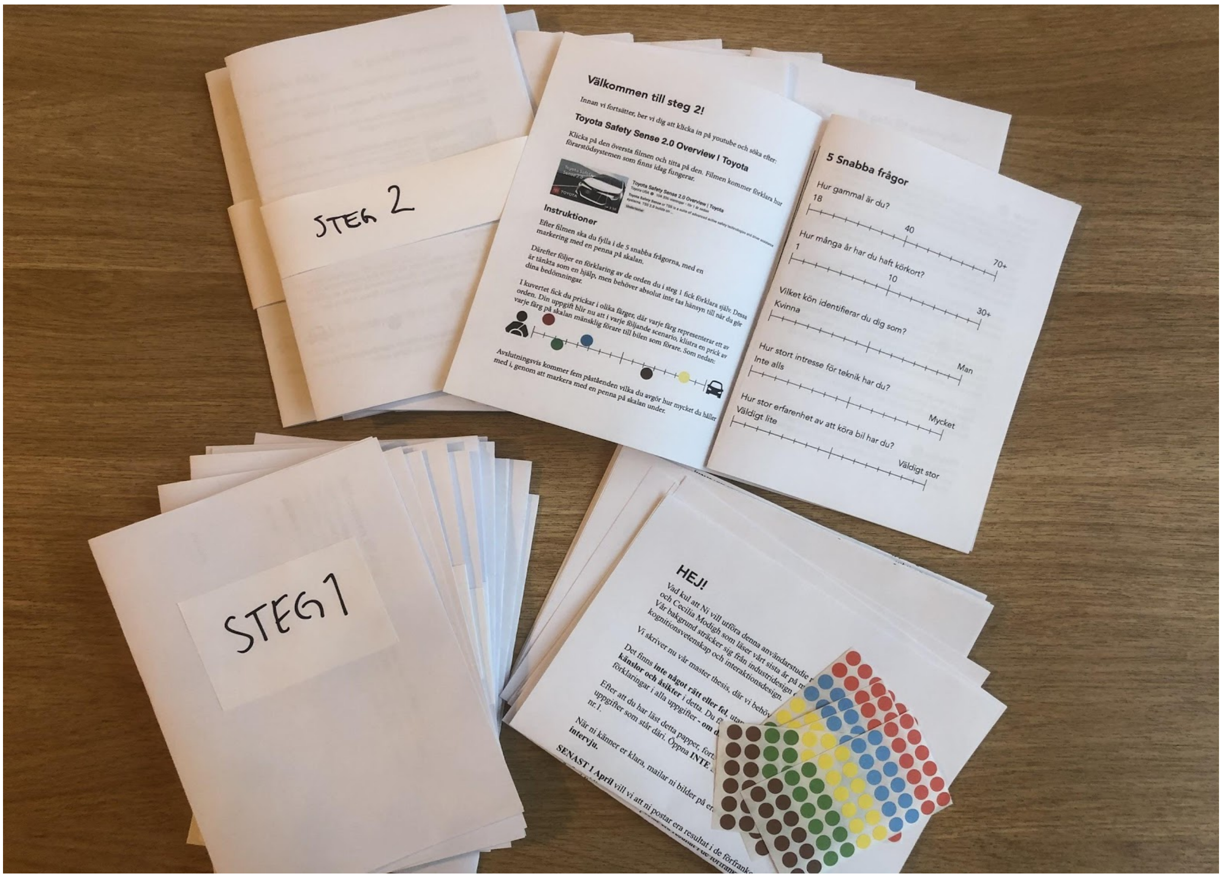

Figure 3.1: Contents of the envelope sent out in the user study.

The instructions made it very clear that step 1 should be conducted first, followed by step 2 only when step 1 was completed. This was done with the intention of giving the participants the possibility to perform step 1 without understanding what the main purpose of the study was.

Step 1 in the envelope contained a piece of paper on which was written the five chosen constructs, i.e., responsibility, ability, authority, control, and relation. The participants' task was to try to define the words based on their own interpretation and understanding. Further, the participants were asked to find pictures representing each of the words. This could be done either by finding a picture on the internet, taking a photograph or by sketching.

In step 2, the participants were asked to go to YouTube and search for the video “Toyota safety sense 2.0 overview in Toyota”. The film explains how automated systems that exist today work. This gave all the participants an introduction to the topic and the necessary information to proceed with step 2.

After the video, the participants were asked to fill in five quick questions; age, gender, how long they have had a driver's license, driving experience, and technology interest. The participants were then given the opportunity to read an explanation of the five words. These explanations were intended as a help, but the participants did not have to take these into account when making their own assessments.

In the booklet, 11 different scenarios were presented, some where the ASs were “activated” but also scenarios without them. The purpose of these scenarios was to show different possible situations that can arise when driving a semi-AV. For each scenario, were included also one or two pictures to facilitate the users’ understanding of the traffic situation. The participants’ task was to use color dots included in the envelope, where each color represented one of the words, and place a dot of each color on the scale; user ↔ AS (see figure 3.2). For example, if the participant believed that responsibility (represented by a red dot) lies on the user, the participant placed the red dot close to the user on the scale.

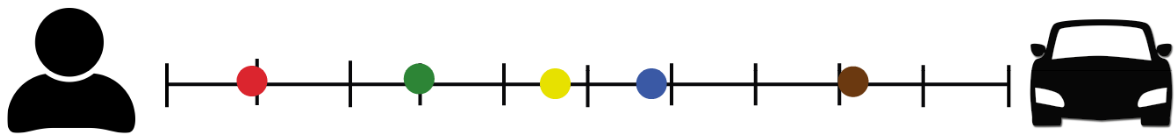

Figure 3.2: The user ↔ AS scale, with color dots as used in the booklet task.

The last task consisted of considering five different Likert statements to which the participants were asked to agree using a 7-step scale ranging from ‘does not agree’– ‘totally agree’ (figure 3.3).

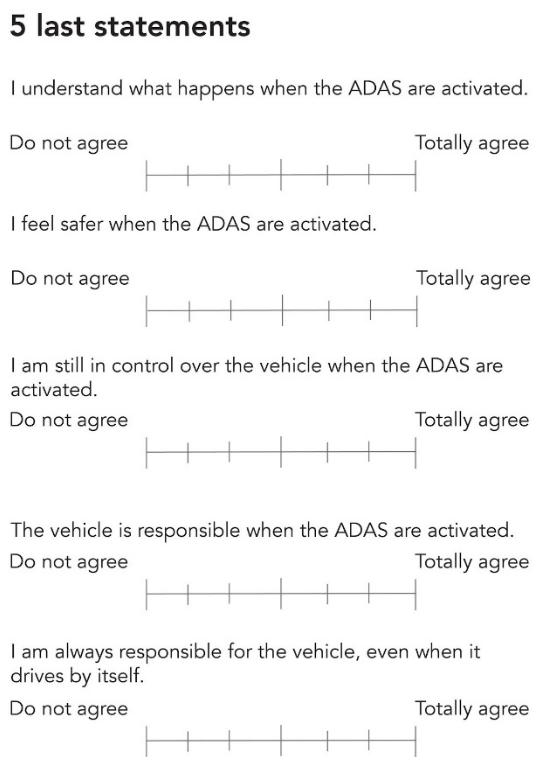

Figure 3.3: The 5 last statements

3.2.2.2 Interviews

After the tasks had been finalized and the material had been collected, interviews with each participant were held. Semi-structured interviews were chosen as a way to gain a deeper understanding of the participants' responses to the two previous tasks. The purpose was to discuss how potential users, as car drivers, understand different scenarios where ASs are involved.

The interviews were conducted via voice calls or face-to-face meetings. The interviewer started by explaining the purpose of the interview and that the focus was on the participants' thoughts, opinions and feelings. This was further emphasized by explaining that there were no right or wrong answers.

The interviewer then informed the participant that he/she was allowed to skip a question or cancel the full interview at any time. Information about anonymity was also explained. Before the interview began, the participant was asked if it was okay to record the sound of the interview. The interviewer followed a script with predetermined questions, but based on the answer of the participant, appropriate follow-up questions were asked.

3.2.2.3 Analysis

The data from the first task, i.e., define words, were collected and compiled by using Google document, one document for each participant in order to organize the information and to prevent errors and confusion. The documents contained all the words, the associated images and the participants' explanations of their choices. These documents were used during the interview in order to be able to ask relevant questions about their choices.

The data from the second task, the five quick questions about age, gender, how long they have had a driver's license, driving experience, and technology interest were summarized and compiled in an Excel sheet. This information, together with the data from the interviews, created the base for the different fictional personas.

All the scenario-based ratings were summarized in one scale for each scenario in order to see all participants' answers at the same time. This created a visual image of how the position of the color dots, according to the participants, differed depending on if the ASs were activated or not.

The results of the five last statements were collected and compiled in an Excel sheet in order to be able to create a diagram of the participants' answers. The diagram shows the five different statements on a scale from 1 (which was the lowest number the participants were able to choose) to 7 (which was the highest number the participants could choose). The participants' responses to the five statements were also used as part of the interview where the participant explained their answers.

All definitions proposed by the participants (as the results of step 1) were compiled in an affinity diagram to organize the different ideas into groups by association (cf. Martin & Hanington 2012). This was done by placing all the definitions on individual sticky notes and then grouping any relations into labelled themes (see figure 3.4). The themes were based on affinity in terms of similar intent, issues, and problems. This method allowed all definitions to be structured into categories, which created a clear overview of the result.

In order to understand more in depth and create an overall picture of the collected material, the interviewers listened to the recorded material after each interview session. Since the two members of the project team interviewed different participants, we divided the work and only listened to those participants we interviewed.

Transcriptions from the recorded material were made directly after the interview session, by writing down the information into a Google document, one for each participant. After that, the material was read through several times in order to get a clear understanding and to find relevant and important parts that created four themes; shared responsibility and control; assisted driving; human vs. technology and system and vehicle limitations. These different themes were then described and examples from the participants provided to enhance understanding.

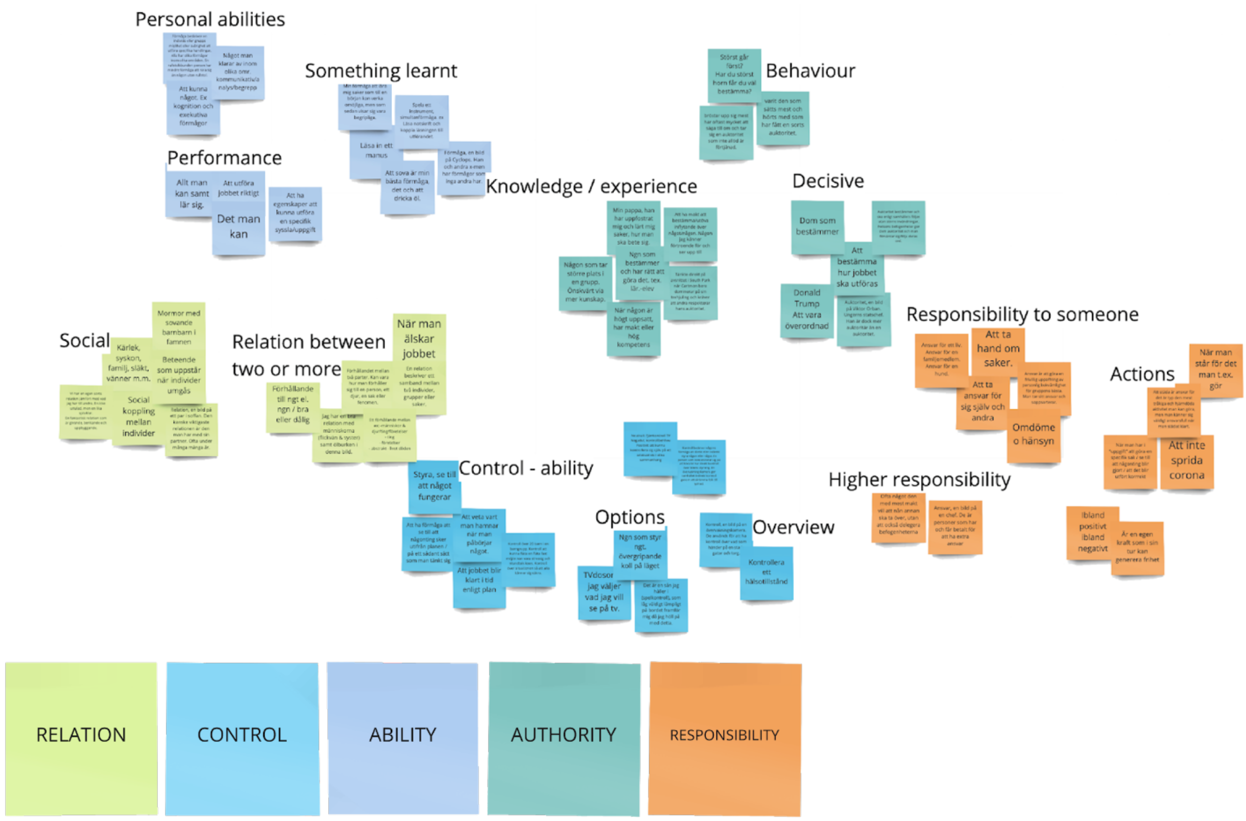

Figure 3.4: Affinity diagram of users' explanation of the words.

The information collected throughout the user study was also the basis for developing three different personas. Persona is a method that helps to understand users' needs, experiences, behaviors and goals by creating fictional characters (cf. Martin & Hanington, 2012). The purpose of this task was to create an understanding of how different types of users, with different traits, understand the concept of responsibility in semi-AVs.

3.3 Results: Responsibility as Understood by the User

3.3.1 Users Understanding of Responsibility Related Concepts and Terms

The result of the first part of the study clarified that there are different interpretations and understandings of what responsibility, and the concepts connected to it, mean. During the interviews, a specific question regarding how these words were connected was asked, and the general answer was that the connection was the user her-/himself, which means that the human has a central role according to users. This could often also be observed in the images the participants chose to attach to the task. The clearest example of this was that one of the participants only sent one image of himself at work (figure 3.5), with the explanation of each word in step 1 as follows:

Responsibility
When you stand for what you e.g. do

Authority
To determine how the job should be executed

Ability
To do the job properly

Control
That the job will be completed on time, according to the plan

Relation
When you love your job

Figure 3.5: Participant 7 sent an image related to the words in step 1. Used with permission.

What this participant shows is that he considers himself being the center of all responsibility related words. Further, he is able to apply all words to the same situation. During the interview, the participant explained that the words are not something he uses regularly, with the exception of the term responsibility. Nevertheless, he felt that he understood the words. This finding is something that can be found in several of the other interviews as well.

3.3.1.1 Responsibility

According to the participants, the key concept of 'responsibility' could be divided into three categories:

- Responsibility to someone, which implies that there is some sort of relationship needed.
- Higher responsibility, meaning that the more power an agent holds, the more responsibilities are assigned.
- Responsibility is something that is applied through actions, which means to act responsible in the actions that are performed, for example to perform a task correctly and to complete it.

Throughout the results from step 1, the participants' explanation always held some aspects that were directly related to humans. This was shown in the images as well, where several of the images showed actions towards other elements (e.g., humans, nature). The actions often revolved around caring for others, such as putting in an effort towards a common goal. Other common images were of people in charge, with one explanation being that *"he gets paid for having the highest responsibility" (ID4).* This implies that responsibility is something important, enough for someone to be rewarded for it.

3.3.1.2 Authority

The participants shared an overall understanding of that 'authority' meant being in charge. However, the participants' further interpretations of, and association with, the term authority differed based on earlier experiences of persons with authority. Those with positive experiences regarded authority as having gained superior knowledge or experiences and should thereby have the power to be decisive. However, if the user had a negative feeling towards authorities, the word was associated with a specific type of behavior.

> *"Damn authoritarian old man" (ID9)*

That is, authority is something gained by exercising a behavior that is superior to others, for example to be seen or heard the most. This kind of behavior is also connected to being decisive, but with feelings of doubt on whether the decisions are right.

> "*Authority - I don't like that. That's why I am a sole trader, there I don't need to be an authority either." (ID8)*

3.3.1.3 Ability

'Ability' was the word of which the users had the most coherent understanding. According to the participants, abilities are personal traits. Those traits are something that is either learned or something that one has been born with. The participants specified these traits as abilities of being able to apply knowledge, or skills in practice. This was also shown in the images that the participants provided. The images varied from showing basic 'skills', such as sleeping or drinking, to abilities that require more practice, such as the ability to paint or play music instruments. Often, all of these images were directly linked to abilities that the participants perceived themselves as mastering.

3.3.1.4 Control

The participants interpreted 'control' in three different ways, which all can be combined. One interpretation was that control offers a form of overview, as in monitoring for example a society or a health condition. A second interpretation was the ability to have control, which is connected with overview as when having control over a situation or a process. For example, making sure a plan proceeds as it is supposed to. Lastly, control was interpreted as having options or having the freedom to choose course of action.

3.3.1.5 Relation

The word 'relation' was the most difficult out of all for the participants to interpret. Yet, a clear distinction between having a relationship and be in relation to something (e.g., size, form) was noted. Having a relationship means a social construct between two or more human beings, such as family or friends. This could sometimes include animals as well. Being in a relation was explained by the relation between two or more parts, such as size, capacity and similar. This could include persons, animals, objects, artifacts and similar.

3.3.2 Users' Expectations of Cooperative Drive

3.3.2.1 Scenario-based Rating

The result of the scenario-based ratings (using colored dots and scales) in the booklet, showed that a majority of the participants saw the human as all-important when in manual drive, that is, the colored dots were most often placed closer to the human than to the vehicle on the scale. This was true for all color dots. In the scenarios where the AS was introduced, the users began to place the dots closer to the vehicle. However, this was not a collective understanding; the dots were placed quite scattered. Again, this applied to all color dots, except the red which represented responsibility. The red dots never moved as far to the vehicle side of the scale as did the other color dots, representing other terms. The scenarios can be seen in figure 3.7-3.11. The color scheme (see figure 3.7) explains the meaning of each color.

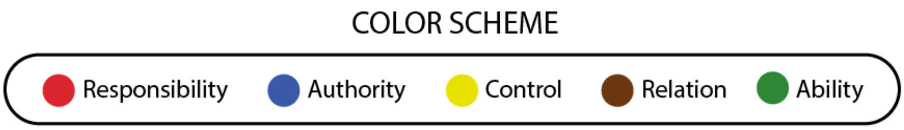

Figure 3.6: Color scheme showing the colors used in the scenario- based ratings and their meanings

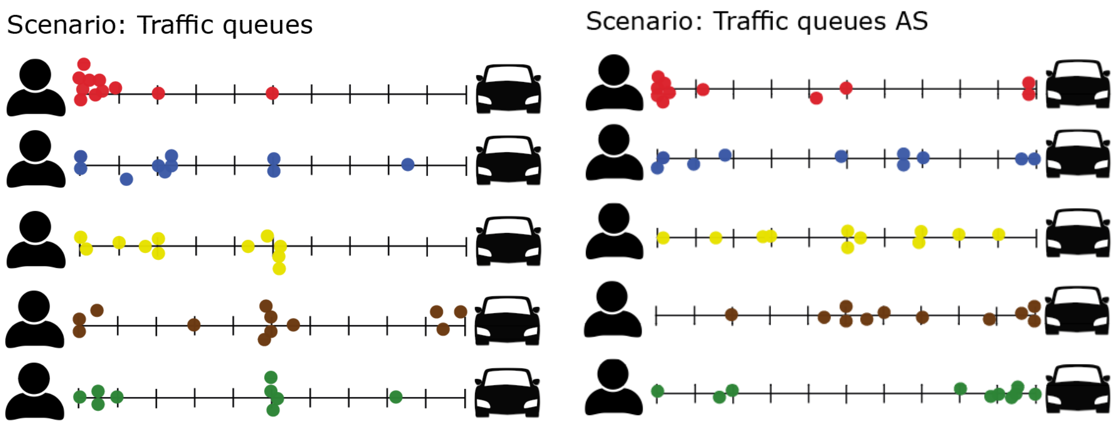

Figure 3.7: The result of the scenario-based ratings (using colored dots and scales) in the booklet. Here the scenarios: traffic queues vs traffic queues with AS activated.

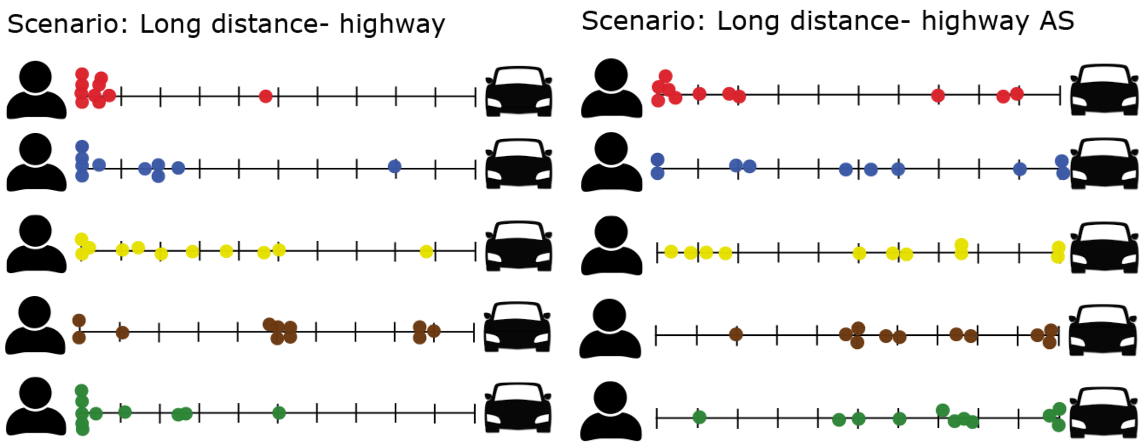

Figure 3.8: The result of the scenario-based ratings (using colored dots and scales) in the booklet. Here the scenarios: long-distance-highway vs long distance-highway with AS activated.

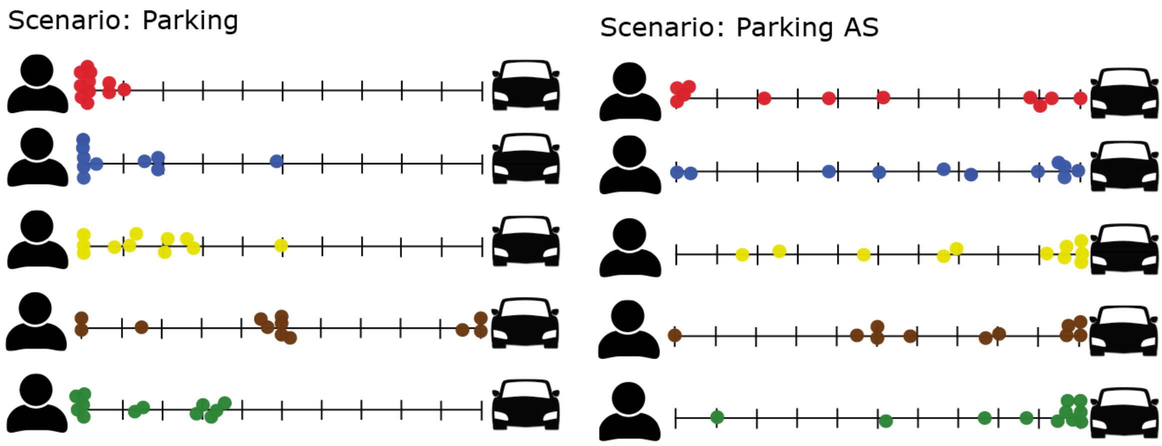

Figure 3.9: The result of the scenario-based ratings (using colored dots and scales) in the booklet. Here the scenarios: parking vs parking with AS activated.

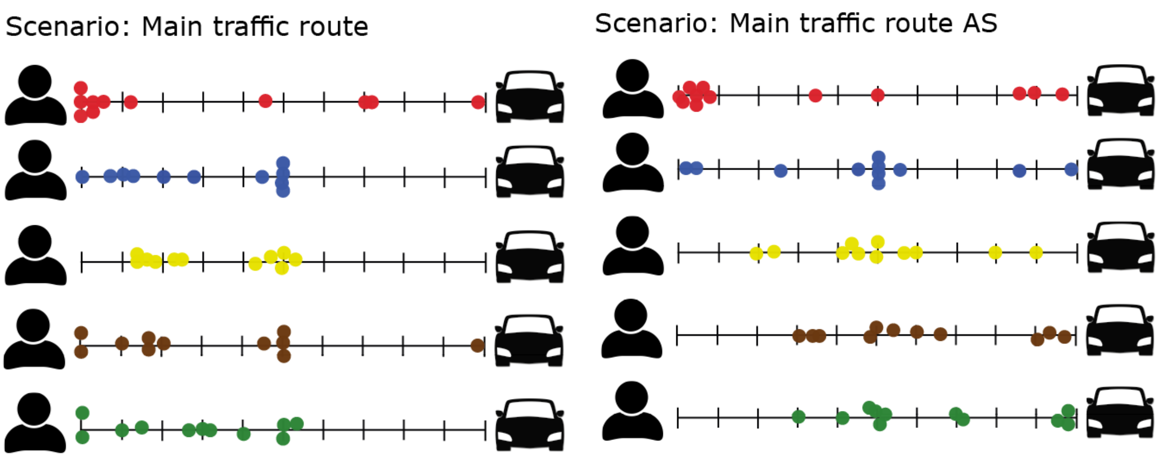

Figure 3.10: The result of the scenario-based ratings (using colored dots and scales) in the booklet. Here the scenarios: main traffic route vs main traffic route with AS activated.

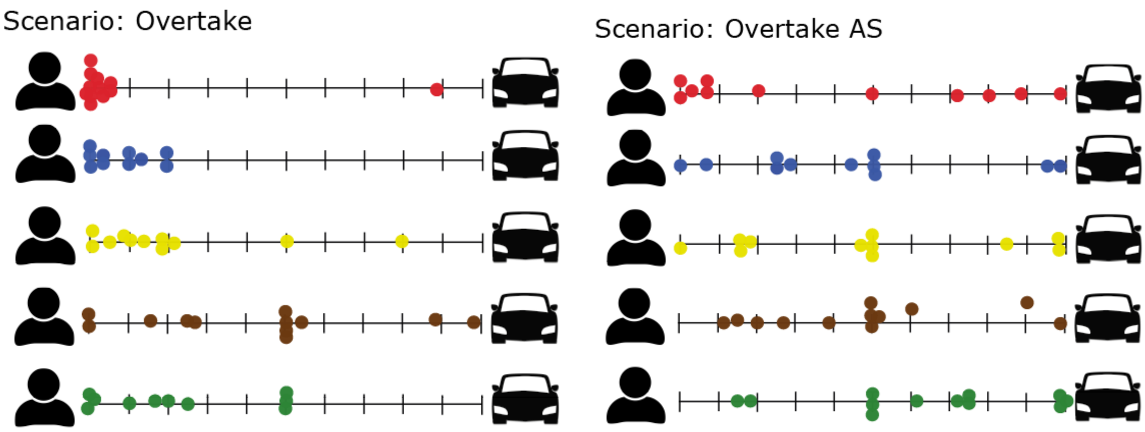

Figure 3.11: The result of the scenario-based ratings (using colored dots and scales) in the booklet. Here the scenarios: overtake vs overtake with AS activated.

3.3.2.2 Interviews

The task which involved placing colored dots on a scale was an introduction to a discussion of AS and in which traffic situation it might be used. This probing did, however, lead into interviews with the participants that raised the issue of expectations regarding sharing responsibility in semi-AVs. Some examples of users' expectations can be seen in figure 3.12.

"I would feel more secure when using a lane trace assist because when driving a long distance, it can easily be that you lose focus or think of something else. Then it feels good that this function exists and has a little control."

"When using an adaptive cruise control you do not have to constantly focus on the speed which is more comfortable."

"If the police stop me for speeding when the adaptive cruise control is activated, it is still my responsibility to keep track of the fact that I drive according to the law. So it is my responsibility as a driver, but I would not be happy about it."

"As a driver, you hand over control to the car, but not the responsibility."

"If the car makes an obvious mistake when the systems are activated, I would have been quite surprised and blamed the mistake on the system and on the car company."

"I trust the technology but I have the command."

"A major reason why you cannot feel safer with these systems is that they only assist you as a driver. Another reason is how drivers behave towards each other. The human factor is the big reason for not feeling safer despite the systems."

"Responsibility lies on the driver regardless of activated ADAS. You cannot trust the technology as it is today."

" I trust technology more than human ability. The technology is not affected by emotions, stress, hearing defects, surroundings etc."

" I don't feel safer using ADAS right now, maybe in the long run when you have used it more."

"I believe it is important that all these driver systems are connected to the car's capacity."

"I probably should read the manual first because I have a responsibility to know how everything works and understand the limitations of a system. But I probably hadn't taken that responsibility."

Figure 3.12: Randomly selected quotes gathered from all participants in the user study.

Shared Responsibility and Control

The most prominent result of the user study was that the **participants expected to always feel responsible for the vehicle**, regardless of whether the AS was activated or not. This was evident from the way the dotted scales were placed in the booklet, as well as from statements made in the interviews.

> *"Responsibility lies on the driver regardless of whether the systems are activated. You cannot trust the technology as it is today." (ID2)*

The same result can be concluded based on the participants' answers to the Likert statements (shown in figure 3.13). However, the study also indicated that the participants (as future users of AVs) expected to share control, rather than responsibility, with the AS although with the need of always being able to override the AS. This was explained in the interviews by some users with experience of using cruise control which allows shared longitudinal speed control.

> *"As a driver, you hand over control to the car, but not the responsibility." (ID3)*

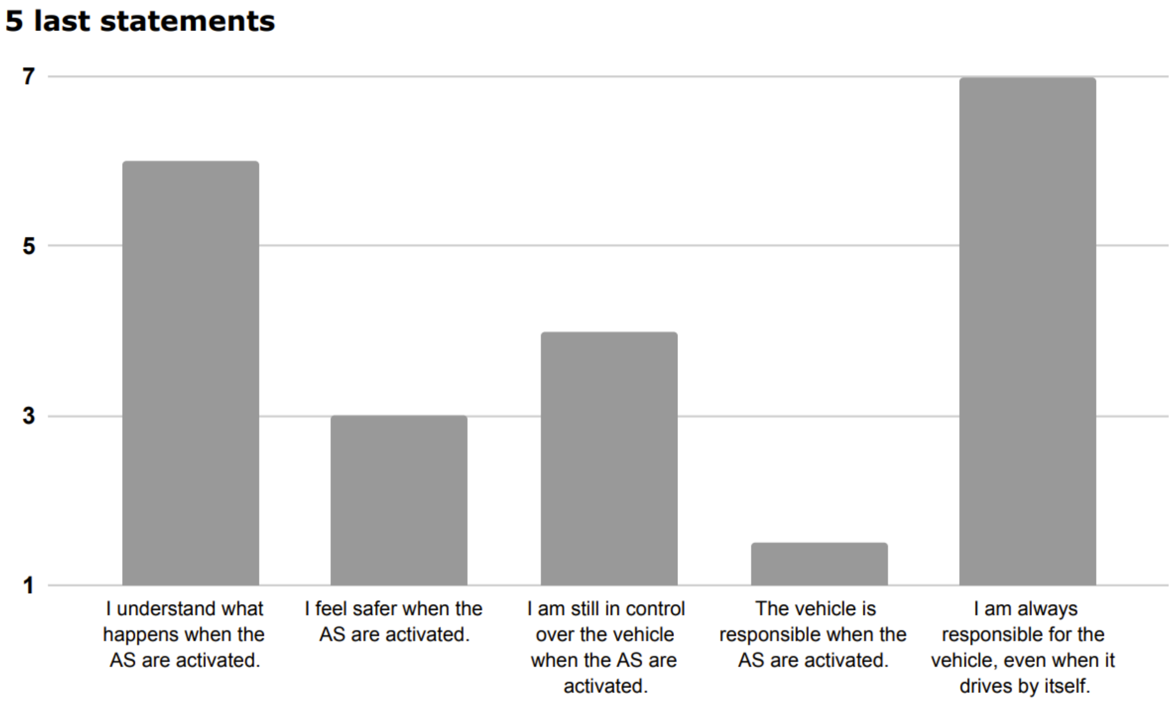

Figure 3. 13: User's expectations as reflected in their responses to the "5 last statements".

Assisted Driving

According to the interviews, the participants had developed a reasonable understanding of AS based on the explanations provided by the YouTube video, although they had no real-life experience. The participants gave some mixed responses to whether the feeling of being safe increased with AS activated or not. One participant explained that:

"I would feel more secure when using a Lane Tracing Assist. Because when driving a long distance, it can easily be that you lose focus or think of something else and then it feels good that this function is there and has a little control." (ID4)

Others explained that as these systems only assist, the feeling of being safe should not increase. The remaining human factor was also mentioned as a reason for why the safety feeling did not increase even though the AS was activated, because it is still difficult to trust other road users in the traffic. It appeared as though an increasing feeling of being safe did not imply a feeling of being less responsible.

Human vs. Technology

During the interviews, a discussion regarding human vs. technology arose. A majority of the interviewees gave similar explanations to why the human should always be responsible over technology and not the other way around; according to the users, technology does have a tendency to fail.

"You can never hand over responsibility to the system. Humans are always lord over technology, something technical always tends to fail." (ID5)

"Responsibility lies on the driver regardless of activated AS. You cannot trust the technology as it is today." (ID2)

A minority of the users did, however, expect to have more faith in technology than in human abilities in the future, when AVs are fully developed.

"I trust technology more than human ability. The technology is not affected by emotions, stress, hearing defects, surroundings etc." (ID9)

Yet, the users did not expect this resulting in handing over any of the responsibility to technology, not in the near future at least.

System and Vehicle Limitations

Through the interviews it appeared that it was important for the users to understand the limitations of the AS, in order to feel safe enough to share control. However, this did not affect the understanding of (not) sharing responsibility.

In manual drive, the more experienced users had an understanding of what the vehicle is capable of. This means that the user is aware of the vehicle's limitations and acts according to those. This applies to the users' understanding the functionality and limitations of the AS. The participants, as future users, expected to be aware of how to cooperate with the AS, in order to keep driving in a responsible way.

"There was one time with one of the company vans, equipped with an emergency brake system. In order to overtake trailers, you had to speed up just right behind before changing

lanes. Due to high weight and low capacity. Just as you got close enough to execute the overtake - the emergency brake system was triggered." (ID7)

One way of knowing the limitations of the AS and vehicle itself, is to read the user manual. However, a majority of the users did not even consider looking at any manual, even though this probably should be considered as a responsibility. Instead, the users expected to just test the AS and learn over time.

"I probably should read the manual first, because I have a responsibility to know how everything works and understand the limitations of the system. But I probably haven't taken that responsibility." (ID3)

3.3.3 Personas

The user study resulted in three fictional personas with the purpose to describe different types of users. It was apparent in the interviews that there are several different internal traits that influence the aspects that are related to responsibility. Based on the results from the five last statements and the interviews these aspects were interpreted and resulted in the creation of three different personas.

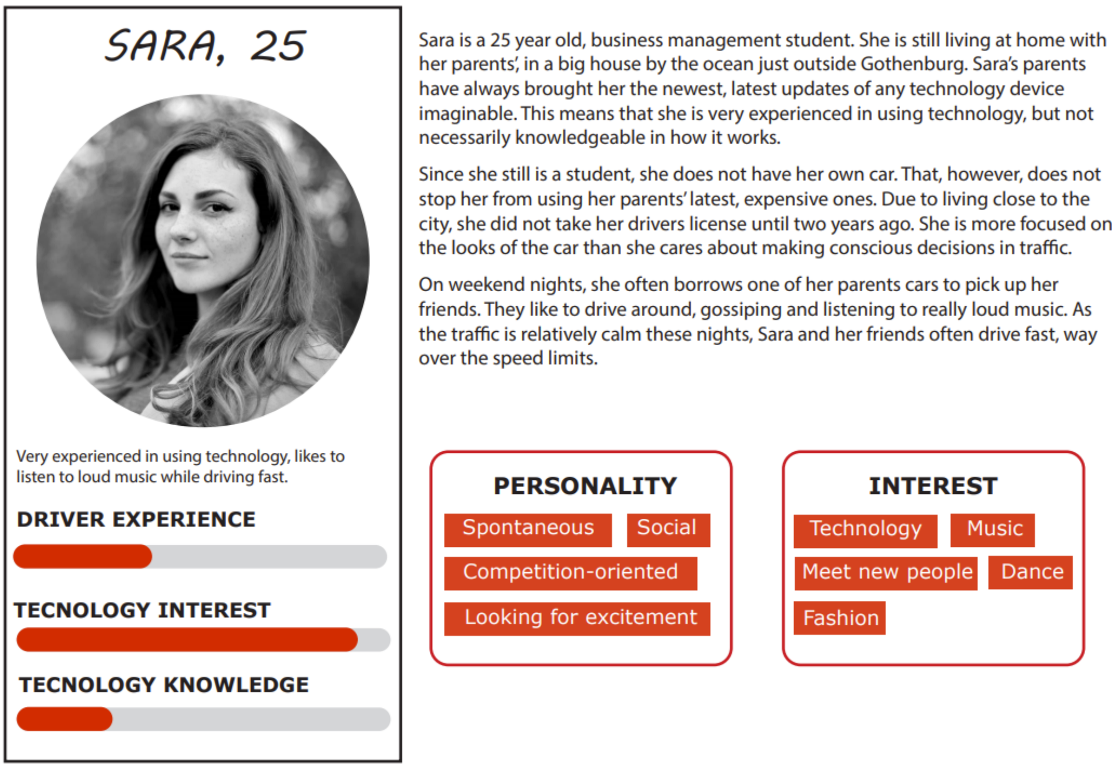

Figure 3.14: Persona Sara, 25

BILL, 42

Tech. nerd, parent with 2 children in the rear seat, tries to drive as safely as possible

DRIVER EXPERIENCE

TECNOLOGY INTEREST

TECNOLOGY KNOWLEDGE

Bill is a 42 year old father of two. He lives with his two children, toddlers, in a house just outside the city center of Gothenburg. Bill has a big technology interest and is always first in the neighborhood with the newest home alarm system updates and robotic lawn mowers. Bill also has invested in a decent drone, which he uses almost every weekend.

Bill works in telecommunication, has a flexible time schedule, and an office in the central of Gothenburg. Every morning, Bill takes his big, new car and leaves his children at the kindergarten and continues on to work. He tries to leave earlier than everyone else, in order to avoid the worst traffic situations. However, as life with toddlers, this rarely happens. The usual morning routine is often delayed, meaning that Bill and his children get stuck in traffic jams on their way to kindergarten.

Bill has very little driving experience, except for in the city. This makes him take safe, conscious decisions instead of speeding through traffic, especially when his children are in the car. However, he often attaches his caravan to his car in the summer, and takes his children with him on shorter trips to nearby coastal campings. This way, he gets the chance to use all AS, which is rarely possible in city traffic. He thinks that these systems help him to drive safely, while still being able to have some attention towards his children in the rear seat.

PERSONALITY

Flexibel, Curious, Creative, Social, Likes to plan

INTEREST

Technology, Travel, Meet new people, Camp, Sport

Figure 3.15: Persona Bill, 42

TOM, 73

Tom is not so interested/knowledgeable in technology, but a highly experienced driver, professional

DRIVER EXPERIENCE

TECNOLOGY INTEREST

TECNOLOGY KNOWLEDGE

Tom is a 73 year old, retired bus driver. He lives with his wife Lotta and his dog, a German shepherd, in Gothenburg, Sweden. Tom and Lotta share an old car, with no driver assistance systems other than power steering and anti-lock braking system.

Tom is a highly experienced driver, as he has been driving both cars and busses for nearly half a century. He describes his experience as being shown through how he perceives the traffic situation. He assesses where surrounding vehicles will head, just by observing their motion behavior. Tom often gets irritated with all younger road users behaving unreasonable.

Since Tom's wife has not yet retired, they still live in the city. However, they try to spend as much time as possible at their summerhouse by the sea in Varberg. The journey is often done every weekend by car on mainly highways. Lotta has suggested that they invest in a newer car, with systems that could help them drive, as they are both getting older.

Tom consistently refuses, as their old car still fills its purpose. Neither does Tom believe that he needs any driver assistance, he is as good a driver as he always has been. Lotta, however, knows that the reluctance to the newer cars actually comes from his lack of knowledge and skills with technologies.

PERSONALITY

Laid-back, Likes to plan, Orderly

INTEREST

Reading, Travel, Dogs, Music

Figure 3.16: Persona Tom, 73

3.4 Discussion and Implications

There are several similarities between the users' understanding of responsibility, and the definitions found in ethics and literature.

3.4.1 How Users Understand the Construct of Responsibility

By letting the respondents first define the words used in the booklet task, any doubts of different interpretations regarding the meanings of the words could be removed. Through this task, it was apparent that the words could be and were interpreted differently. However, the aspect that responsibility cannot be shared was not clearly noted when the participants explained the words. This only provided information of how participants regarded themselves as somehow included in the concept of responsibility itself.

It was first when responsibility was placed in the context of semi-AVs that the participants clearly stated that they did not expect to share **responsibilities**. Even though discussions revolved around developers' possibilities of being assigned some of the responsibilities, all of the discussion ended up with deciding that this aspect did not affect the conclusion that the user is responsibility when using the AS. Neither did the participants' explanations of **control** hold any clues to the possibilities of being shared, until it was set into the context of semi-AVs.

The participants' interpretation of **authority**, which according to literature is something that decides the final control allocation, appears to be connected to earlier experiences with authoritarian persons. That is, for some of the participants the word had a negative ring to it. This negative interpretation of authority emphasizes that one must be careful in one's choice of words when discussing task allocation in cooperative drive.

The participants regarded **ability** as something personal, an internal factor that differs between different users. Ability was considered to be closely connected to experiences, understanding and skills. Ability was also considered as being able to make use of these things. Thus, enhancing the ability of the user in terms of driving semi-AVs could improve the overall HMC.

The participants struggled with the word **relation**, but during the interviews the two themes of a social construct and be in relation to something (e.g., size; shape) emerged. Being in a relationship with someone could, according to the participants, also include the AS. Thus, having a good relationship with the AS implies having good knowledge about the AS's functions, intentions and limitations - just as in a relationship with another person. This could further be applied in the concept of HMC, where user and AV need to have a good relation with the other.

Concluding the user study, the most prominent result was that **the user expects to still have the overall responsibility when using semi-AVs**. **The user did, however, consider control**

to be shared with the AS, as long as it was possible to override the AS. This implies a need for the user to always have the authority, to be able to cancel the AS's decisions or actions. This aspect is important, and also considered in the NHTSA guidelines (NHTSA, 2018). This need for complete authority, however, goes against the notion of never assigning the authority to one part in a cooperation as was concluded from the literature review. Further, it is possible that this need for authority describes the need of feeling in control rather than a need to be the decision maker.

Overall, the participants' understanding of the core concept of responsibility did match the literature. Even though the morality aspect was not mentioned by the participants, it was nevertheless underlying their responses regarding themselves as solely responsible.

3.4.2 Scenario-based User Study

The result of the scenario-based user study implies that future, possible users expect to share control with the vehicle, but not responsibility. Even though the red 'responsibility' dots in step two of the user study (see figures 3.7-3.11), began to move towards the vehicle in the AS's scenarios, the interviews made it clear that the majority did not expect to actually share responsibility with the AS.

The dots representing the other words that users were asked to apply in the booklet (i.e., ability, authority, relation) were moved more towards the vehicle end of the user-vehicle scale when introducing ASs. This was due to the users expecting to share some of the workload with the AS.

Several participants found it difficult to place the word 'relation' on the scale due to not understanding why the word was included in the task. The word relation could therefore be difficult to interpret in the context of AS, which explains the uncertainty that emerged. However, no one had trouble understanding the meaning of the word itself.

3.4.2.1 Factors Influencing Users Understanding of Responsibility

Internal Factors

When introducing the AS in the same scenarios as the ones with manual drive, a pattern was clearly noted, that of a move of the dots towards the vehicle but also that the placements were scattered across the scale. This applied to all words, except responsibility. This distribution of dots can be interpreted as though expectations or understanding vary among the users.

This could depend on users' internal factors, i.e., personal traits, such as driver experience, technology interest and future beliefs. This implies that there are difficulties in creating an interaction that brings the same understanding of responsibility to all, different users. Further, this scattered distribution of dots could also imply that not all future users have enough trust in or accept semi-AVs, explained by the same internal factors as mentioned earlier.

The results of the AS scenarios may also be due to the users' understanding of the AS itself. This understanding was mainly created by a YouTube-video *(Toyota Safety Sense 2.0 Overview, Toyota*), which explained the different systems in English. If the users did not grasp the explanations, then the task was not performed as was intended.

Vehicle Related Factors

Since the user-study was scenario-based with images, the participants were unable to test and experience the AS properly in real-life. Thus, neither any interaction nor the features of the AS could be measured or tested. The participants therefore had to respond based on their expectations of the systems.

Several of the participants had no experience of using these ASs, which made it difficult for them to respond to whether they would feel safer when these systems were activated. To find out, they explained that they needed to use the system and thus they could not give a definitive answer. However, several did explain that the continued involvement of humans in driving would not eliminate human errors, making it hard to increase the feeling of safety.

The limitations of the AS are important for the user to understand, not only as this will affect trust which influences users' understanding of appropriate responsibilities, i.e., the responsibilities that the user is expected to take, which is based on how the user should use the AS according to the user manual. It also affects the cooperation between the user and the AS, foremost in control transitions. If the user is aware of the limitations of the AS, the user might be able to prepare for take over before receiving any information and the transitions become smoother. Thus, having a good relationship is important.

Furthermore, a poor understanding of the limitations in the AS might put even the most experienced driver at the same level as a novice. Thus, there is a need for mutual understanding of all limitations in the communication between human and "machine" (the HMC). This could be tackled by having an accurate level of system transparency, which determines how much or how little information that is presented in the user interface.

Throughout the user study, knowledge and understanding were central aspects discussed. As the participants clearly stated that they remain responsible for the vehicle, even with activated ASs, they required the ability to override the system and thus regain control of the vehicle if needed.

From a design perspective, the most discussed aspects regarding driving semi-AVs can been summarized into three design-related questions:

1. *How do we (as designers) make users feel certain so that they can regain control easily?*
2. *How do we (as designers) get users to understand the limitations of the AS?*
3. *How do we (as designers) prevent compromising with the user's understanding of constant responsibility?*

Based on the results of the user study, it is clear that the users do not intend to share responsibility, regardless of whether the AS is activated or not. Therefore, it is important that the HMC does not compromise with this understanding. However, the factors related to responsibility (i.e., control etc.) may indeed be shared between user and AS. Hence, the design challenge concerns the cooperation between the user and AS, to clarify who is in control and to communicate this in an efficient, appropriate and safe way, that does not create a conflict with the users' understanding of being responsible while using a semi-AV.

3.4.3 Extracted HMC-guidelines from User Study

The following HMC-guidelines have been extracted from chapter 3, *User Study*.

- The HMI should not compromise with the users' expectations of always having responsibility when driving a semi-AV (LOA 3)
- The HMI should provide adequate system transparency
- The HMI should communicate limitations, AS → user
- The HMI should clarify that the user can always override the AS
- The HMI should clarify who is in control, AS ↔ user
- The HMI should clarify who has authority, AS ↔ user
- The HMI should keep the user in-the-loop when AS is activated
- The AS should facilitate workload sharing
- The vehicle should enable system adaptation for different types of users
- Enhance the users' understanding by incorporate training possibilities
- Developers should consider how users differ when it comes to their understandings of semi-AVs

3.4.4 Research Questions

The user study answered RQ 1, as well as added to RQ 2 (figure 3.17). It also contributed to the main aim of finding out about users' understanding of responsibility. However, RQ3 still requires more answers. In order to be able to answer RQ 3, more knowledge on HMI aspects was needed. Therefore, the knowledge gained was kept in mind while carrying out a small benchmark, testing and evaluating two different vehicles, conducting interviews with car sales representatives, locomotive and aircraft pilots, and running a workshop with three developers from Toyota Motor Europe. This is described in the next chapter, *4. Searching for inspiration*.

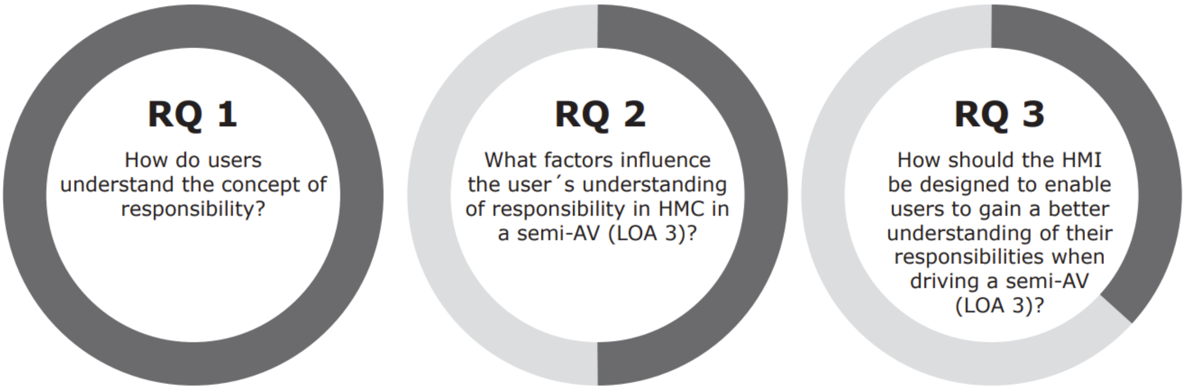

Figure 3.17: Progress towards answering the research questions after the user study.

4. Searching for Inspiration

4.1 Aim

This part of the project aimed to seek inspiration regarding HMC with focus on the design of HMI in vehicles with AS. Alongside this, the need to understand how users of other automated systems understand responsibility allocations emerged. Therefore, a small benchmark study, interviews with car sales representatives as well as locomotive and aircraft pilots and a workshop with developers from Toyota Motor Europe were conducted.

4.2 Method

4.2.1 Benchmark

The benchmark included the two members of the project team, making self-observations of driving cars during which the project members acted as users, and then used NHTSA guidelines to evaluate the HMI regarding the for responsibility relevant aspects extracted from chapter 3. This was followed by interviews with persons who should have insights into different ASs, such as car sales representatives, two locomotive pilots and one aircraft pilot.

The observations were made in two different vehicles. The evaluated vehicles were **Toyota RAV 4** and **BMW X6**. The selected vehicles were those with the latest ASs, relative to other vehicles of the same brands. The aspects that have been considered are the different ASs used in SAE LoA2 AVs, how information on these systems is communicated and how this differs between manufacturers.

In order to enable a comparison of how the ASs were understood by the user, guidelines from NHTSA (see table 4.1) relevant to responsibility were used (Campbell et al., 2018) such as *"The automation does not let the user adapt bad patterns such as paying attention somewhere else than the road", "A message that confirms the control transfer to the user, or if failed attempt"* and "*The user receives correct information on when to take over control."* The ASs were evaluated by the two members of the project team giving a rating of 1 to 5 on each of the chosen criteria. A rating 1 meant that the guideline was judged as not fulfilled and a rating 5 meant that the guideline was completely fulfilled. In other words, how good or bad the vehicles' AS lived up to the guidelines. The points were distributed individually so that the two members of the project team would not influence each other. The results were then compared and summed up into one value.

This evaluation was necessary to see the differences in how the different vehicles communicate information regarding the AS, through the HMI. Further, this was an aid in understanding if any of these interactions influenced the way responsibility was understood.

Adaptive Cruise Control (ACC) and Lane Tracing Assist (LTA) were evaluated especially, as these included more interaction moments. There are, however, several other safety systems included in ASs, such as for example Pre-Collision Systems, which are hard to evaluate without staging an incident.

4.2.2 Complementary Interviews

In order to broaden the perspectives when it comes to the user's responsibility in the context of semi-AV, interviews were conducted with car sales representatives, as well as locomotive and aircraft pilots. The particular purpose for doing these interviews was to extract information around how ASs could be used in different settings and how these users understood the ASs.

4.2.2.1 Car Sales Representatives

Quick, non-structured, interviews were held with two car sales representatives, where they were asked to explain the most advanced AS of their particular brand. This was done in different vehicle stores and each interview lasted approximately 10 minutes. Representatives from BMW and Toyota were interviewed. The questions can be found in appendix E.

4.2.2.2 Locomotive Pilot

Nine questions were sent out via email to two locomotive pilots. The first questions were about the ASs in the train and how these interact with the pilot. The remaining questions regarded how the pilots experienced and perceived their role as drivers, focusing on the ability to let go of control, being responsible and the similarities of driving a car. The questions can be found in appendix F.

4.2.2.3 Aircraft Pilot

When considering other vehicles with high automation, the most prominent one is aircrafts with their autopilot system. To get an insight into how aircraft pilots understand their assigned responsibility when operating the plane, 12 questions were emailed to a pilot flying mainly passenger airplanes. The questions addressed the different types of ASs, how information was presented and responsibility allocation. All questions can be found in appendix G.

4.2.3 Workshop

A workshop was arranged with the purpose to find ideas, hints or guidelines that could help facilitate the user's understanding of responsibility while driving semi-AV (LoA 3). The main focus was to solve problems that seem to occur in the cooperation between the user and the AS and how an HMI can be designed to affect the users' understanding of responsibility. The participants in the workshop were three developers from Toyota Motor Europe, working with semi-AV.

The methods and tools used during the workshop were personas, brainstorming sessions and PNI. The programs used were Skype for Business and Miro. Miro was a new program for all participants, however, an opportunity of testing it before the workshop was given.

About a week before the workshop, the participants received an email with an invitation containing information about the workshop, its purpose, and what programs were to be used. With this invitation email, the three participants also received a digital version of the booklet that was used in the user study, although translated to English, as homework to be finished before the workshop. The day before the workshop, all participants received another email with more detailed instructions of the workshop. This gave them a chance to prepare, as well as facilitated the process of the workshop itself.

The workshop itself consisted of four parts, where the first part began with discussing the homework that all had completed. The purpose of this task was to get a deeper understanding of the answers received on the five last statements of the homework, as well as starting a discussion around the subject.

The goal of the second part was to create an understanding of what type of users that had been noticed through the earlier conducted user study by assigning quotes, extracted from earlier interviews with users (chapter 3.3.2, figure 3.12), to the three different personas that were created in chapter 3.3.3.

The third task consisted of three shorter brainstorming sessions where each session was based on one of three questions. The three questions were:

1. *How do we make users feel certain so that they can regain control easily?*
2. *How do we get users to understand the limitations of the AS?*
3. *How do we prevent compromising with the user's understanding of constant responsibility?*

These questions were selected as they had played a central role in the discussions in the user study, as well as summarizing the problems associated with vehicles with a LoA 3. The participants' task was to brainstorm different thoughts, ideas, and solutions around these problems. The time was set to seven minutes on each question. After each session, a brief discussion followed where all participants were allowed to share their thoughts.

The final task of the workshop was to create a PNI matrix, which is a method to identify positive (=P), negative (=N) and interesting (=I) aspects regarding an idea. All participants collectively chose the three most promising ideas from the third part of the workshop, and discussed positive, negative and interesting qualities with each. The purpose was to consider the idea from different perspectives, as well as being able to compare them.

4.3 Results of Inspiration Activities

4.3.1 Benchmarking Findings

During the observations in the benchmarking, it was clearly noted that the interface design used in ASs differ between the different car brands.

In both test vehicles, the user was able to release control over the pedals and steering wheel. The only requirement was lightly touching the steering wheel (figure 4.1) for the vehicle to acknowledge the user still aware of the situation.

Figure 4.1: Only applying a small touch to the steering wheel to acknowledge the vehicle.

The results of the evaluation can be found in Table 4.1, which shows that BMW X6 scored a total of 59 points while Toyota Rav 4 scored 42 points. The most considerable differences in this evaluation appeared to be in the transition modes, i.e., when the AS is activated and when the AS fails, requiring the user to take over.

Table 4.1: NHTSA Guidelines- most relevant to the thesis field of research (I= BMW X6; II= Toyota Rav 4)

NHTSA GUIDELINES	SCORE (1-5)	
	I	**II**
The automation does not let the user adapt bad patterns such as paying attention somewhere else than the road.	4	4
The allocation of functions, while in automated mode are visually clear.	5	2
A visual indication of any active automation mode.	5	2
A visual indication of an emerging transition in automation, or in near future.	4	2
A message that confirms the control transfer to the user, or if failed attempt.	5	2
Automation requests are confirmed only directly when activated, to prevent the user from handing over the control with no active automation.	5	3
The user receives correct information on when to take over control.	5	3
The user receives information on how or which control to take over.	4	2
‘Take control’ messages are multimodal.	4	4
Information from the collision avoidance systems is given to the user.	3	2
The user can easily override the activated automation functions.	5	4
Multimodal communications.	4	4

HUD information is interpretable without any other visual information.	5	4
The level of warnings is indicated with correct use of colors.	5	4
TOTAL POINTS	**59**	**42**

The evaluation based on NHTSA guidelines resulted in the BMW X6 scoring higher points than Toyota RAV 4. In the following sections, the different aspects of the HMI that led up to this result are explained.

4.3.1.1 Displaying Active AS

The dashboard behind the steering wheel in the BMW was completely digital (figure 4.2). This gave opportunities to display information using the entire screen.

Figure 4.2: Head-down display, BMW X6.

The Head-down display on the BMW always confirmed that the AS was active with large, green symbols that stood for active ACC and active LTA. The Toyota, on the other hand, had two analog meters with information about power, gas and motor temperature and as well a digital screen in-between the meters (figure 4.3).

Figure 4.3: Head-down display, Toyota.

Toyota confirmed the active AS by showing symbols in the upper left corner of the digital display in the HDD. However, these symbols did not disappear when the system was disabled, but merely changed color to white.

4.3.1.2 Displaying the Active Safety View

The placement of the vehicle in the lane can in most vehicles be seen, displayed in the center of the dashboard.

In BMW X6, the display showed the complete traffic situation, i.e., the vehicle itself, the road with different lanes and all moving objects around the vehicle. The objects are shown as cars or trucks, and the system could even differentiate trailers (figure 4.4). This meant high system transparency, since the interface displayed much information about the user's own vehicle and the surrounding vehicles. However, this display held very much the same information that the user received by looking out through the windows at the real traffic situation, as well as by observing the blind spot monitors in the side mirrors (figure 4.5).

Figure 4.4: BMW X6’s traffic situation display. Figure 4.5: Blind spot indicator

In Toyota RAV4, the active safety view display showed only the front vehicle itself, the different lanes on the road and the rear of the vehicle in front. The color used was a bright blue (figure 4.6) which was hard to see when the sun was out. The absence of other objects or vehicles, in combination with the pale blue color used in the display, created a feeling of lower system transparency. However, the blind spot monitors in the side mirrors (figure 4.7) still made the user understand that the AS was aware of the surrounding traffic.

Figure 4.6: Toyota RAV4's active safety view. Figure 4.7: Side mirror blind spot monitor

4.3.1.3 Take Over Request (TOR)

BMW marked the user's need for engagement by firstly changing the color of the active AS symbol from green to yellow (figure 4.8 and figure 4.9). If the user did not follow the request, the symbol turned red and a larger symbol appeared in the middle of the dashboard screen (figure 4.10).

Figure 4.8: Green symbol when AS is activated. Figure 4.9: Yellow symbol with hands on wheel. Figure 4.10: Red symbol with hands on wheel, both to the left and in the middle of the display.

In Toyota's active safety view, it was announced not only where between the lines the vehicle was placed, but also when the vehicle's AS could not resolve where the file ended, all this in the same interface image. This made it difficult to note obvious clues to when the AS failed, which in turn made some of the TORs feel very abrupt and insecure. However, if there were a more important TOR, a "pop-up" appeared across all information in the digital screen. This pop-up showed a red symbol for taking the wheel, which was intensified with the same message displayed in text (figure 4.11).

Figure 4.11: Toyota hands on wheel pop-up

4.3.1.4 Dynamic Motion Behavior

Dynamic motion behavior is one aspect that was observed during the benchmark which does not concern the interface. One of the most apparent aspects considering dynamic motion behavior when evaluating the two vehicles, appeared when the AS reached one of its limitations, i.e., when the sensors did not perceive the surroundings correctly or when the required user interaction failed.

The BMW did not make any sudden movements or adjustments from the route if any of the sensor-based systems lost its perception. However, when the required 'hands on wheel' command was not fulfilled while using the lane change assist, the full action was abruptly interrupted. This happened halfway during a lane change and resulted in unexpected behavior of the vehicle.

Toyota, on the other hand, had a more uneven motion behavior. When the LTA sensors lost track of the lane, even if just for a second, the vehicle acted unstable. This also applied when the vehicle in front exited the highway, which made the Toyota to abruptly make a turn to follow.

4.3.1.5 Colors

The colors used in the HMI in BMW were white and shades of gray on a black background, in combination with highly contrasted accent colors of red and bright green (figure 4.12).

Figure 4.12: HDD - BMW

Toyota used white on a background of black, with accent colors in bright green and blue (figure 4.13). The contrast was not perceived as high as in the BMW.

Figure 4.13: HDD - Toyota

In general, the car brands tried to use the colors green, orange/yellow, and red for the messages to the user to indicate different levels of urgency in a given situation. There was a certain difference in how long the yellow symbol in a TOR lasted before the symbol turned red. In the BMW, it was visible for a longer time than it was in the Toyota.

4.3.2 Results of Complementary Interviews

Interviews were conducted with some car sales representatives, two locomotive pilots and an aircraft pilot.

4.3.2.1 Car Sales Representatives

None of the car sales representatives interviewed had any deeper knowledge of the ASs in the vehicles and believed the best way for the user to understand it, was to test drive the vehicle.

One of the car sales representatives explained that the user always needs to touch the steering wheel when making an automated lane change. If this explanation had been left out, the function could not have been tested. Another car sales representative could neither describe any of the ASs, nor any limitations. This resulted in him showing a YouTube video that was supposed to explain these aspects. However, it was still clear that he lacked understanding.

4.3.2.2 Locomotive Pilot

A solid education is required for being allowed to drive a locomotive. In the interviews with the locomotive pilots, it turned out that they feel more responsibility when driving trains than when driving other vehicles, mainly due to the number of passengers. Nevertheless, the locomotive pilots (in Sweden) are rarely held responsible for any accidents, as long as they have followed signals and information.

The train has an emergency brake system that operates without any assistance from the pilot. This system acknowledges if the pilot misses to reduce speed or break at a given stop signal, activating the emergency brake. Even though this emergency brake exists, the pilots do not rely on it, thus they do not acknowledge sharing any of the responsibility when driving the train.

4.3.2.3 Aircraft Pilot

From the interview with an aircraft pilot, it turned out that a commander/first pilot can be held responsible if an accident occurs. It is the aircraft, the co-pilot, the traffic management etc. that form the basis for decisions, but the first pilot has always the final word.

This means that the first pilot continuously collects information about the context, the engines, the plane, its behaviors and such. Thus, the pilot wants to "*keep it on the dry*" if something unpredictable or any accident was to occur.

The aircraft pilot believes that the major differences between driving a car and an aircraft, is the required education. It can take up to 2-3 years just to get started as a pilot, in comparison with the two-week intensive course for a driver's license. Moreover, aircraft pilots are required to carry out competency controls every six months, and other types of regular training just to maintain their status. The aircraft pilot also pointed out that these continuous knowledge updates are non-existing when it comes to car driving, but the driver is still allowed to use extremely complex cars without adequate training.

In terms of aircraft HMI, the most prevalent concept since a few decades ago is the *dark cockpit*: as long as everything is okay, all indicator lights are turned off.

4.3.3 Workshop Outcome

The workshop with developers from Toyota involved four different tasks: discussing the homework, developing further understanding of users by assigning quotes, brainwriting and creating a PNI. The results of these tasks are described here.

4.3.3.1 Discussing the Homework

The discussion on the homework focused on the last five statements in the booklet which started a good conversation. All participants responded that they understand what happens when AS is activated and that they also felt safer when the AS is activated. The participants assumed that part of the control is taken over by the AS, and one participant said that: "*I feel less in control than if the AS is not activated*". The participants considered that when it comes to LoA 3, the user is still the one who is responsible but, the higher level of automation that is reached, the more responsibility lies on the AS.

4.3.3.2 Understanding Users by Assigning Quotes

All participants discussed the different quotes and assigned them to the different personas that were created in the user study (figure 3.12). The purpose of this task was to understand different types of users and how these different types of users might think when using a vehicle with AS, as well as what they think is more important to the users. Some of the quotes were assigned to all the personas since the participants thought it suited all the different types of users and some quotes were only assigned to one of the personas.

Sara, 25 years old, very interested in technology, likes to listen to very loud music while driving.

"I would feel more secure using a lane trace assist because when driving a long distance, it can easily be that you lose focus or think of something else. Then it feels good that this function exists and has a little control."

"When using an adaptive cruise control you do not have to constantly focus on the speed which is more comfortable."

"As a driver, you hand over control to the car, but not the responsibility."

"Responsibility lies on the driver regardless of the activated AS. You cannot trust the technology as it is today. "

"If the car makes an obvious mistake when the systems are activated, I would have been quite surprised and blamed the mistake on the system and on the car company."

"I should read the manual first, because I have the responsibility to know how everything works and understand the limitations of a system. But I probably hadn't taken that responsibility."

"I trust technology more than human ability. The technology is not affected by emotions, stress, hearing defects, surroundings etc."

"I think it is important that all these driver systems are connected to the car's capacity."

"I trust the technology but I have the command."

Bill, 42 years old, parent with 2 children in the rear seat, tries to drive as safely as possible.

"I would feel more secure using a lane trace assist because when driving a long distance, it can easily be that you lose focus or think of something else. Then it feels good that this function exists and has a little control."

"When using an adaptive cruise control you do not have to constantly focus on the speed which is more comfortable (and safer)."

" If the police stop me for speeding when the adaptive cruise control is activated, it is still my responsibility to keep track of the fact that I drive according to the law. So it is my responsibility as a driver, but I would not be happy about it."

"As a driver, you hand over control to the car, but not the responsibility."

"Responsibility lies on the driver regardless of the activated AS. You cannot trust the technology as it is today. "

"If the car makes an obvious mistake when the systems are activated, I would have been quite surprised and blamed the mistake on the system and on the car company. "

"I don't feel safer using AS right now, maybe in the long run when you have used it more."

"I think it is important that all these driver systems are connected to the cars capacity" (because safer)

Tom, 73 years old, not so interested/knowledgeable in technology, but highly experienced driver.

" If the police stop me for speeding when the adaptive cruise control is activated, it is still my responsibility to keep track of the fact that I drive according to the law. So it is my responsibility as a driver, but I would not be happy about it."

" As a driver, you hand over control to the car, but not the responsibility."

"Responsibility lies on the driver regardless of the activated AS. You cannot trust the technology as it is today."

"If the car makes an obvious mistake when the systems are activated, I would have been quite surprised and blamed the mistake on the system and on the car company."

"A big reason why you cannot feel safer with these systems is that they only assist you as a driver. Another reason is how drivers behave towards each other. The human factor is the big reason for not feeling safer despite the systems."

"I think it is important that all these driver systems are connected to the cars capacity" (because of experience as a driver)

Figure 4.14: The quotes assigned to the three different personas

4.3.3.3 Brainwriting

It was mainly in *task 3*, i.e., brainwriting, when the participants were asked to brainstorm around the three different main issues that appeared in the user study that several thoughts, ideas, and solutions surfaced. Therefore, the result is mainly focused on this part.

I: *How do we make users feel certain so that they can regain control easily?*

The first point is to increase the users' understanding of control and responsibilities; the user needs to know who is in charge of what and when. It should be clear which functions the user is still in control over. This can be facilitated by a step-by-step transition which can be achieved by showing a visual control transition and changing the interior ambiance (in terms of sound, light, etc.).

The second point is to increase the users' contextual understanding. It is not only what happens in the vehicle but in what context what happens that are important. The user needs to have a better understanding of the situation and the conditions of the traffic around them, i.e., situation awareness. The AS should inform the user as early as possible before giving back control and the information should be gradual. If the TOR is urgent, it should be multi-sensory. It is also important that there is no information overload during TOR.

II: *How do we get users to understand the limitations of the AS?*

To get users to understand the limitations of the AS, the first issue is to raise awareness about the responsibilities. The vehicle needs to clearly explain what it 'can do'. This can be done using intuitive HMIs showing status and limitations (visual level), but also by having a conversational agent, humanizing the AI, and detailing the limitations something that could help the user understand better.

The second issue is training. This can be in the shape of an on-boarding process/ tutorial for new users where there is an interactive explanation like the ones available when using a new app on the phone. The user can go through this training process in order to easier understand the systems functions. Incorporating a type of training could either be in terms of an in-vehicle solutions or achieved via other technical solutions connected to the vehicle. It can for example be done at the dealers or on the phone at home. If the user has a clear picture of what the vehicle can do from the beginning of the experience with the vehicle, it can help the user understand its limitations better. The AS can also help the user by re-explaining features that are not used, explain updates, and give warnings when the user misuse something. It can also provide feedback with clear instructions to guide towards correct usage.

III: How do we prevent compromising with the user's understanding of constant responsibility?

It is important to understand who the primary driver is, who is in charge (i.e., who is in control) and always show clear indications of this attribution of control in the HMI. Top priority should be to avoid any misunderstanding. The user should never say that she's not sure and therefore, smooth communication with the system is important. Collaborative driving with AI can also be encouraged where the vehicle can ask for support if not 100% sure of its surroundings.

It is also important to keep the user in the loop. The AS can also give feedback on (e.g., leaning towards rear seats, sleeping, looking at a smartphone) that are unsafe for the current condition. This feedback is based on information from user monitoring systems. Training, as described above, can also be used to solve this issue.

4.3.3.3 PNI

The participants did three PNIs for three different areas that surfaced during the workshop. These three areas were the most frequently discussed and were therefore selected to be part of the task PNI. The three areas that were selected were “Feedback regarding TOR where the transitions are gradual” (table 4.2), “Training” (table 4.3) and “Displaying awareness of control & responsibility” (table 4.4).

Table 4.2: PNI showing aspects about feedback regarding TOR where the transitions are gradual

POSITIVE	NEGATIVE	INTERESTING
Avoids information overload	How car might give an accurate and relevant contextual information (when/ reason for tor)	How to make TOR a positive event that will generate trust and not only a moment where the car was not working properly.
Allows to put user´s attention on most critical information first	How to make sure users understand this gradual change? If pedal control is not given back but user wants to operate, he might want to have priority	If intuitive with clear balance between manual and automatic & clear awareness of the use and limitations
Very positive when there is no urgent action to be taken so far, and very useful if it can support driver decisions	How can it be adapted? Lack of awareness regarding clear responsibility, from whom/what, conditions, contexts, misuse/ overuse	Info should also be localized

Table 4.3: PNI showing aspects about training.

POSITIVE	NEGATIVE	INTERESTING
Allow systems to understand user´s knowledge, profile	Interrupts the user experience	If adapted to driver ability to understand use, limitations and responsibilities
If intuitive + supported by relevant clear feedback	Customers are not reading handbook so how to make a training acceptable	
Gamification opportunity - get trained, get experienced, get rewarded	If it requires a specific level of technical skills	
Opportunity for more direct interaction/communication between user and car manufacturers		

Table 4.4: PNI showing aspects about displaying awareness of control & responsibility.

POSITIVE	NEGATIVE	INTERESTING
Relevant case study AI and conversational agent for car to human interactions	Digital gap and inclusion issue for elderly not being able to set those functions because of complexity	It should be done in a visual (and multisensory) and intuitive way. Studies are necessary to identify the best UI.
		Very important step-up if conditions can be created for optimal intuitive interactions between driver and vehicle.

4.4 Discussion and Implications

4.4.1 Benchmarking

The interviews with the locomotive and aircraft pilots resulted in more insights into views and perspectives on how users of other AS's understand responsibility allocations. The concept of 'dark cockpit', which is used in aircrafts, was an interaction element that was discussed in the benchmarking. This could translate well into the context of semi-AVs, as it could facilitate transitions into for example control, making it easier for the user to acknowledge when the AS reaches its limits, and needs the user to take over. This could be achieved by reducing all information on what is supposedly working as it should, to emphasize more urgent changes in the system. As of today, there is plenty of information, especially in the HDD in vehicles that could be hidden until any drastic changes occur (e.g., drastic increase in motor temperature). The HDD should only display information that is relevant for decision making during the actual drive.

The idea of minimizing information in the HDD needs to be implemented with consideration so that it does not affect the users understanding of the AS, and in turn their decision making.

In the interviews with the two car sales representatives, it turned out that neither of them had any deep insight into ASs. Before the interviews were conducted, it was expected that the car sales representatives would be more familiar and have more knowledge. Instead, to gain more knowledge and understanding of how the system works, the car sales representatives recommended us to test drive the cars ourselves. However, the lack of information provided by the car sales representatives may have resulted in that there were ways of interacting with the AS that did not get evaluated when performing the test drive. This is though not different from an actual user experience.

Designs improving situation awareness, as in understanding how the AS works, was the active safety view in both of the tested vehicles. The BMW showed all surrounding vehicles with high detailing in the display, which can be considered as an advantage due to the user becoming aware that the vehicle 'sees' what the user sees. The Toyotas active safety view did not provide the same amount of information regarding the vehicle and its relation to other vehicles in the traffic. All these aspects, discussed in relation to the active safety display, could also be described as different levels of system transparency.

System transparency has been discussed in the literature as one interaction element that facilitates the users' understanding of the AS. The findings in the user study also support the importance that the AS mediates its status, abilities, and limitations, in order for the users to, in the end, understand the different roles of user and AS in this cooperation. Showing a high detailed display as the BMW did can be an advantage, because the AS and the user "sees" the same things. With this design, the communication between the AS and the user can be facilitated since they agree with each other. A too low detailed display can instead create confusion and lead to poorer cooperation between the two.

Another vehicle related factor that appeared through the test driving of the vehicles was the vehicle's dynamic motion behavior and the way the two different test vehicles acted if the AS failed in any way. Unanticipated motions showed that this does affect the users' understanding of control. This was most noted in the Toyota, as the vehicle quickly started to change motion behavior when, for example, the AS did not detect the sides of the road. For the user, this could be interpreted as a need for take over. This further strengthens the feeling of the user always having to be aware of the situation, keeping the motivation of acting responsibly, agreeing with the users' understanding of constant responsibility. However, since this thesis project focuses on HMI, this factor was not prioritized or further developed but studies on the importance of vehicle behavior in different situations have been presented, for example in Ekman et al. (2021) and Ekman et al. (2019).

4.4.2 Workshop

After discussing the homework with the developers at Toyota, it became apparent that there was a difference in how, on the one side, the developers and, on the other side, the users in the user study view responsibility. The developers expressed the attitude that the user will hand over some responsibility to the AS, to be completely removed from responsibility in the final states of automation. However, most of the user study participants declared that they would never share responsibility with the vehicle – even though a few mentioned that they possibly could hand over responsibility completely if the vehicle was fully automated. Nonetheless, the most common opinion was that the user was always responsible. To make sure that it was not cultural factors that influenced this view, two potential users from Belgium were asked to answer the same “five last statements” as were the Swedish users in the booklet task. The responses from the Belgian users could be compared to the Swedish participants, which indicates that the differences may indeed lie between user and developer, rather than between users. This itself creates an issue.

The difference could possibly be explained by the users and developers having different goals. As the developers are working towards fully AVs, minimizing human influences, they will have a more positive attitude towards assigning responsibility to the AS. Users, who are deeply interested in technology, might have the same opinion. Therefore, internal aspects must be considered as something that could influence users' beliefs about whether responsibility can be shared or not.

During the workshop, the importance of reaching beyond the traditional communication channels when it comes to AVs was addressed. Users need to be aware of their roles as a driver, which actions they are able to perform as well as when. The role as a driver starts when entering the vehicle, but the understanding is formed even before that. Therefore, it is important that users have access to relevant information, via different communication channels. These can for example be to talks with a sales representative person in a physical store, digital channels like websites, apps, social media but also channels that are not immediately interactive, like for example TV and newspapers.

Another conclusion from the workshop was that it is important to consider more aspects than the users' interaction with the in-vehicle user interfaces when talking about AVs. This can for example be about aspects regarding the vehicle's interior. However, since the thesis project focuses on HMI, this aspect has not been prioritized or further developed.

In order to create good human-machine cooperation, it is preferable to combine user-friendly interfaces with an overall understanding of what it means to be in a driving situation when the ASs are activated. There is a need for an increased understanding of what control means and how this is distributed between the AS and the user, in order to enable a cooperation between the two.

During the workshop, take-over requests (i.e., TORs) were discussed a lot and were also summarized in a PNI showing the positive, negative, and interesting aspects. As mentioned, it can be positive if a TOR is gradual since one could avoid information overload and allow the user to put attention on the most critical information first. This is in line with the design implications that were mentioned in chapter 2.3.2. One of the interesting aspects regarding gradual TORs that appeared in the PNI were about how to make TOR a positive event that will generate trust and not only a moment where the AS does not work properly. It can for example be that if a TOR is presented gradually, it could be perceived as safer and in turn generate trust, but if a TOR is very abrupt it could create a more negative feeling regarding the control transition.

In conclusion, the workshop showed that the designers had a different view on the way responsibility can and will be completely removed from the user, when the vehicles are reaching a higher level of automation. This view was contradictory to what the user study suggested; the user study results could in turn be argued to comply with the implications from the literature review, i.e., that responsibility cannot be shared.

4.4.3 Extracted HMC-guidelines

Extracted guidelines from chapter 4; *Searching for Inspiration – benchmark*

- The HMI should not compromise with the users' expectations of always having responsibility when driving a semi-AV (LOA 3)
- The HMI should provide adequate system transparency
- The HMI should clarify who is in control, AS ↔ user
- The HMI should meet user's existing mental models
- Dynamic motion behavior should be incorporated into the interaction
- Minimize information repetition on the vehicles' displays
- The HMI should take inspiration from the dark cock-pit concept; show changes in information
- The HMI should clarify the time frame from information to required action
- The HMI should enhance the feeling of being responsible for others
- Enhance the users' understanding by incorporate training possibilities

Extracted HMC- guidelines from chapter 4; *Searching for Inspiration* - *Workshop.*

- The HMI should communicate limitations, AS→ user
- The HMI should communicate intentions, AS → user
- The HMI should not compromise with the users' expectations of always having responsibility when driving a semi-AV (LOA 3)
- The HMI should use multisensory interactions
- The HMI should visualize the flows of control
- The AS should re-explain features that are unused
- The HMI should provide gradual information
- The HMI should provide feedback on unsafe behaviors
- An AI used in the AS should be humanized
- The HMI should provide possibilities to "ask" for, rather than request, support, AS ↔ user
- The HMI should keep the user in-the-loop when AS is activated
- The HMI should enhance the feeling of being responsible for others
- The design should consider elements beyond the interaction, i.e., interior

4.4.4 Research Questions

Based on the results from this phase, all research questions have been answered (figure 4.15), as well as have the results contributed to the main aim. The knowledge gained has been validated in a concept development phase, described in chapter 6. The next chapter presents all the guidelines that have been extracted throughout the thesis project and which forms a basis for the concept development phase.

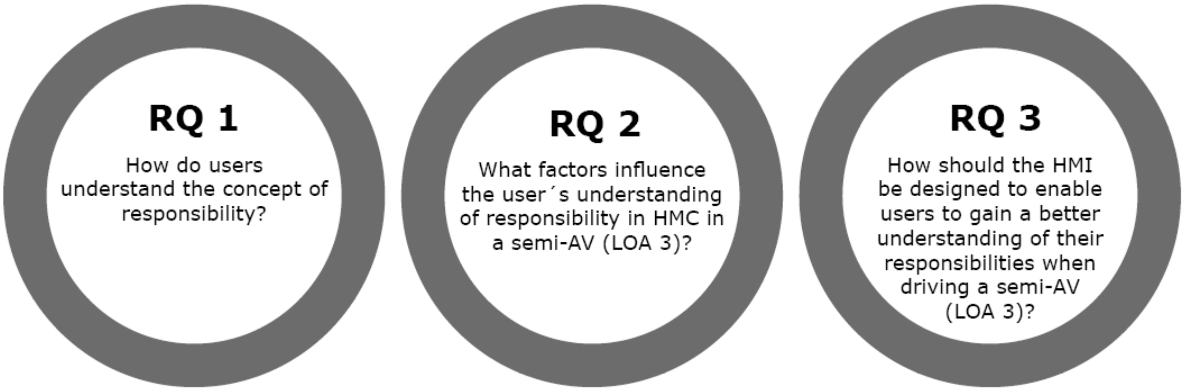

Figure 4.15: Progress of answering the research questions.

5. Guidelines

The findings throughout the thesis project have been gathered, summarized, and interpreted into a set of guidelines to consider in the development of AVs in order to be able to facilitate the cooperation between user and AS. The guidelines have become manifest when searching for and gaining a better understanding of aspects that influence users' understanding of responsibility.

The guidelines that have been extracted throughout the thesis project are in the field of human-machine cooperation (HMC). HMC concerns both the human (user), the machine (AS) and the environment around these two. Environment refers to the relation to passengers, other road users, geographic variation, weather conditions, potential for hostility and temporal constraints within a particular environment. The AS needs to understand its environment in order to be able to communicate relevant information to the user via an interface. As a designer, ones designs are limited to the vehicle. External factors such as the driving environment are not included in the design process. Therefore, the focus on this project is on the in-vehicle user interface and to design an appropriate HMI that can facilitate HMC. This can in turn enable the users to gain better understanding regarding control, which is a factor that influences the user's understanding regarding responsibility.

As described in the literature review (see chapter 2.3.2), it is through the interface that the human and the AS communicate information during their cooperation. The major design changes in the automotive industry concern the interface rather than the physical design of the vehicle. Therefore, the direction and focus are on the interfaces, 'inside' the vehicle and how these could be designed to facilitate HMC. Most of the guidelines concern the design of the HMI since the third research question was "How should the HMI be designed to enable users to gain a better understanding of their responsibilities when driving a semi-Av (LoA 3)?"

The other guidelines that emerged during the thesis project concerned "users and their understanding" of semi-AVs, "vehicle behavior" and the vehicles' "interior". These were not selected for further focus or development in this thesis project, due to the chosen HMI focus. Figure 5.1 shows how all these parts are connected and why the guidelines focus on HMI.

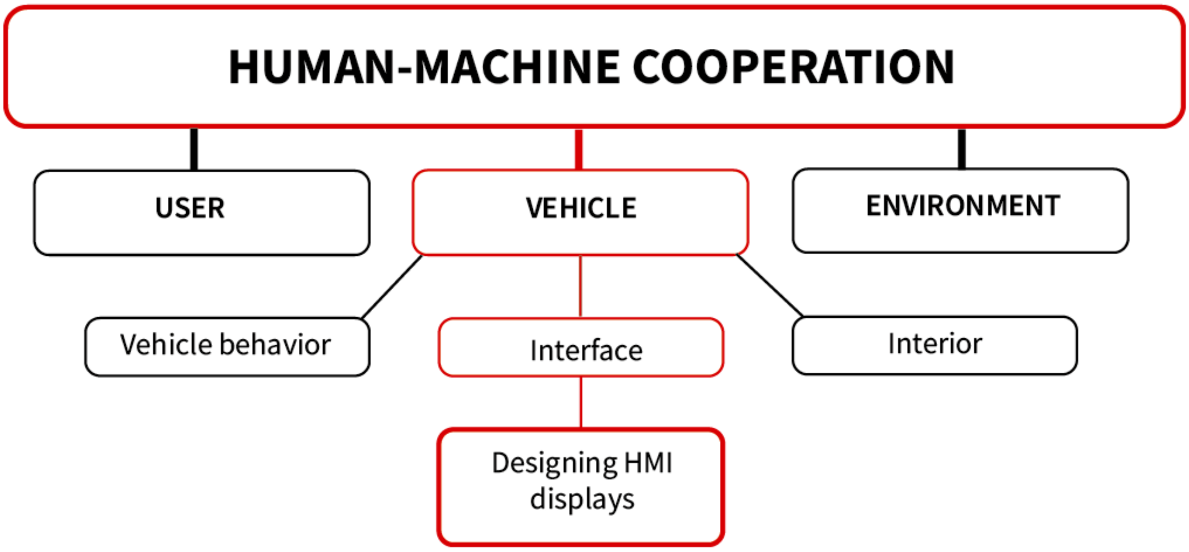

Figure 5.1: Shows the “path” from HMC to designing HMI displays

Based on from where the guidelines were extracted, a colored box appears next to the respective guideline. The different colors and their respective meaning are shown in the color scheme. Many of the guidelines were extracted from more than one phase during the thesis project and have therefore more than one color-box next to it. The color coding (see figure 5.2) explains from where the guideline originates.

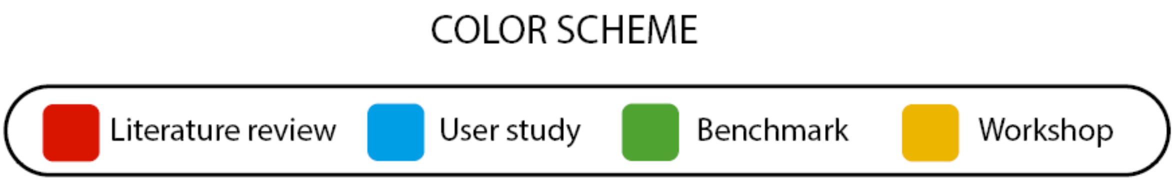

Figure 5.2: Color scheme:

5.1 HMI

The following guidelines refer to human-machine interfaces (HMI) and how these interfaces should be designed, what kind of information they need to communicate, how much and why in order to facilitate human-machine cooperation, and in turn the users' understanding of using a semi-AV.

The HMI should provide adequate system transparency

System transparency is one of the vehicle related factors that influences the understood responsibility. Depending on the system transparency level, different amounts of information are displayed and communicated through the interface. Therefore, it is important to provide adequate system transparency in order to facilitate the cooperation between the user and the AS.

The HMI should communicate limitations, AS → user

It is of great importance that the HMI communicates limitations in the AS, as well as the vehicle's overall abilities. This mainly concerns the AS's communication to the user, in order to give the user important information to be able to understand the AS and in turn their responsibilities.

The HMI should clarify who is in control, AS → user

Suggested throughout the study, control is to be shared between user and AS. For efficient cooperation, the allocation of control needs to be clear. However, one aspect to consider is that the feeling of control may be as relevant as the actual control. It is important that the control transitions are easy to understand, notice and interpret in order to avoid misunderstanding and confusion.

The HMI should communicate intentions, AS → user

The intentions of the AS should be clearly communicated to the user in order to enhance the understanding of the user. Included in this communication, lies the status and abilities of the AS. Thus, the communication should entail the active mode, future actions and reasons why.

The HMI should clarify who has the authority, AS ↔ user

In a cooperative driving situation, the authority is divided between the user and the AS, since transfer of full authority to the user or the system are often more difficult to perform. It is important that the HMI clarifies this information in order to prevent misinterpretation of responsibilities and loss of situation awareness.

The HMI should use multisensory interactions

To communicate the right information at the right time and in an appropriate form, one could use multisensory interaction and present the information auditory, visually, and haptically (vibrotactile). This is more important in emergency situations.

The HMI should meet user's existing mental models

It is important that the designers' HMI design meets the users' existing mental models to prevent problems regarding usability.

Minimize information repetition on the vehicles' displays

This can be done by grouping the information and prioritizing the most important information on the display behind the steering wheel. This avoids that the same information is being displayed in several places. This also helps to ensure that different types of information do not interfere with each other and prevent information overload for the user. However, it is relevant to place information about TOR in both the HDD and the HUD, as it can have serious consequences if the user does not notice it.

The HMI should counteract different automation related misunderstanding

The HMI should prevent misuse due to issues such as automation complacency or automation bias. This is important since both aspects could cause major errors in the HMC, if the automation fails. This can be prevented by increasing user accountability for decisions and displaying the information in an appropriate position.

The HMI should clarify the shared cooperative goal, AS ↔ user

To increase the possibilities of an efficient HMC, clarifying the shared goal is needed for both AS and user.

The HMI should clarify that the user always can override the AS

The users wish to have the ability to override the AS, as a direct consequence of being responsible. However, this lies in conflict with the intention of minimizing the human factor in AVs. However, since the users do not expect to share their responsibilities, the human factor still needs to be central in vehicles with LoA 3.

The AS should facilitate workload sharing

The AS should reduce the overall workload of the user, not increase it. It is therefore important that the HMI communicates the appropriate amount of information, at the right time.

The HMI should provide possibilities to "ask for", rather than request, support, AS ↔ user

This can enable a dialogue and increase collaboration between the user and the AS.

The HMI should communicate correct information at the right time, in an appropriate form (i.e., feedback)

In order to achieve a user-friendly interface, it is important that the systems provide feedback in form of necessary information about how the users' actions is progressing. The feedback must be easy to understand without obscuring or interfering with the user's actions. In order for the user to have a feeling of control and also understand their responsibilities it is important that the AS cooperates with the user and communicates the right information at the right time, in an appropriate form.

The HMI should take inspiration from dark cockpit; show changes in information

This can be done by enhancing the contrast/colors if certain information is more important or urgent. This will make the information more visible which in turn could make it easier for the user to notice important information, for example when a control transition occurs, and thereby act responsible.

The HMI should clarify the time frame from information to required action

In a TOR, this can be shown by displaying the transition between green, yellow and red on the TOR symbol and how long it is left until the yellow symbol reaches red, which can help the user to know when they need to act, before the AS is deactivated.

The HMI should visualize the flows of control

This could make it easier to notice a control transition which in turn can enhance the feeling of being in a cooperation.

The HMI should provide gradual information

By providing gradual information it will be easier for the user to receive and interpret the information. If everything is presented at the same time, this may result in information overload. However, it is important to decide which kind of information that is gradual, so that it does not make it more difficult for the user to make decisions and interact with the AS.

The HMI should provide feedback on unsafe behaviors

Providing feedback on unsafe behavior can help the user avoid repeating this behavior another time. This can increase the user's understanding of the limitations of the AS, as well as how to use the AS in the best possible way. Providing feedback also increases the overall cooperation between the vehicle and the user.

The HMI should keep the user in-the-loop when AS is activated

Keeping the user in-the-loop can be done by enhancing the understanding of the AS in whole, increasing contextual understanding and by ensuring to avoid misunderstandings.

The HMI should not compromise with the users' expectations of always having responsibility when driving a semi-AV (LOA 3)

Currently users perceive themselves as the holder of all responsibility regarding the activity of driving. Thus, this must not be compromised as it would create confusion. It is therefore important that the HMI does not create a conflict regarding this understanding.

The HMI should enhance the feeling of being responsible for others

The users' understanding of being responsible for others (passengers, road users) should be enhanced. Further, this should also be considered for the AS, since it may entail a more shared workload.

The HMI should clarify that the user has the "final" responsibility to act adequately while using a semi-AV

It must be clear that the responsibility to act adequately is not allocated somewhere else than to the user.

5.2 Users and Their Understanding

The following guidelines refer to users and their understanding where the focus is on factors which do not necessarily occur while driving a semi-AV but instead take place before or after.

Enhance users' understanding by incorporate training possibilities

Training possibilities could be such as a separate guide/tutorial, provided in close connection to the vehicle, as well as in vehicle learning i.e., learning by doing. This should also be considered to facilitate the HMC. Combining this with some type of competency tests could guarantee that the user and AS “understand” each other. Further, this type of education could be suggested for persons involved in communicating the automation functions, such as car sales representatives.

Developers should consider how user differ when it comes to their understanding of semi-AVs

Founded in the factors that influence the users’ understanding of their responsibilities, different users have different understanding. Developers must consider how culture, philosophical views and similar factors may influence the user. Developers must also consider abilities and experiences that the different users have. These all may affect how these guidelines should be followed.

The vehicle should enable system adaption for different types of users

Since there are many different types of car drivers, the target group is very broad. Thus, the design of the interface and its interaction must take this into account. Thus, users should be able to adapt the AS to their needs and preferences so that they get the best user experience possible. System adaptation could mean that the user can customize how much information they want available in a display, which for example can depend on how experienced the user is.

The AS should re-explain features that are unused

Re-explaining unused features can help the user to understand how the feature works and increase the chance that the user wants to use it. Since the AS communicates information to the user, it contributes to better cooperation and thus a more efficient interaction.

The AI used in the AS should be humanized

Humanizing the AI could increase the user’s motivation to create a good relation with the AS.

Elements beyond the interaction needs to be considered in order to create better user understanding

What is communicated to users before even entering the vehicle is important and can create a better understanding for the user of how the AS works.

5.3 Dynamic Motion Behavior

The following guideline concerns the dynamic motion behavior that could be noted during the benchmark.

Dynamic motion behavior should be incorporated into the interaction

Since motion is also a type of interaction where the user receives information from the vehicle, this could also be part of the interaction. This can help improve the cooperation between the user and the vehicle and create a more effective interaction.

5.4 Interior

The following guideline concerns the vehicle's interior.

Consider elements beyond the interaction i.e., the interior

The vehicle's interior refers to color choices, materials, buttons, lighting etc. which are important to consider when designing for user experience when driving a vehicle. For instance, lighting and vibration can be used to alert the user that attention is needed somewhere. This can be done by flashing light in the steering wheel or using vibration in the seat.

This chapter has presented 31 guidelines that aim to facilitate HMC between the user and the AS. The majority of guidelines concerned the HMI and used as a basis for Concept Development, described the next chapter.

6. Concept Development

The information that concerns the intended cooperation between the user and the automated system (AS) needs to be clearly understood and communicated in an efficient, appropriate and safe way, during use of a semi-AV. Two vehicle related factors were chosen to be in focus throughout the concept development; *control* and *system transparency*; control, since it influences the user's understanding of responsibility and system transparency, since it facilitates effective interactions between the user and the AS.

As stated in the literature review (see chapter 2.4.1), semi-automated driving is ever changing cooperation, since it combines manual and automated driving. Therefore, control transitions are inevitable and a vital aspect to consider. These control transitions, or TORs, require the user to always act responsible regardless of whether the AS is activated or not. In order to do so, the user needs to be aware of the AS's status, its limitations and abilities, which are all important when understanding one's responsibility.

Status refers to information regarding the current state of the AS, for example if a TOR is active which is important in order to understand and prepare for future actions. **Limitations** refer to when the AS reaches a situation where it cannot function anymore, for example due to external factors like weather or traffic environment. **Abilities** refer to what the AS can do, its actions and performance; in this case how much longer the AS can be activated and cooperate with the user, until it reaches its limitation and an action from the user is required.

System transparency can have different levels, meaning that different amounts of information will be displayed in the vehicle. Low system transparency means that the AS communicates less information to the user whereas high system transparency means that the AS communicates more information to the user. The challenge is to find an adequate level of system transparency that communicates the right type of information at the right time, without creating information overload or confusion. Therefore, it is relevant to test different levels of system transparency in order to investigate and find a solution appropriate for control transitions in semi-AVs.

6.1 Aim

Increasing the user's understanding for control allocation could facilitate the transitions and in turn the cooperation between the user and AS, which may become more efficient, suitable and safe during semi-AV use. Depending on the system transparency level, different amounts of information will be displayed in the in-vehicle displays. As mentioned in the literature review (see 2.3.2), it is important that the user always receives a timely warning to take back control to avoid uncertainty and automation surprises. The AS also needs to inform the user if it is not able to cope, as well as why, and provide clear information about the required takeover. Therefore, the concept development aimed to develop and test alternatives using the knowledge gathered and summarized in the previous chapters, i.e. the *literature review*, *user* *study, searching for inspiration* and the collected HMI guidelines explained in the *guidelines* chapter in order to be able to compare these against today's TOR solution.

The concept development phase consisted of two parts. First, the *concept creation* and second, the *concept evaluation with users*.

6.2 Concept Creation

6.2.1 Methods

Different ideation and prototyping methods were used in order to be able to create the concepts.

6.2.1.1 Ideation

The ideation focused on developing design solutions that improved the control transition and in turn the cooperation between the user and the AS.

As described in the literature review (see 2.3, results of literature review) the in-vehicle interface is the primary and most widely used communication channel for communicating information to the driver/ user. Therefore, the concept development focused on design solutions for visually displayed information regarding TORs. The type of displays that were in focus were the HDD and HUD, since a more centralized information position, like in an HDD or a HUD, has shown to result in better driving and task performance (see 2.3, results of literature review). Another reason (see 3.3 results of user study) was that since the users were willing to share control, but not responsibilities, they still need to look at the road and be ready to intervene and take over. This makes a centralized position more preferable for a TOR.

The ideation was based on 13 guidelines that were selected from the guideline chapter 5.1. These 13 HMI guidelines were chosen since they have shown to be relevant to address when designing an interface for control transitions and system transparency.

- The HMI should provide adequate system transparency
- The HMI should communicate limitations, AS → user
- The HMI should communicate intentions, AS → user
- The HMI should clarify who is in control, AS↔ user
- The HMI should meet user's existing mental models
- The HMI should clarify the shared cooperative goal, AS ↔ user
- The HMI should communicate correct information at the right time, in an appropriate form (i.e., feedback)
- The HMI should take inspiration from dark cockpit; show changes in information
- The HMI should clarify the time frame from information to required action
- The HMI should visualize the flows of control
- The HMI should provide gradual information

- The HMI should provide feedback on unsafe behaviors
- The HMI should not compromise with the users' expectations of always having responsibility when driving a semi-AV (LOA 3)

Based on the previous findings regarding control transitions, the following questions were asked:

1. How much information regarding the AS's status, limitations and abilities is needed for the user during a TOR in order for an efficient and safe control transition?
2. How can TORs be conceptualized visually through the HDD and/or the HUD?

Two brainwriting sessions were conducted to summarize the ideas that have arisen throughout the project. These were performed using small post-it notes, a timer, and some pencils. For the first brainwriting session, the time was set to 5 minutes, during which the participants (in this case the two project team members) wrote down solutions or ideas, reasonable or not. After 5 minutes, discussions regarding the ideas were held. For the second brainwriting session, the time was set to 5 minutes, during which the participant (in this case only the author) wrote down solutions or ideas regarding control transitions.

6.2.1.2 Prototyping

Based on the different ideas that emerged during the ideation, a prototyping session was completed to further develop ideas (cf. Martin & Hanington, 2012). The prototyping session contained paper prototyping by sketching some ideas on paper and digitally prototyping by using the program Adobe Illustrator. The paper prototypes were used as inspiration when the concepts were created digitally, with a more realistic look. The digital prototypes were then used in the evaluation with users. Altogether, five different TOR designs were created.

6.2.2 Results of the Concept Creation

The results of the activities are presented in *Concept Creation.* The process for generating ideas by brainwriting and prototyping is first described, followed by a description of the more realistic, digital prototypes.

6.2.2.1 Ideation

The ideation focused on developing TOR alternatives, different from the one used in today's vehicles, in order to facilitate the control transition and in turn the cooperation between the user and the AS.

According to the guidelines, it is important to meet or match the users' existing mental model. Since a user's mental model is affected by previous experiences it could be important to use symbols that already are used in AS, for example the "hands on steering wheel" symbol for a TOR. A redesign of a common symbol that is used in many vehicles could create confusion and make it even harder for users to drive vehicles from different brands. Therefore, the consistency principle was applied to design decisions, for example regarding symbols, and therefore these were not changed in this thesis project. In addition, the colors green, yellow/orange and red are used in all concepts.

The following guidelines “The correct information should be communicated at the right time, in an appropriate form i.e., feedback”, “Clarify the time frame from information to required action”, “Visualize the flows of control” and “Provide gradual information” have been very central throughout the ideation. This has been done by implementing functions like showing a softer transition and a flow. This could enhance the users’ understanding of how the system processes information, from internal and external information sources, which in turn can create better communication regarding the AS’s status, limitations and abilities.

One of the more interesting aspects that arose during the ideation was the possibility of incorporating the concept interface with the concept of dark cockpit, which was influenced by the guideline “Take inspiration from dark cockpit; show changes in information” and thus, only communicate the information needed for the user to make correct decisions during the drive. With a higher contrast in the active TOR symbol, and the other symbols dimmed, it could be easier to notice the TOR from the AS. This is also in line with the guideline “Provide adequate system transparency”, since it is important to present relevant information and to prevent information overload.

6.2.2.2 Prototypes

The brainwriting sessions resulted in some paper prototypes, which can be seen in figure 6.1. Based on the ideation and the paper prototypes, five prototypes were created digitally and are presented as concepts A to E.

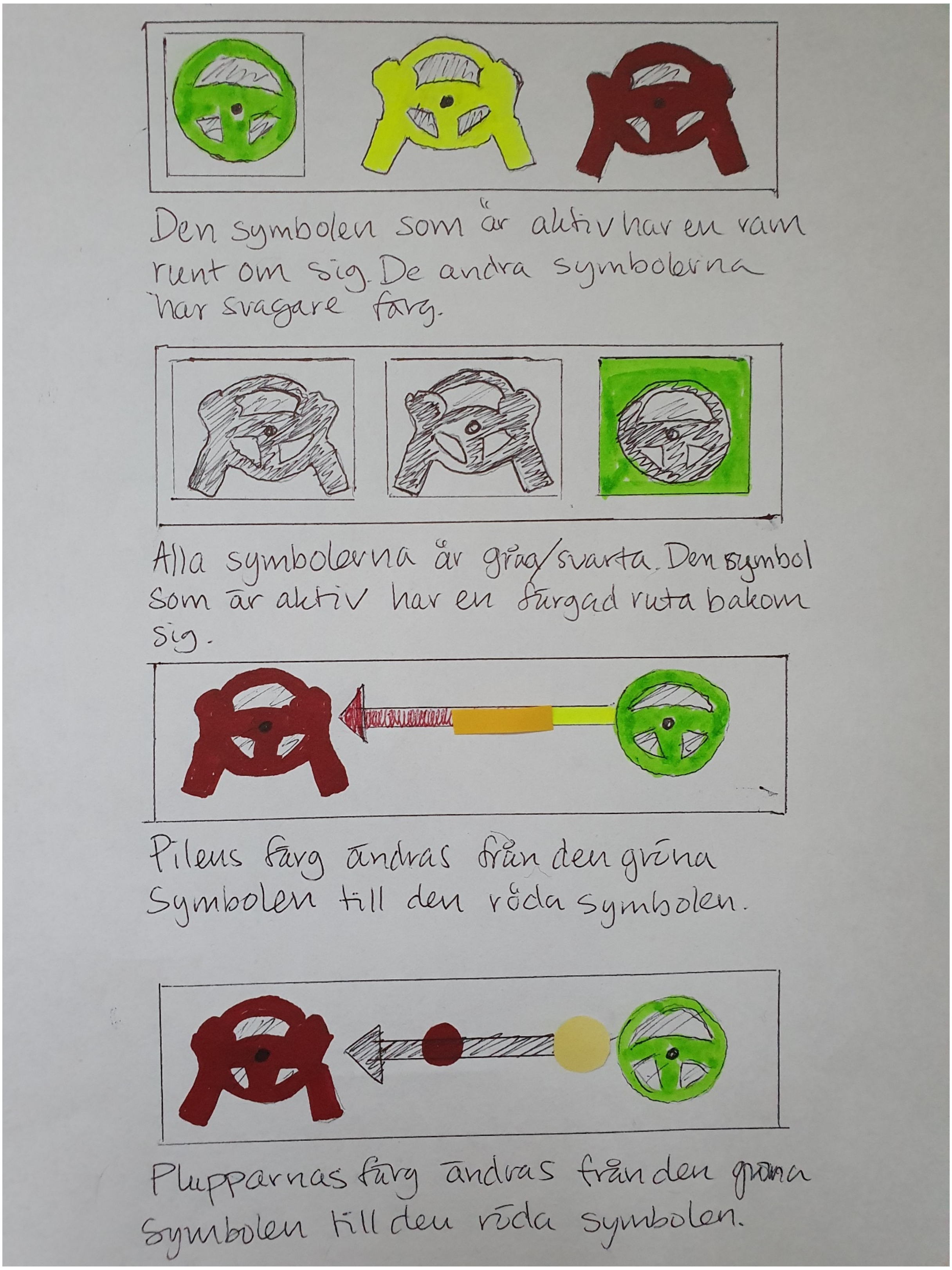

Figure 6.1: Paper prototypes

Concept A (Baseline)

This concept is based on how the TOR looks like today in most of the vehicles that are available on the market, that is, a steering wheel symbol in green to yellow/ orange and finally red. Each symbol is displayed separately and changes from one color to the other. The green steering wheel symbol means that the AS is activated and that everything works fine. The yellow steering wheel symbol with hands on the wheel means that a TOR is active and that it is time for the user to place his/her hands on the steering wheel and regain control over the vehicle. The red symbol is displayed when it is the last chance to act, before the AS will be deactivated. The background is dark grey in this concept since it makes the symbols more visible. When the concept is shown in the HUD, the background is transparent in order to not block the view (see figure 6.2).

This way of displaying a TOR was for example noted in the vehicles during the benchmark. There is no smooth transition between the colors. This may be because drivers in LoA 2 are not expected to wait until the TOR reaches 'the red hands on the steering wheel' symbol. However, in a LoA 3, where the user has only temporary attention on the road and the driving (since the user can do some non-driving related task) it would be more reasonable to show a smoother transition to avoid automation surprises. This could help facilitate the communication and in turn the cooperation between the user and the AS. This concept has low system transparency, since the amount of information that is displayed on the interface is very limited. This concept is considered the baseline and is compared against the other concepts, in order to find out which of the concepts that works the best.

Figure 6.2: Concept A

Concept B

Concept B is based on the idea that all the symbols are displayed at the same time, but the active symbol is more visible, with higher contrast against the background and a white frame around the symbol. The other two, non-active symbols, are dimmed. The background in this concept is dark grey since it makes the symbols and the white frame more visible. When the concept is shown in the HUD, the background is transparent to not block the view (see figure 6.3).

The strength of this concept lies in its ability to make use of the “dark cockpit” approach (cf. Guidelines, i.e. “Take inspiration from dark cockpit; show changes in information”) by fading out less important information to enhance more urgent. More information is mediated from the AS to the user, since all the different stages (green, yellow, red) are shown to the user. Therefore, this concept has higher system transparency which could help clarify that a TOR is a cooperation.

In this concept the symbols are displayed from left to right: green, yellow and red, since we from the western world read from left to right and most often interpret information from that direction. A left to right direction also indicates that something will happen soon, i.e., in the future, which is the case with a TOR.

Figure 6.3: Concept B

Concept C

Concept C is also based on the idea that all the symbols are visible at the same time, but the steering wheel symbols are dark gray and the color box behind is in the colors green, yellow and red. The background is medium gray (see figure 6.4). Using and changing the color behind the steering wheels creates higher contrast, which can make it easier to notice when a TOR occurs, since the box moves and lights up in another color. This concept does not make use of the "dark cockpit" approach since the focus is on the color box behind the steering wheel symbols. Concept C has the same level of transparency as concept B. When the concept is shown in the HUD, the background is transparent in order to not block the view.

Figure 6.4: Concept C

Concept D

Concept D is based on a scale. When the AS is switched on and everything works as it should, the green symbol is visible. When it is time for a takeover request, the scale appears, which goes from the automation symbol, i.e., green steering wheel, to 'gray hands on the steering wheel' symbol. The steering wheel with hands is gray since the AS is still activated. An arrow moves to the left since the TOR aims to inform the driver to take back control, i.e., the arrow moves from automation to manual mode.

A yellow color in the arrow begins to move towards the gray symbol with hands on the steering wheel. Then, the yellow color in the arrow turns into orange and finally red. When the arrow moves to the left, the automation symbol to the right is still green because AS is still

active, but the symbol becomes lighter and lighter as the arrow becomes more and more red. This idea is based on the “dark cockpit” approach, i.e., fading out less important information to enhance the more urgent information.
When the arrow is red at the end of the scale, the scale disappears and a larger red symbol with hands on the steering wheel, and the text ‘Please take over’ appear. On HDD the background is dark grey and on HUD the background is transparent, in order to not block the view (see figure 6.5).

The strength of this concept is its ability to show a scale which the user can follow during the transition. This prevents confusion and / or surprises for the user as the AS communicates the flow with a visual countdown with color. This creates higher system transparency than the previous concepts, since more information is shown about the transition which could enhance the feeling of cooperation between the user and the AS. The moving scale can also make it easier for the user to notice the TOR if the driver is involved in a non-driving related task. Since this concept displays more information about the transition, the display can feel cluttered which creates information overload and makes it difficult to get an overview of all the relevant information.

Figure 6 5: Concept D

Concept E

Concept E is based on the same principle as concept D, but instead of the arrow showing the colors, it is a circle that moves on the arrow towards the gray steering wheel with hands symbol. The colors go from yellow, orange and red. The background is dark grey and when displayed at the HUD it will be transparent in order to not block the view. This concept also displays more information about the transition which means that there is high system transparency (see figure 6.6).

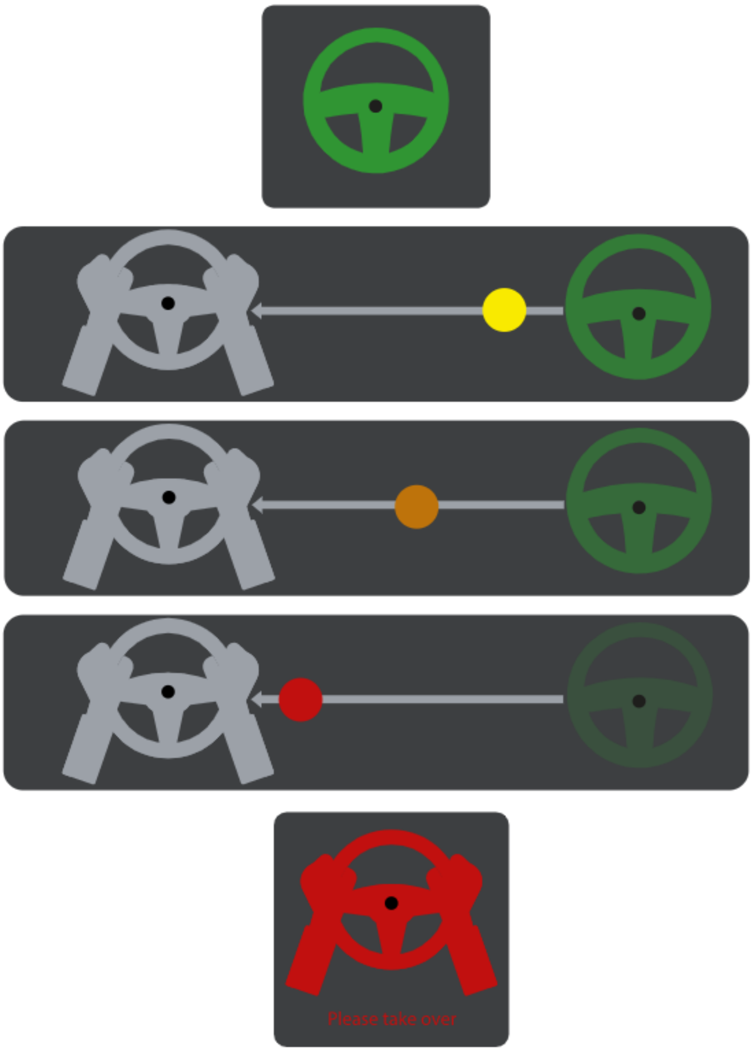

Figure 6.6: Concept E

6.3 Concept Evaluation with Users

The second part of the concept development concerns the concepts evaluation with users. First, the evaluation methods are described, then the user evaluation is presented, and lastly a discussion regarding the results is presented.

6.3.1 Method

The evaluation session was scenario-based and included two different tasks: *Task 1: Complete user- vehicle scale* and *Task 2: Compare the concepts*. The evaluation of the concepts was made by involving potential users of a semi-AV. Since there are many different types of users who drive a vehicle, the participants for the evaluation should reflect this variation. Therefore, age, gender and driving experience were relevant factors to consider when choosing the participants.

6.3.1.1 Introduction & Driving Scenario

Due to the Corona situation, physical meetings with users were replaced by digital meetings over Facebook messenger. Shortly before the meeting started, a Google presentation was sent out to each and every participant. All the participants were invited in the editing mode. The participants were asked to open the presentation, but they were not allowed to scroll through it.

The interviewer then informed the participant that they were allowed to skip a task/question or cancel the entire evaluation at any time. Information about anonymity was also explained. Before the interview began, each participant was asked if it was okay to record the sound. The participants were also informed that all the data were to be used only for this evaluation.

Before the evaluation started, the participants were asked to answer four short questions about their age, gender, driving experience and experience of driving a vehicle with an advanced automated system. An advanced AS was explained as a vehicle with features like for example Adaptive Cruise Control (ACC) and Lane Tracing Assist (LTA).

Thereafter the participants were asked to read through a short description about semi-AVs. The information considered AS with focus on level 3 take-over processes, e.g., how a TOR works and why it appears. This information was necessary to understand to be able to evaluate the concepts. By providing this information it was also ensured that all participants started the evaluation with the same information. The information could be found in Appendix H. The evaluation of the concepts was based on a driving scenario that was described in a text. The driving scenario reads as follows (in the presentation, the scenario was in Swedish):

You are on your way home from work and drive on the highway. The automated system (AS) is activated, and a green symbol is visible on the display behind the steering wheel. Everything seems to work error-free and smooth. You look down at your mobile and start writing a message to your friend about tonight's plans. Since you drive a vehicle with LoA 3, your attention switches between your mobile and the road, but every now and then you look up on the road and on the display to see if you received a TOR notice from the system. In about 800 meters, a queue begins to form, and a TOR notice is visible on the display.

After the participants had read through the introduction and the driving scenario, they were informed that it was okay to go back and read the scenario again. Thereafter, they were able to complete the first task, i.e., *Task 1: Complete user- vehicle scale,* which was similar to the method used in user study (see chapter 3.2.1). Before the task, the participants were given the opportunity to test to drag and drop the color dots onto the user ↔ vehicle scale, in order to be comfortable with the first task. They also got to read an explanation regarding the words, which reads as follows:

Responsibility: *Having responsibility can be explained as being responsible for the situation, the actions that are being performed and the consequences of those actions.*
Control: *The ability to have control can be explained as having a form of overview as in monitoring a situation or a process where one has options to choose course of action.*

6.3.1.2 Evaluate the Concepts

When the users had read through the explanation of the words, the concepts were shown in the presentation. The concepts were presented one by one, and all different modes of a concept were shown sequentially, e.g. first a green symbol, then a yellow symbol and finally a red symbol.

In order to minimize the learning effect (cf. Albert, Tullis & Tedesco, 2010), all the concepts were displayed in different order for each user, except for the first concept (A) which was always the first one, since it is the benchmark concept that was compared to the other concepts. This meant the first participant experienced the concepts in order A, B, C, D, E, the second participant in order A, C, D, E, B, the third participant in order A, D, E, B, C and so on.

Task 1: Complete User ↔ Vehicle Scale

The user-vehicle scale, similar to the one in the user study (see chapter 3.2.1), was chosen also for the concept evaluation. The participants' task was to place two color dots, a blue dot which stands for 'responsibility' and an orange dot, which stands for 'control' on the available user ↔ vehicle scale next to each concept. These colors were chosen since they provided good contrast next to each other. The purpose of the task was to find out what the concepts meant to the participants, how they interpreted the symbols, the different modes and the colors, in relation to the driving scenario.

The first concept (A), which was displayed as the first concept for all participants, consisted of three symbols with different colors, which are displayed in different stages during the drive. For example, when the green symbols were displayed, and if the participant thought that responsibility lies with the user, the participant placed the blue color dot at 'the user' end of the scale. If the participant thought that control lies with the vehicle, the participant placed the orange color dot at 'the vehicle' end of the scale. When the participant had placed both the color dots on the scale, the scale was copied and used for evaluating the yellow symbol and so on. The participant was able to move the dots on the scale if the participant thought that the relation between responsibility and control had changed due to the status of the symbol.

During the *Task 1: Complete user ↔ vehicle scale*, the evaluation method *concurrent think-aloud protocol* was used. The method lets the participants articulate whatever comes into their mind, i.e., what they are doing, thinking and feeling, as they complete the task (Martin & Hanington, 2018). In this case, the participants were asked to explain what they thought when the symbols changed, why or why not they moved the colored dots and why they placed them on a certain spot on the scale. By letting the participants move the color dots when the TOR changed, they had a chance to indicate and show how they interpreted the displayed information during the TOR. By showing their answers on scales, one can visualize the changes that were made by the participants, which makes it easier to interpret how they understood the concepts.

When the first concept was evaluated, the next concept was shown and evaluated in the same way.

See figures 6.7, 6.8, 6.9 and 6.10 for an evaluation example of concept A from the presentation. The participants' task was to drag and drop the two color dots from the box in the right corner of the image to the user-vehicle scale (figure 6.7). Next, the participant has placed the color dots on the scale (figure 6.8). The blue color dot is closer to 'the user' end and the orange color dot is closer to 'the vehicle' end. Thereafter, the next symbol was shown and the scale from the last image was copied (figure 6.9). The participant's task was to move the color dots on the scale if the participant wanted to do that. In this example the participant chose to move both the dots closer to 'the user'. The words in the box in the upper right corner have the same color as the dots, so that the participants could remember which color represents which word. The last symbol, the red one, was shown and the participants' task was to move the color dots on the scale if the participant wanted to do that (figure 6.10). In this example the participant chose to move both color dots to 'the user' end of the scale. The words in the box in the upper right corner have the same color as the dots, so that the participants remembered which color represents which word.

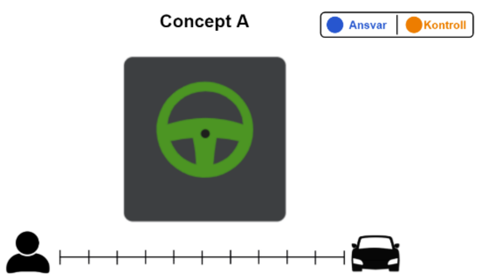

Figure 6.7: The green symbol is first shown in concept A.

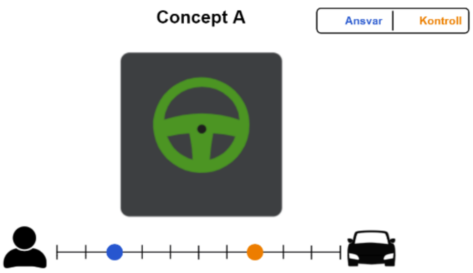

Figure 6.8: The participant has placed the color dots on the scale.

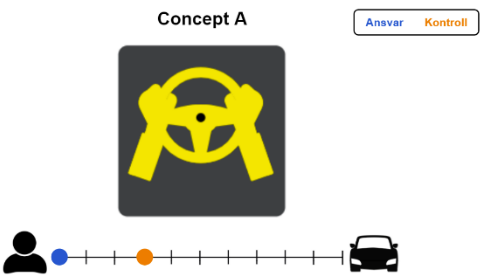

Figure 6.9: The yellow symbol is shown

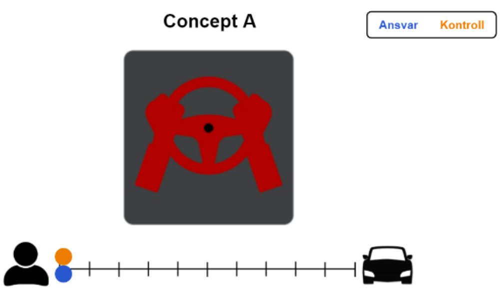

Figure 6.10: The red symbol is shown

Task 2: Compare all the Concepts

When all the concepts had been evaluated separately, they were displayed all together in one image in the presentation, in order for the participants to compare all the concepts. Before the second task was shown, the participants were asked to read a short description about the two displays in the vehicle where the information could be displayed: the *head-down display (HDD)* and the *head-up display (HUD)*. When the participants had read through the short information regarding the displays, the image with all concepts were shown (figure 6.11).

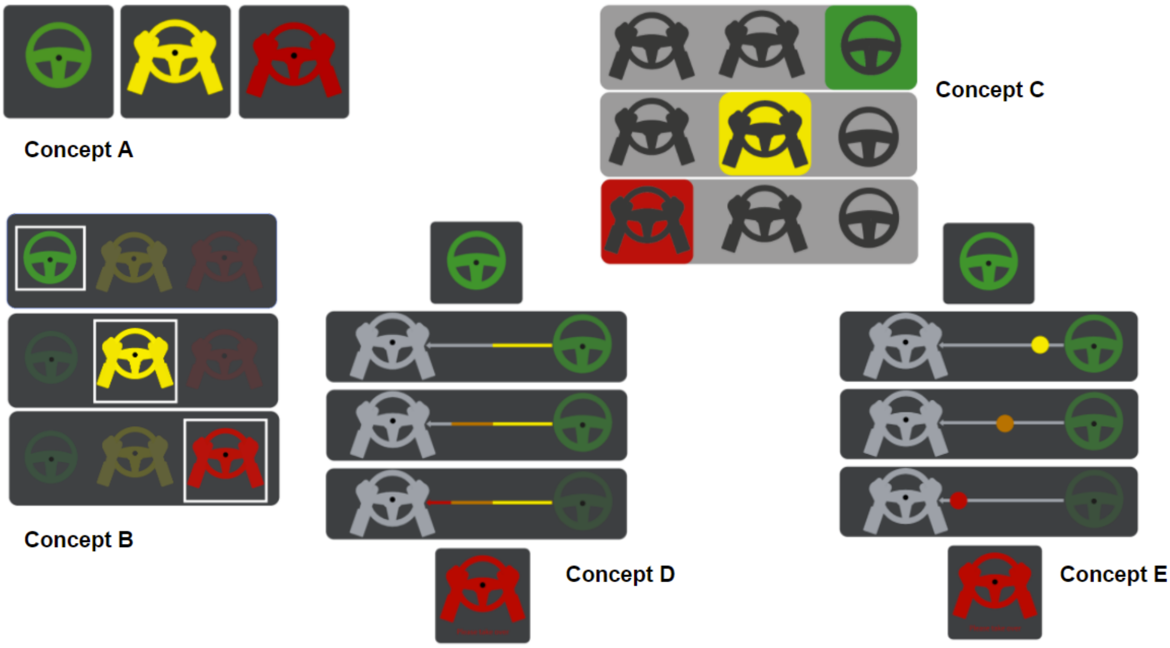

Figure 6.11: All the concepts

In this case the method used was semi-structured interviews, which is a method that combines both structured and unstructured questions which is a way to gain a deeper understanding of the users' answers and opinions (Martin & Hanington, 2018). The following questions regarding the concepts were asked and created the basis for the discussion with the participants:

1. Which one of the concepts do you prefer the most and why?
2. Which of the following concept do you think facilitates a TOR the most in the driving situation explained in the scenario?
3. Which of these concepts do you think facilitates cooperation the most during the transition? (The concept that makes it most clear and understandable that you, as a user, cooperates with the AS)
4. If one of these concepts were placed on both HDD and HUD, which one do you think is the least visually disturbing and why?

6.3.2 Analysis

After the interviews have been completed with all participants, all their answers were analyzed. All the participants' responses to the *Task 1: user-vehicle scale* were compiled in a document and were compared against each other in order to be able to find patterns. A summary of all scales from each participant was compiled for each concept in order to be able to analyze the participants' answers and to visualize the color dots position on the scales. The recorded material was listened through, and notes were made in a document.

6.3.2.1 PNI

The participants' thoughts regarding the different concepts were compiled by using the method PNI and were summarized in a PNI table. This method was used since it provides a good structure of the strengths and weaknesses of different alternatives and an overview that is easy to interpret.

6.3.3 Results of the Concept Evaluation with Users

There were 10 participants in the concept evaluation, five women and five men with an age distribution between 25 and 66 years (mean =38.9). The driver experience was measured by a scale from 1-10, where 1 corresponded to little experience and 10 to high experience, and the participants were asked to answer based on their own judgment. There were eight participants that chose a 5 or higher whereas two participants chose a 3 on the driver experience scale. The majority of the participants had limited experience of a vehicle with an automated system, and they chose between 2 and 4 on the scale. One participant had more experience of driving vehicles with AS and chose an 8 on the scale.

6.3.3.1 Result Task 1: Complete User ↔ Vehicle Scale

The result of the first task of the evaluation clarified that there is a clear difference between how the dots representing the two words *responsibility* and *control* were placed on the scales when the automated system was activated. None of the participants placed the responsibility dot in the middle of the scale or closer to the vehicle, regardless of the active symbol and the different concepts. The responsibility dot was always closer to the user end of the scale than to the vehicle end. However, the control dot did change position on the scale more, depending on the active symbol. When the symbols were green, the control dots were often closer to the vehicle end, but as the symbols turned yellow, the control dots started to move towards the user end, which indicated that all the participants interpreted the yellow symbol as a warning from the system. When the red symbol was active, both the control dot and the responsibility dot were placed to the left on the scale, i.e., on the user end of the scale, regardless of the different concepts shown in the evaluation.

The result from the first task, Complete user ↔ vehicle scale, clarified that control is more changeable between the user and the vehicle since it can be both shared and divided. Responsibility however, showed to be more static in its position and moved in smaller steps to the user side of the scale.

Concept A

When the green symbol was active and displayed, all participants placed the responsibility dot closer to the user end of the scale whereas the control dot was closer to the vehicle end of the scale. When the green symbol was replaced by the yellow symbol, the control dots started to move closer to the user end of the scale. When the red symbol was displayed, all participants placed both color dots on the user end of the scale; one participant placed the control dot very close to the user end of the scale (see figure 6.12). Here are some examples of what the participants said when the green symbol was active:

> *"I have both responsibility and control when this symbol is displayed, but the control is distributed between me and the system. But I have the responsibility."* ID 1

> *"I have the responsibility, but the system has more control."* ID 2

> *"The responsibility always lies on the human, you never know 100% what could happen to the car, and something can go wrong."* ID 3

> *"I am skeptical. I had not written that text message regardless of if the vehicle is a level 3 or not, therefore responsibility is closer to the user and control is a little more in the middle."* ID 6

When the yellow symbol became visible, a majority of the participants chose to move the control dot closer to the user end. They did this because they thought that the system communicated important information regarding the driving situation. One participant explained it like this:

> "*When the yellow symbol is shown, the control dot moves closer to me as a driver, I have to be involved and ready to take over, because I am not only responsible now, I also have more of the control. The system expects that kind of action from me as a driver."* ID 5

Figure 6.12: Results Concept A

Concept B

When the green symbol was active, all the participants placed the responsibility dot closer to the user end. The control dot was now placed closer to the vehicle end. When the yellow symbol became brighter, the control dots started to move closer to the user end. When the red symbol became brighter, all participants considered that the responsibility dot and the control dot were placed on the user end of the scale, i.e., both responsibility and control lie with the user (see figure 6.13).

> *"When the green symbol is active there is more responsibility on the user, but the vehicle has the control. When the symbol changes to the yellow, the control is more in the middle of the scale, it is more shared control. When the symbol turns red, everything is on the user. Something else is not conceivable."* ID 2

> *"When the green symbol is active, I as a driver have the responsibility, but the vehicle is driving, which means that the vehicle has more control. Therefore, I can focus on my SMS."* ID 5

Figure 6.13: Result concept B

Concept C

When the green symbol was active, the majority of the participants placed the responsibility dot closer to the user end and the control dot closer to the vehicle end. When the yellow symbol became brighter, the control dots started to move closer to the user end. When the red symbol became brighter, all participants considered that responsibility and control lie with the user and placed both the color dots on the user end. Below are some quotes from participants during the evaluation of concept C:

> *"I can lose control, but I am still responsible for that. It is my fault if I made a misjudgment. Therefore, when the green color is visible, the control is closer to the vehicle and responsibility is closer to the user."* ID 1

> *"When the yellow color is visible, that creates a signal that it is time to take back the control from the system."* ID 5

> *"I think it will take many more years before I can trust an automated vehicle. I chose to put both control and responsibility close to the user, regardless of the color being visible. But when the green color is visible you can be a little calmer."* ID 6

Figure 6.14: Result concept C

Concept D

When the green symbol was active, the majority of the participants placed the responsibility dot closer to the user end and the control dot closer to the vehicle end. When the green symbol started to fade out and the yellow line moved closer to the grey symbol, all the participants moved the control dot closer to the user end. When the line gradually became orange, some small changes were done; and dots were moved closer to the user end. When the line became red, all participants considered that responsibility and control lie with the user and placed both color dots at the user end. It was only one participant, participant 4, that placed the control dot very close to the user end of the scale when the red line was active. All the other participants interpreted that when the color red is visible, there is not any time left to wait until one needs to act (see figure 6.15). Many of the participants thought that the different color steps made it more difficult to understand what the system tries to communicate and that it was confusing that the color red appeared more than once.

> *It was easier when you saw a yellow steering wheel symbol, this line makes it more difficult. "ID* 1

> *"When the yellow line appears, the system communicates that I need to take over in a short manner of time. Therefore, control is closer to the user. When the line turns orange I interpret that as there is now very little time left until the system is deactivated, but since it is not red I choose to not move the dots on the scale. "* ID 3

> *"When the yellow line is visible, I think there is quite much time left until the driver needs to take back the control. Therefore I place the control dot in the middle. When the line turns orange, I choose to put the control dot closer to the user, but since it is not red it seems that it is some time left."* ID 5

> *"I am not going to put any of the color dots on the right side of the scale, regardless of the symbols and colors. I don't trust the system that much."* ID 6

> *"Is it worse when the orange is visible? I am a little confused."* ID 6

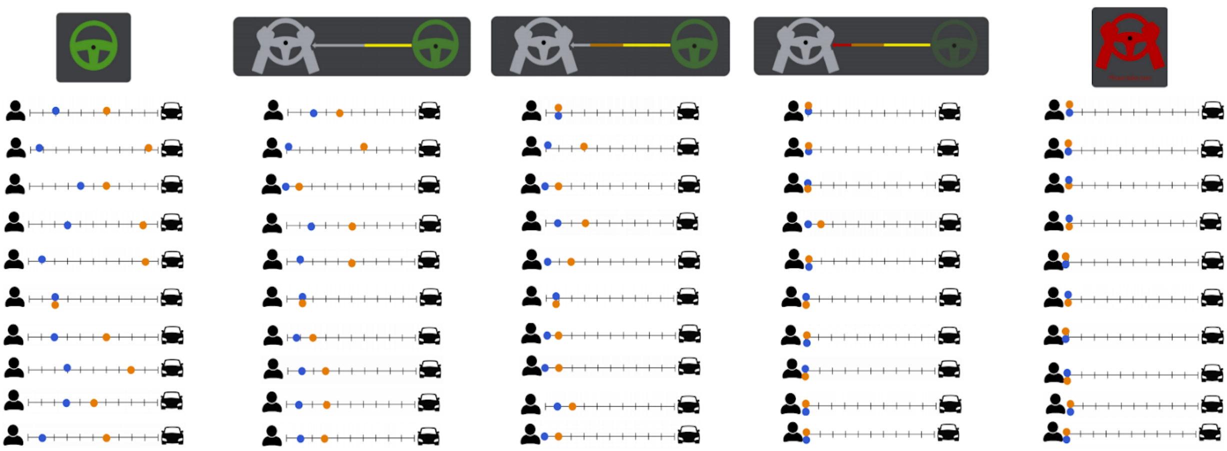

Figure 6.15: Result concept D

Concept E

When the green symbol was active, the majority of the participants placed the responsibility dot closer to the user end of the scale and the control dot closer to the vehicle end. When the green symbol started to fade out and the yellow circle moved closer to the grey symbol, all the participants moved the control dot closer to the user end. When the circle became orange, the majority moved both the color dots closer to the user end. When the circle became red, a majority of the participants considered that responsibility and control lie with the user and placed both the color dots at the user end. However, participants 2 and 4 chose to place the control dot very close to the user end of the scale and moved them to the user end when the line disappeared, and the red steering wheel symbol was shown. All the other participants interpreted that when the color red is visible there is no time left to wait until one needs to act (see figure 6.16). Many of the participants thought that the different color steps made it more difficult to understand what the system tries to communicate and that it was confusing that the color red appeared more than once.

> *"The system is about to change from auto to manual mode, therefore I move both the dots closer to the user when the yellow circle is visible. When the red circle is shown, I think everything is on the user."* ID 3

> *"The control dot is more in the middle, since the yellow circle is still very close to the green symbol. It is difficult to know if it's serious when it is so much time left to the grey take over symbol."* ID 4

Figure 6.16: Results concept E

6.3.3.2 Results task 2: Compare the Concepts.

In *Task 2: Compare the concepts*, the participants were asked to compare all the concepts by answering the following four questions:

1. Which one of the concepts do you prefer the most and why?
2. Which of the following concepts do you think facilitates a TOR the most in the driving situation explained in the scenario?
3. Which of these concepts do you think facilitates cooperation the most during the transition? (The concept that makes it most clear and understandable that you, as a user, cooperate with a vehicle)
4. If one of these concepts were placed on both HDD and HUD, which one do you think is the least visually disturbing and why?

Concept A

All the participants thought that concept A was very simple and clear and thought that it is difficult to misunderstand the message from the system. The design is compact and does not require much space, which was mentioned as an advantage. Some of the negative aspects mentioned about the concept were that it is very on/off, i.e., there is no soft transition between the symbols since it changes from green, yellow and red, which feels more abrupt. None of the participants thought that concept A facilitates cooperation since it lacks a flow or a soft transition. Concept A was preferred to be placed on HUD, since it takes up minimal space.

Concept B

Concept B was chosen as the overall favorite by most of the participants. The participants thought that concept B was very easy to understand and that the white box around the symbol made it clear which one of the symbols (and hence modes) that was active. However, some of the participants pointed out that the color of the frame around the symbols may not have to be white. The participants thought that the concept had a clear design and that the design communicated that there is a cooperation between the user and the AS.

One participant explained that concept B is very easy to interpret quickly since one understands what the symbols means and what the system wants to communicate. Many of the participants mentioned that concept B was better when it comes to understanding the process/transition. In comparison with concept A, concept B was the more preferred since it gave the user more information about the transition which created more trust to the AS and in turn a more positive feeling regarding the TOR:

> "When *I am driving I want the most of my attention on the road. Concept D and E demands more of your direct vision and more of your attention in order to be able to interpret what the system communicates. Therefore I prefer concept B, since it lets me have the main focus on the road. It is the clearest concept since you see all the indicators, the active one is framed and highlighted.* "ID 6

> *"I think concept B is very clear and easy to understand. It feels safer when the system displays more information and shows a transition."* ID 2

Another thing that was mentioned was that it can be an advantage that each symbol has its own position, meaning that the green is always to the left. This can help the user to understand the message merely by seeing where the highlighted symbols are placed. One negative thing that was mentioned regarding concept B was that since all the symbols are displayed all the time, the concepts take up more space in the display which can be a negative factor.

There were some different opinions regarding the position of Concept B. Many of the participants preferred the concept to be placed in the HDD and some also in the HUD. One participant thought that the concept was more suitable for a HDD than a HUD, since it is important that there is not too much information in the HUD, so it does not obscure the view. One idea that was mentioned was to combine concepts A and B, where concept A is more suitable for a HUD and B more suitable for an HDD. Since both concepts are based on the same symbols and colors, a combination of the two could work.

Concept C

None of the participants considered concept C was a favorite. The most common reason was that the steering wheel symbols were dark grey and that the color was placed behind the symbol. All participants thought that it is easier to understand the system's message when the symbols are colored. One participant explained it like this: "*Since you are very used to seeing the symbols in colors, this concept creates confusion and makes it more difficult to interpret the information as quickly as possible."* (ID 3). However, by using the color in this way, i.e., behind the symbols, there are more colors visible, which can be an advantage. However, when the symbols are dark grey one immediately thinks that they are not active and that is why this concept makes communication between the user and AS more difficult. None of the participants chose concept C as an answer to the question regarding position since they preferred other concepts, mainly because concept C was difficult to interpret.

Concept D

None of the participants considered concept D to be a favorite. The most common reason was that there is too much color and too much information which make it more difficult to understand what it means. Another reason was also that it takes up more space in the display. One participant said that *"It is more detailed, and you have to look more carefully in order to be able to understand. However, it is good that there is something that constantly moves, but I prefer concept A and B."* (ID 4).

Another participant mentioned that there is too much information regarding the transition and that it is difficult to understand what it means in reality: *"I prefer to have three colors instead of four. I think it is enough. More colors and steps create uncertainty of what I as a user should do. I mean when the orange color is shown is it time to take over or can I wait until the red color?"* (ID 5).

The same thoughts were expressed by other participants, such as participant 6 who explained that one is so used to the colors green, yellow and red. If something turns yellow, one pays a little attention to it, and when it is red one pays a lot of attention. Red is always more serious than yellow. The color orange can therefore create confusion since it is somewhere in between the two other colors. It was good that the concept combines text and symbol when the red color is visible, since it reinforces the message that the situation is serious. None of the participants chose concept C as an answer to the question regarding position since they preferred other concepts, mainly because concept D required more space and more attention from the user.

Concept E

There were mixed opinions regarding concept E. None of the participants though this concept was the best. Common reasons were that it takes too much time to understand, that there are too many details and that it takes up too much space, as concept D did. Several participants said that both concepts D and E demand more of your direct vision and more of your attention, which makes it more difficult to interpret what the systems communicate. Many participants also mentioned that the design of the interface inside cars should be very simple and clear, and that concepts D and E demand more cognitive effort from the user, in order to understand the messages from the system.

One positive aspect of concept E was that it shows the transition and communicates that there is cooperation between the user and the vehicle. One participant said that concept E might be good after more use experience. Another positive thing that was mentioned was that it is good that the concept combines both symbol and text when the red color appears. None of the participants chose concept E as an answer to the question regarding position since they preferred other concepts, mainly because concept E required more space and more attention from the user.

Analysis

PNI

A PNI table summarizes the users' thoughts regarding the different concepts (see table 6.1).

Table 6.1: PNI table summarizes the users' thoughts regarding the different concepts

PNI	POSITIVE	NEGATIVE	INTERESTING
Concept A	Simple and clear, one cannot misunderstand what the symbols mean. Compact and does not take up too much space which is good.	The concept is very on or off, there is no flow or transition between the symbols. Difficult to get a complete picture of what is happening. It is not clear that there is a cooperation between the user and the vehicle.	Basic design, easy to understand.
Concept B	Clear design, easy to understand. One can use the peripheral vision and quickly understand what is happening. By showing a transition, the TOR feels safe which in turn generates higher trust to the AS.	The fact that all symbols constantly are shown, means that the design takes up more space than, for example, concept A.	The symbols that are not active are toned down. It is very easy to understand which one is active by using a frame. It is good that each symbol has a position, so that one knows what it means when the left symbol is in focus.
Concept C	More color	The steering wheel symbols are dark grey which creates confusion. It is not as clear as when the symbols are colored. All symbols are visible at the same time.	-
Concept D	It is good that one can follow the development, the transition. When the red symbol is visible there is also a text message which makes it even clearer.	There is too much color, and the design is not clear. It is much easier to see a yellow symbol than a yellow line. Takes up too much space. Hard to include both on a HDD & a HUD. Requires more of your peripheral vision.	It is a flow where you see the change. The green symbol becomes less visible as the time goes on.

		Requires more attention to interpret what it means.	
Concept E	Shows the transition clearly. Can be good when you have become more used to it. When the red symbol is visible there is also a text message which makes it even clearer.	Takes a little too long to understand what it means. Too many details, takes up too much space. Difficult to have both on HDD & HUD. Requires more of your peripheral vision. Requires more attention to interpret what it means.	Shows that it is collaboration between the user and the vehicle. The green symbol becomes less visible as the time goes on

6.4 DISCUSSION

6.4.1 Task 1: Complete User ↔ Vehicle Scale

The aim of the concept development phase was to create possible solutions for TOR by implementing different levels of system transparency. The challenge was to find an adequate level of system transparency, which communicates the right type of information at the right time, without creating information overload or confusion.

The result from task 1, 'complete the user-vehicle-scale', clarified that control can be both shared and divided between the user and the AS. Responsibility however, showed to be more static in its position and moved in smaller steps towards the user end of the scale. None of the participants placed the responsibility dot in the middle of the scale or closer to the vehicle end, regardless of the active symbol and the different concepts. This clearly indicated the perception that responsibility lies with the user, not the vehicle. Also, the majority of the participants did move the responsibility dot closer to the user end when the green symbol changed. This can be interpreted as though that the user expects to be the one responsible when using a semi-AV, but that control can be considered to be more changeable and shared between the user and the AS, as long as the user can override the AS.

During the first task, the participants were asked to think out loud and described why they placed a dot on a certain spot. The method gave more depth to the evaluation and contributed with a lot of interesting thoughts. From the participants' explanations it was clearly noted that none of them thought that the AS can be the one responsible. However, the responsibility dot was never placed at the user end of the scale when the green symbol was active, regardless of which concepts were shown. When the red symbol was active, the responsibility dot was always placed at the user end of the scale. This can be interpreted as though that it can be difficult to grade the word 'responsibility' on a scale, and especially on a scale ranging from 0 to 10. One could have used a scale ranging from 0 to 1, where 0 could have described the user has the responsibility, a value 1 that the AS has the responsibility and a value 0.5 that responsibility is shared. A shorter scale like that could have been easier to interpret and understand. However, since it was noted from previous results that control could be shared between the user and AS, this might have been more difficult to see if the scale had been shorter. Also, since the task aimed to visualize the relation between the two words (and concepts), responsibility and control, and how they correlate and affect each other, a shorter scale could have made that more difficult to visualize.

As mentioned in the user study, personal traits such as driver experience, technology interest and future beliefs can affect users' understanding of responsibility, and in turn their trust or acceptance of semi-AVs. As mentioned in the participants' quotes, this seems to be a central factor which applies to the users' understanding, both when it comes to responsibility and control. Also, as this thesis project showed, responsibility is a complex term, which is affected by other related factors such as control and trust. It became very clear during the evaluation with the users that it is difficult to discuss responsibility only, without taking other concepts into account like for example control and trust.

Before the participants completed the first task, they were asked to answer four questions regarding age, gender, driver experience and experience of using a vehicle with AS. The author chose to not ask a question regarding the number of years with a driver license, since the number of years does not necessarily correlate to how much experience a person has. Someone can have had a driver license for over 30 years but only drives a few times a year, whereas another may have had a driver license for five years but drives every day. Therefore, they were asked to rate their own experience level based on their own judgement.

The two words, responsibility and control were explained based on the insights and results from the user study (see chapter 3.3.1*)*. By giving the participants a definition of the words, the intention was that everyone started the task with the same understanding of the words. However, since internal factors can affect the users' understanding, one could also have let the participants base their answers on their own interpretations of the words. A predetermined definition may have affected their view or opinion, which could have led to uncertainty and/or confusion among the participants. However, letting the participants interpret the meaning of the words on their own could also create uncertainty and/or confusion among the participants.

The color of the dots that were used in the evaluation were first grey and brown, since these colors are natural and do not disturb the other colors in the concepts. However, since the thesis report needs to work for both digital and print versions, the colors were changed to two brighter colors, blue and orange, which creates a clear difference between the two words. It also makes it easier to compare the results so that the two colors do not risk fade into each other.

6.4.2 Task 2- Compare the Concepts

The result from task 2 showed that the participants preferred concept B the most. Concept A was also preferred, but the more visible transition in B was mentioned as an advantage. Concept A had low system transparency, since the amount of information that was displayed on the interface was low; only the active symbol was shown in concept A. However, Concept B had higher system transparency since more information is mediated from the AS to the user; all the different stages (green, yellow, red) are shown at the same time but with different contrast on the symbols and a colored frame around the active symbol. The symbols in concept B also have a specific position since the symbols change from left to right. By presenting the TOR gradually, the users perceived the TOR as safer which in turn generated higher level of trust.

The making use of the "dark cockpit" approach was appreciated by the participants and many thought it made the TOR very easy to understand. On the question which of these concepts you think facilitates cooperation the most during the transition, no one chose concept A, but many chose concept B. That could indicate that the dark cockpit approach and the system transparency level communicate the appropriate amount of information in order for the user to feel that there is a cooperation between the user and the AS.

As described in the result, concept C was not the favorite of the concepts, since many of the users thought that it was more difficult when the color was placed behind the steering wheel symbol and that the grey symbols created confusion. One conclusion that could be drawn from the result is that it is important to use the commonly used colors (like green, yellow and red) and, further, to not change where the color is visible, i.e., it should be on the steering wheel symbol, not behind or on a line/circle. All participants thought that concept D was the concept that was the most difficult, since it both had more colors and a line which several of the users mentioned would be too detailed to pay attention to during a drive.

Both concepts D and E showed more detailed information regarding the stages of transition which resulted in that many participants thought it was difficult to interpret the information from the AS and understand how to act. As one participant mentioned, the design of these kinds of TORs needs to be very easy to understand because as a driver one cannot be confused or uncertain about what the AS is trying to communicate. As mentioned in the result, the color orange created that kind of uncertainty since it is positioned between yellow and red. Also, more steps did not make the transition feel safer and more effective but instead the opposite. That indicated that a higher level of system transparency does neither equal a more safe and effective transition, nor does it simplify cooperation between the user and the AS. Also, it did not make it clearer and easier to understand the AS information regarding status, limitations and abilities.

The evaluations were made digitally due to the covid-19 pandemic. By using Google presentation and Facebook messenger it gave the participants the opportunity to carry out the evaluation in a comfortable place and not having any test leader/interviewer next to them which could create stress. There are evidently advantages as well as disadvantages with both digital and face-to-face meetings which one has to handle in the best possible way, depending on the situation.

Before the concept evaluation, two questions were asked, which were based on the previous finding regarding control transitions:

1. How much information regarding the AS's status, limitations and abilities is needed for the user during TOR in order for an efficient and safe control transition? and
2. How can TORs be conceptualized visually using an HDD and/or a HUD?

Based on the concept evaluation, these questions have now been answered and can be summarized as follow:

In order to create an efficient and safe control transition, the AS needs to maintain a system transparency level between low and high which means that the information regarding the AS's status, limitations and abilities is best communicated with a transition/flow. This emphasize that there is a cooperation between the user and the AS. A too low and a too high system transparency level can instead create confusion and uncertainty at the user. Therefore, maintaining a level that is between these two, where the AS communicates the right type of information at the right time, is considered to be important during a TOR in semi-AVs (LoA 3).

Also, the AS needs to communicate information that is quickly understandable and allow the user to make use of their peripheral vision. By making use of the dark cockpit approach, only the important information is active, which could help a user understand and interpret the TOR information and in turn reduce the risk for information overload or confusion.

Regarding a position in the HDD, the TOR should be conceptualized visually by showing a transition/ flow of the TOR process, like concept B did. If placed in the HUD, the TOR should take up as limited space as possible in order to not obscure the view. Therefore concept A, the one that is used in most of today's vehicles with AS, is the most preferred option when displaying the TOR visually. A combination of the two concepts A and B could be a solution, where concept A is placed in the HUD and concept B is placed in the HDD.

7. Final Concept

7.1 Aim

The final concept intends to present an HMI design solution regarding control transitions in semi-AVs, based on the results from the concept development. The solution aims to facilitate the transition and in turn the HMC between the user and AS, in terms of efficiency, appropriateness and safety, during use of semi-AVs.

7.2 Method

The final concept was created based on the insights from the concept development phase, especially from the evaluation with the users. In order to be able to combine the most important and interesting aspects that surfaced during the concept development a short prototyping session was held in order to reach a final concept.

7.2.1 Prototyping

The prototyping session focused on the visual aspects (the look) of the TOR and its position. As mentioned in the concept evaluation, an idea was to combine the two concepts A and B. These two concepts were the most preferred ones, where concept A had the advantage of taking up little space on a display, while concept B had the advantage of showing a transition and higher system transparency. Therefore, some prototyping was performed, focusing on combining the two concepts and refining the design of the two concepts, to be able to reach a final concept.

7.3 Results

The final concept is a proposal based on the concept development and the overall findings throughout this thesis project. The final concept aimed to create an adequate level of system transparency to facilitate control transitions as well as not compromising with the users' understanding of constant responsibility.

7.3.1 Prototyping

Some minor changes have been made to the two concepts based on the insight from the user evaluation. On concept A, a colored box around the symbol was added, in order to make the symbol easier to notice and more clearly visible. On concept B, the white box has been changed to the same color as the symbol, since users thought that it was clearer and that it minimizes the risk that the white color creates confusion. Another thing that was changed was the shape of the box. In addition, when the red steering wheel symbols were active, a text with the words "please take over" was added, in order to clarify the TOR even more. An HDD and an HUD were created in order to be able to show the two concepts in a more realistic way. These are presented as the final concept.

7.3.2 Final Concept

The final concept shows an HMI solution for control transition and how this can be conceptualized visually through the use of HDDs and HUDs. In the HDD the information regarding the TOR is placed in the upper center of the display, this to make it easy to see and interpret for the user. In the HUD the TOR information is placed to the left of the display.

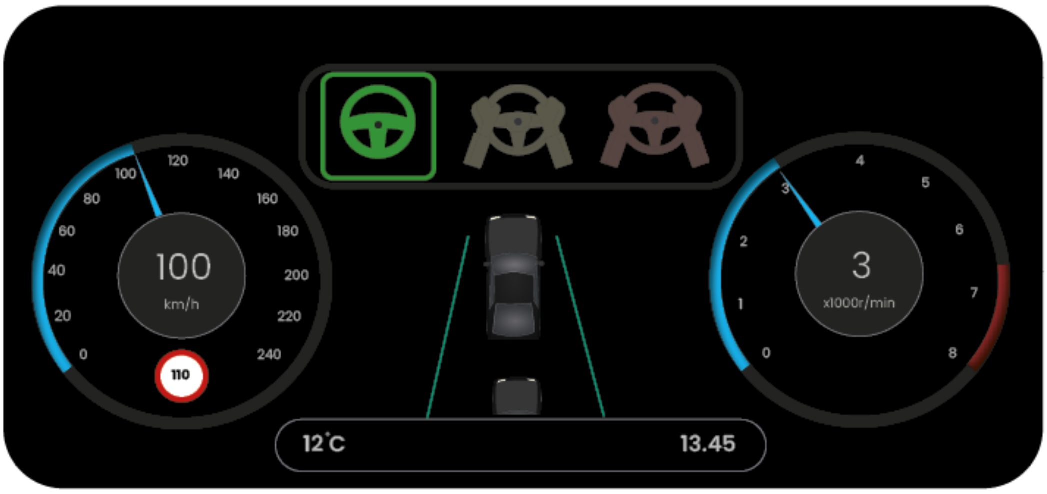

Figure 7.1: TOR is activated and works fine

When the TOR is activated and works the way it should, the two interfaces, HDD and HUD, visually present the information as shown in figure 7.1. In this mode, the AS has control and the user can carry out a non-driving related task, like for example writing an SMS. The AS communicates its status by having the green symbol active and highlighted. On the HDD the other symbols are dimmed.

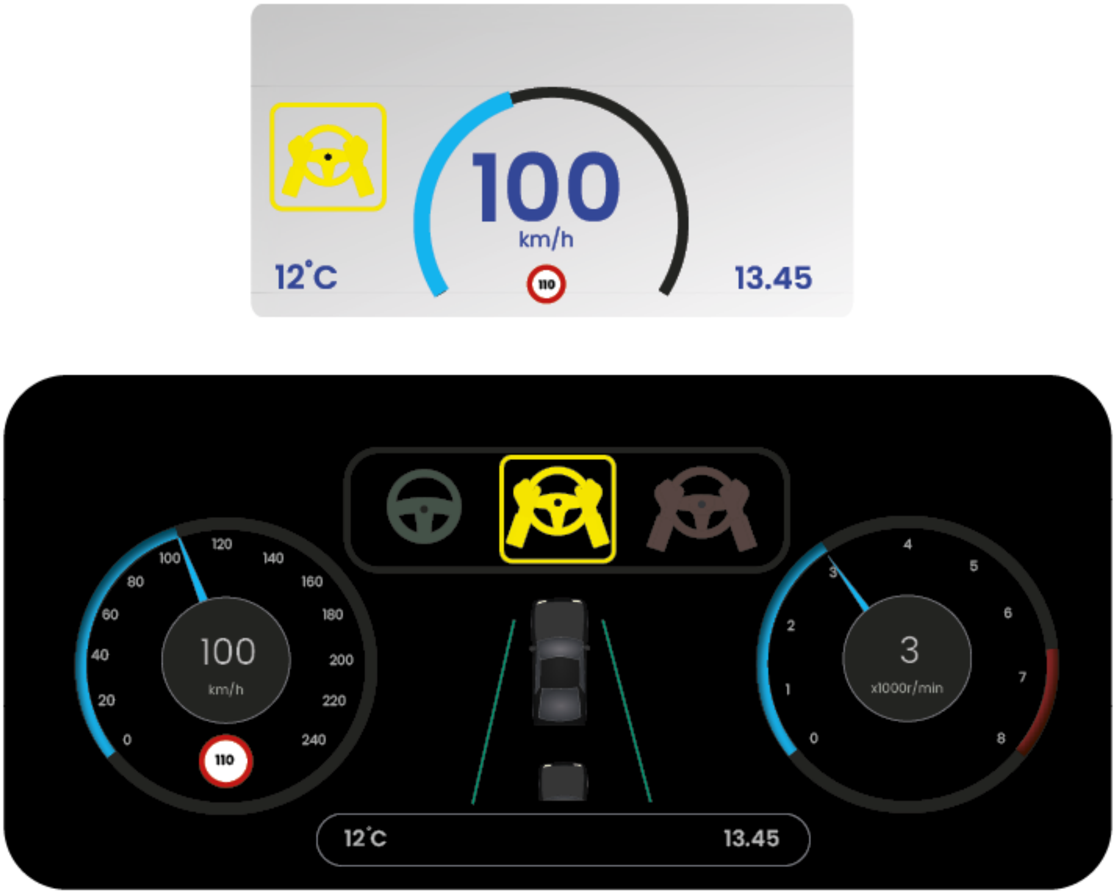

Figure 7.2: TOR begins to reach its limitations

When the TOR begins to reach its limitations and deactivate, the two interfaces, the HDD and HUD, visually present the information as shown in figure 7.2. The AS communicates that action is needed from the user, i.e., the user needs to take back the control and put his/her hands on the steering wheel. In this mode, the AS communicates its status by having the yellow symbol and frame active and highlighted. On the HDD the other symbols are dimmed.

Figure 7.3: TOR has reached its limitations

When the TOR has reached its limitations and are very close to deactivating, the two interfaces, the HDD and the HUD, visually present the information as shown in figure 7.3. The AS communicates that action is needed from the user, i.e., the user needs to take back control and put the hands on the steering wheel. In this mode, the AS communicates its status by having the red symbol and frame active and highlighted. On the HDD the other symbols are dimmed. On the HDD a text with the words “please take over!” is also added, in order to emphasize the emergency of the situation. When the driver has put his/her hands on the steering wheel the vehicle changes from automation mode to manual mode and the information about the TOR is removed from both displays.

7.4 Discussion

The two vehicle related factors - control and system transparency - were central throughout the concept development and the creation of the final concepts. Control influences the users’ understanding of responsibility and system transparency facilitates effective interactions between the user and AS. Therefore, these two factors were relevant to address in order to evaluate and present a redesign of a TOR that could result in user having a better understanding regarding control transition, when driving a semi-AV (LOA 3).

Based on the concept evaluation with the users it became very clear that control can be shared and divided between the user and AS during the different modes, whereas responsibility is something that regardless of the active mode, is closer to the user end of the scale than the AS end of the scale.

The final concept tends to solve one specific interaction aspect of control allocations, with focus on the visual aspects and position of TOR. However, since TOR should use multisensory interaction principles, and present visual, auditory and vibrotactile information it could be relevant to combine the insight from this thesis project and investigate how other communication modes and channels could help create an efficient, appropriate and safe TOR, during use of semi-AVs.

The strength of the re-design solution lies within the use of the dark cockpit approach, since it shows a clear transition/flow of the TOR process. Another strength is that the solution combines concepts A and B in order to conceptualize the TOR visually in the best possible way, depending on the display used (HDD and/or HUD). Both concepts include the same symbols and colors, to avoid confusion, which also enable a combination of the two concepts.

8. General Discussion

This chapter aims to discuss the overall approach and results for the thesis project by highlighting the strengths and discussing challenges and weaknesses.

8.1 General Approach

The general approach that has had an effect on the project can be divided into time allocation and defining the project, which are shortly discussed as follows.

8.1.1 Time

The planning phase and the allocation of available time were influenced by the fact that responsibility is difficult to assess initially. Following this, a major part of available time was allocated a literature review. This meant that the user study, as well as development of the concept, were allocated less time. However, it is important to have a firm theoretical ground in order to be able to produce a reasonable, final result. If more time had been allocated producing the final result, this would have enabled a creation phase concerning a wider spectrum regarding HMC and HMI and as well a more detailed final solution. This would probably have mean that important insights from the literature review had been lost.

The time frame allocated user study and concept development phases was also affected by the need for changing the whole project to fit within the new restrictions of social distancing.

8.1.2 Defining the Project

Due to the difficulties of assessing responsibility, defining the project and its aim was iterated until the start of the user study. Various insights from the literature study, as well as test driving vehicles with responsibility in mind helped form the final aim of the project. However, the iterations of the project aim did not necessarily result in added time - as all studies that had been completed could be applied to the final result.

8.2 The Main Results

In the following section, the main result is discussed based on the parts; the fundamental issue of responsibility, the results compared to literature research, and the final concept.

8.2.1 The Fundamental Issue of Responsibility

One of the results of this thesis project was that there are clear differences between how users and developers view the concept of responsibility. The users in the user study believed that they would never be removed from having responsibility when driving a vehicle, regardless of the level of automation. The developers however meant that responsibility will be completely removed from the user in the final state of automation.

The reason why users and developers differ is not because any of them knows the right answer. However, users and developers can have different goals for what they want to achieve and internal factors such as technology interest, driving experience and future beliefs can also influence these goals. Since the developers are working on developing vehicles that should be able to be driverless, they will have a more positive attitude when it comes to handing over responsibility to the vehicle. A user, who is very interested in technology and trusts the technology, will probably have the same attitude as the developers, while a user who is more skeptical of the technical development will have a more negative attitude when it comes to handing over responsibility to the vehicle.

However, this issue may also be due to the users having difficulties to imagine what a completely driverless vehicle would be like. Therefore, the users believed that they will still have responsibility when using an automated vehicle.

8.2.2 The Results Compared to Literature Research

It was discovered in literature that the concept of responsibility can be understood differently based on different internal factors. It was also discovered that these aspects influenced the factors connected to responsibility. This was notable in the user study as well. However, as the participants in the user study were from the countries and cultures that are connected to the term 'Western world', there were not that many differences in understanding the term responsibility. A broader group of participants, representing different countries and cultures, could probably have shown more diversity.

The AV literature discussed responsibility in terms of maybe being allocated to both user and AS, along different tasks. However, the literature on philosophy made it clear that it is difficult (if not impossible) to assign responsibility to a non-human. Further, the user study shared the perception of the human being responsible – always. This was noted in the aircraft pilot interview as well; the first pilot is always responsible. With this in mind, the conclusion was that **responsibility cannot be shared**.

There was one notable difference between literature and users, which was whether or not authority should be shared. The literature was clear on that the authority in HMCs should never be applied to one of the cooperating parties, to avoid unnecessary difficult transitions. However, the user study found that it was important for the users to always have the possibility to override the AS; thus, always having the authority.

Based on the literature review it turned out that users' primary responsibility in terms of cooperation lies with a correct use of the AS. However, from the user study it turned out that nearly none of the participants had any thought of first reading the manual before they used a vehicle with these advanced ASs. These insights made it clear that users' understanding of their responsibilities should be taken into consideration even before a user uses the ASs.

One of the most central findings from the literature review was the conclusion that responsibility in the context of semi-AV LoA 3 is a non-problem. In this level of automation, responsibility cannot lie with the AS. However, since control is considered to be a part of responsibility, the challenge was instead directed towards the distribution of control and that the appropriate information is communicated in the right way and at the right time, in order to result in an effective cooperation between the user and the AS. Therefore, the focus of the thesis project changed, but the knowledge about responsibility and how users understand their responsibilities was still needed in order to reach the conclusion that the challenge concerns control and how user's understand control allocations when using a semi-AV.

8.2.3 The Final Concept

In order to create a smooth interaction between the user and the AS, the information needs to be displayed so that it is easy for the user to interpret and understand the information. Since the final concept combined two concepts, the TOR design was suitable for both HDDs and HUDs. According to the literature on system transparency, this should enable the user to easily understand how a system works and intuitive ways of interacting with the system and also facilitate effective interactions between users and the AS.

The final concept aims to solve a smaller part of the HMI in semi-AVs with focus on a visually conceptualized TOR. However, auditory and vibrotactile information are also important communication channels during TOR, especially in emergency situations.

The concept evaluation with the users showed a positive reaction towards higher system transparency than used in most of today's vehicles. By showing the transition and the available modes they considered it easier to understand and notice the transition. Also, a majority thought that a combination of the two concepts A and B could be a smart solution.

However, it is difficult to evaluate a concept. It may work well in theory (i.e., in a test situation at the computer), but not in practice (i.e., when using an AV in traffic). Therefore, further work is needed to be able to further test and evaluate the concept before it is possible to give a more comprehensive analysis of its importance.

8.3 Study: Strengths and Weaknesses

To have the users define the terms related to responsibility before the actual booklet task and interviews should be considered as a strength. Thus, this ensured a similar interpretation/ understanding of the terms. In addition, being able to describe the words themselves also gave the participants a chance to reflect on something they do not usually think about, which provided a good basis for many interesting discussions.

The contents of the envelope that was used in the user study was sent out with mail in order for the participants to be able to complete the tasks and familiarize themselves with the material and the subject over a longer period of time, rather than all of it in one seating. However, it turned out that most of the participants did the whole task at one time, indicating that a digital version would have been possible. In addition, because people are so used to doing everything digitally, participants may find it difficult to complete a task on paper. However, this goes both ways as older people, for example, may find it more difficult to complete such a task digitally. Another aspect is that this procedure was to some extent time-consuming, for example due to some postal delays, which could have been avoided if the material was sent out digitally. Thus, the choice to send the material by mail can be seen as both a strength and a weakness in the thesis project.

One weakness of the study is that the user study is based on expectations rather than experiences, which is a consequence of Covid-19. However, as the thesis focuses on LoA 3, the results of having the users experience LoA 2 would still have to be considered as resulting in expectations for LoA 3. The opportunity to test drive more vehicles in LoA 2 was also affected by Covid-19. If the two members of the project team had been able to test more car brands it could have resulted in more variation in the evaluation. There was for example a plan to test a Tesla, considered as being one of the leaders in semi-AVs. This might have been solved if we had planned differently and prioritized testing this before the restrictions regarding Covid-19 were established. This experience could have added another dimension to our evaluation, which could have contributed with more aspects to consider, since this vehicle could offer features and functions that we have not taken into account.

It is difficult to know if the results would have been different if the users had been allowed to actually test drive vehicles. It was clear during the interviews with the participants that it was difficult to respond to something that they have not been able to test or experience. Many participants also mentioned that they needed to test the design in order to give an honest answer. However, since the user study focused more on the users' understanding than their real experience of driving a semi-AV this can also result in that the philosophical part became more central in the work; the users got the opportunity to reflect and reason about things that they might not have done if they just tested the cars. Thus, this can be seen as a strength.

The philosophical perspective has played a central role throughout the thesis project which can be seen as a strength, even though this has not been the focal point as much as the HMI and HMC. Further philosophical studies could have enabled a deeper understanding of why and how understood responsibility is dependent on internal factors.

The guidelines have also been a central role throughout the thesis project and gave important knowledge and inspiration to move forward with the concept development.

8.4 Research Question Assessment

The thesis projects aimed to investigate how users understand their responsibilities in a semi-AV (LoA 3). This generated knowledge was then used in order to formulate user-centered HMC guidelines that created a foundation for future design developments regarding the HMI, and in turn the cooperation between the user and the AS in semi-AVs. Following are the research questions from chapter 1.2.1 stated once more, along with answers which emerged during the thesis project.

RQ 1 How do users understand the concept of responsibility?

Users understand the concept of responsibility as something that cannot be shared, someone always has “final responsibility”. This was apparent in the user study, but also in interviews with users of other ASs, such as aircraft pilots. The users did, however, considered that control could be shared with an AS, as long as it was possible to override the AS. This implies a need for the user to always have the authority; to be able to cancel the AS's decisions or actions.

RQ 2 What factors influence the user’s understanding of responsibility in HMC in semi-AVs (LoA 3)?

The factors that influence the users’ understanding of responsibility in a cooperative drive situation can be divided into **internal factors**, **vehicle related factors** and **external factors**. Several of these factors are related to and can influence each other.

Internal factors

- Driver experience
- Technology interest
- Future beliefs
- Trust

Vehicle related factors

- Understanding the AS, like for example its limitations
- Ability to regain control
- System transparency
- HMI
- Dynamic motion behavior

External factors

- Relation to others (humans/passengers)
- Driving environment, like weather or traffic environment

There are, however, several more aspects to consider that are important when understanding responsibility in semi-AVs. Those presented above are influenced by other aspects, which are relevant to consider as well. Nevertheless, the research questions could be considered as answered.

RQ 3 How should the HMI be designed to enable the users to gain a better understanding of their responsibilities when driving a semi-AV (LoA 3)?

The extracted guidelines from the inspiring activities, i.e., benchmark and workshop, provided guidelines regarding how the HMI should be designed in order for the users to gain better understanding of their responsibilities when driving a semi-AV (LoA 3). These guidelines can be found in chapter 4.4.3.

The users appear more likely to share control than responsibility. This infers that the HMI should not only facilitate the users' understanding of responsibility overall - but also in control transitions. It is important that the HMI assists the user in understanding that the correct actions always are their responsibility, even with an AS activated. This is also in line with what the literature implied.

How the HMI should be designed is something that depends on the users and the influencing factors. Thus, the answer to this research question contains and explains relevant aspects to consider while designing the HMI, rather than specific requirements or designs. Several of the guidelines presented may be in direct opposition to one another, which implies that there is a need for a careful consideration of how to follow them.

In the concept development, the focus regarding the HMI was directed to control transitions. However, this is just one factor that needs to be considered when designing an HMI for semi-AVs. The HMI should for example take into consideration that the users' understanding of their responsibilities are closely influenced by internal factors. Thus, there is a need for an HMI that takes this into consideration. However, there may also be external factors that in turn influence the users' internal factors.

8.5 Implementation

8.5.1 The Guidelines

Using the HMI guidelines in the development process can help the developers create semi-AVs that are easy to understand and use. The users need to understand the AS's status, abilities and limitations in order to be able to maintain a safe and efficient cooperation. Since it is through the HMI the user and the AS communicate, the interface needs to be well-designed and facilitate the cooperation.

However, the guidelines take more aspects than just HMI into account; they also focus on the philosophical perspective on responsibility and control. The guidelines can give developers an insight into what is considered necessary for the users to understand their responsibilities and in turn control allocations when using a semi-AV. However, the guidelines may need to be clarified. Some guidelines mention the importance of understanding how users differ and to implement system adaptation into the AS.

Further, as the guidelines tend to more aspects than HMI, it is important that developers have the ability to consider these aspects as well.

8.5.2 The Final Concept

Implementation of the final concept concerns the two displays: HDD and HUD. Since concept B, which is placed on the HDD, takes up more space of the display than the nowadays solution, developers have to reconsider how all the relevant information on the HDD should be organized in order for the information to be easy to notice.

It is important to test the concept further, with more users, to guarantee that the concept does not negatively interfere with the users' understanding of sharing control and being the responsible one. Further, the testing should consider the aspect of system transparency in connection to trust since it is important that the concept does not infer with the users' appropriate level of trust. The final concept should also be tested together with auditory and haptic feedback to ensure that the concept works in a multimodal TOR.

As already mentioned, the internal factors affect the users' overall understanding of semi-AV and drivers are a broad group of different users. It is therefore relevant to test how one could add more adaption to the concept, to enable a more adaptable design solution.

8.6 Future Prospects

8.6.1 Training/ On-Boarding process

Based on the findings throughout the thesis project, it appeared that the users' understanding of responsibility in a cooperative drive situation can be divided into internal factors, vehicle related factors and external factors. Several of these factors are related to and can influence each other. Also, as mentioned in the user study, none of the participants had some thought of first reading the manual, before using a vehicle with advanced AS's.

Since control transitions are a central aspect of driving a semi-AV (LoA3), it is important that the user understands the distribution of control, communicated by the AS. This could be facilitated by some type of on-board process/tutorial to follow while considering these aspects. However, it is a challenge to make a training/on-boarding process acceptable and interesting for users.

This on-boarding process could be an app that allows the system to understand users' knowledge and their profile. It should consider the learning phase, which includes steps from when users first encounter semi-AVs, the actual cooperative drive and the outcome of each control transition. This process could also create opportunities for more direct communication between users and car manufactures. Also, it could be interesting to investigate the next levels of automation, i.e., LoA 4 and LoA 5, and what might affect the users, both when it comes to their attitude towards higher levels of automation, but also how their understanding regarding responsibility and control might change, as the development of automated vehicles proceeds.

9. Conclusion

The primary aim of this master thesis project was to investigate how users understand their responsibilities in a semi-automated vehicle. The results showed that the users expect to have constant responsibility and that the core of responsibility cannot be shared - neither between humans, nor between humans and vehicles. There is always someone having “final responsibility”. However, responsibility related aspects, such as control, can be shared between the user and the automated system (AS), as long as the user can override the AS.

Further, there are several internal factors that influence how the users understand their responsibilities, i.e., technology interest, driver experience, future beliefs, trust, earlier knowledge and similar. All these internal factors could in turn be influenced by both vehicle related and external factors, such as in-vehicle HMI, system transparency, dynamic motion behavior and surrounding traffic. Further, it was found that there are more aspects to consider than just those in direct connection with the semi-AV.

Summarizing the compiled understanding of the concept of responsibility in the context of semi-AVs; In order to assign responsibility, the act must be exercised for/to someone that the user has a relation to. Vehicles lack the perception of social relations. (Though, vehicles can be in relation to other vehicles, in terms of capacity, size and similar). Thus, the user needs to retain authority over the vehicle to ensure responsible actions. This is in line with the conclusion that responsibility cannot be shared.

In the context of semi-AV (LoA 3), responsibility can be seen as a non-problem, since the users expect to have constant responsibility. Related factors, i.e., control can however be shared between the user and the AS. Therefore, the concept development phase was directed towards creating possible re-design solutions regarding TOR. By using HMI guidelines, five TOR concepts were created, all with different levels of system transparency. The challenge was to find an adequate level of system transparency that communicates the right type of information at the right time, without creating information overload or confusion. The result of the concept development showed that in a HDD users prefer a control transition with medium system transparency, where the AS communicates more information to the user regarding the transition. In a HUD, the users preferred a control transition with a low system transparency, where the AS communicates less information to the user. A combination of these two concepts could increase the user’s understanding for the control allocation, which in turn facilitate and enable an efficient and safe cooperation between the user and AS, during use of a semi-AV.

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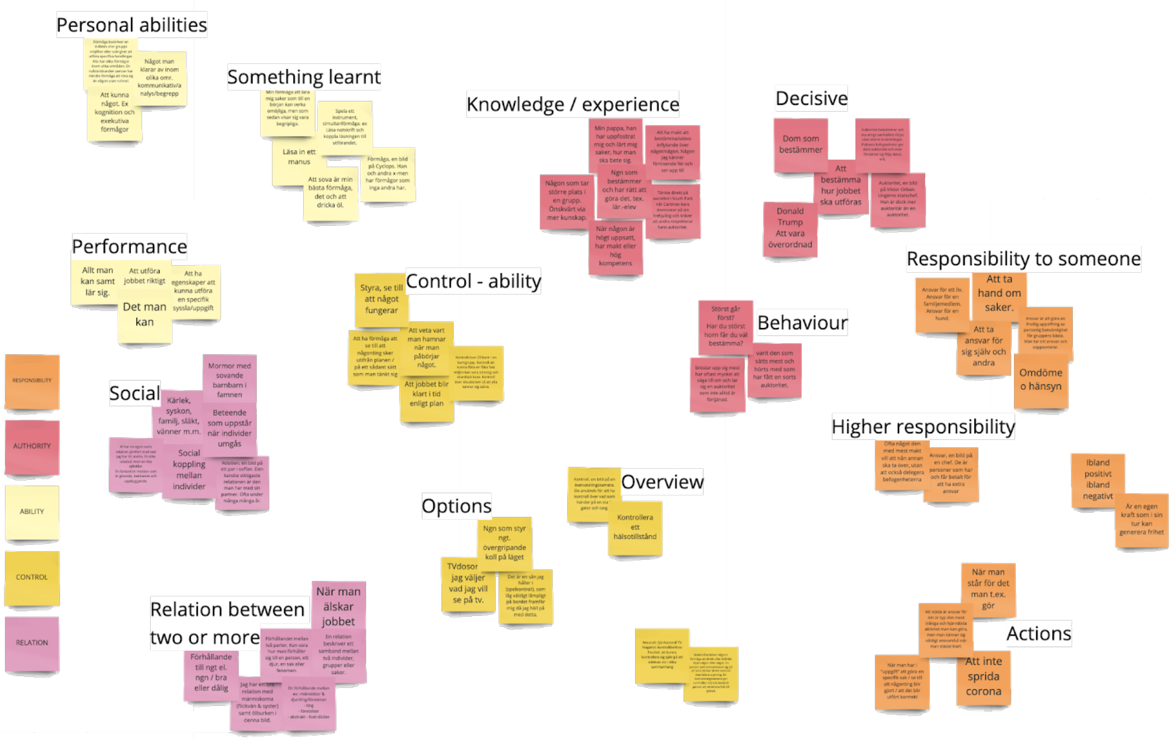
Appendices

Appendix A: Users Meaning of Words




Responsibility to someone
Ansvar för ett liv. Ansvar för en familjemedlem. Ansvar för en hund.
Att ta hand om saker.
Ansvar är att göra en frivillig uppoffring av personlig bekvämlighet för gruppens bästa. Man tar sitt ansvar och soppsorterar.
Att ta ansvar för sig själv och andra
Omdöme o hänsyn
Actions
När man står för det man t.ex. gör
Att städa är ansvar för det är typ den mest tråkiga och hjärndöda aktivitet man kan göra, men man känner sig väldigt ansvarsfull när man städat klart.
När man har i "uppgift" att göra en specifik sak / se till att någonting blir gjort / att det blir utfört korrrekt
Att inte sprida corona
Higher responsibility
Ofta något den med mest makt vill att nån annan ska ta över, utan att också delegera befogenheterna
Ansvar, en bild på en chef. De är personer som har och får betalt för att ha extra ansvar
Ibland positivt ibland negativt
Är en egen kraft som i sin tur kan generera frihet
Störst går först? Har du störst horn får du väl bestämma?
Behaviour
varit den som sätts mest och hörts med som har fått en sorts auktoritet.
bröstar upp sig mest har oftast mycket att säga till om och tar sig en auktoritet som inte alltid är förtjänad.
Knowledge / experience
Min pappa, han har uppfostrat mig och lärt mig saker, hur man ska bete sig.
Att ha makt att bestämma/utöva inflytande över något/någon. Någon jag känner förtroende för och ser upp till
Någon som tar större plats i en grupp. Önskvärt via mer kunskap.
Ngn som bestämmer och har rätt att göra det. tex. lär.-elev
Tänkte direkt på avsnittet i South Park när Cartman bara dominerar på sin trehjuling och kräver att andra respekterar hans auktoritet.
När någon är högt uppsatt, har makt eller hög kompetens
Decisive
Dom som bestämmer
Auktoritet bestämmer och ska enligt samhällets följas utan större invändningar. Polisens befogenheter ger dem auktoritet och man förväntar sig följa deras ord.
Att bestämma hur jobbet ska utföras
Auktoritet, en bild på Viktor Orban. Ungerns statschef. Han är dock mer auktoritär än en auktoritet.
Donald Trump Att vara överordnad


Personal abilities
Förmåga beskriver en individs eller grupps möjlihet eller svårighet att utföra specifika handlingar. Alla har olika förmågor inom olika områden. En rullstolsbunden person har mindre förmåga att röra sig än någon utan rullstol.
Något man klarar av inom olika omr. kommunikativ/analys/begrepp
Att kunna något. Ex kognition och exekutiva förmågor
Something learnt
Min förmåga att lära mig saker som till en början kan verka omöjliga, men som sedan visar sig vara begripliga.
Spela ett instrument, simultanförmåga. ex Läsa notskrift och koppla läsningen till utförandet.
Läsa in ett manus
Förmåga, en bild på Cyclops. Han och andra x-men har förmågor som inga andra har.
Att sova är min bästa förmåga, det och att dricka öl.
Performance
Allt man kan samt lär sig.
Att utföra jobbet riktigt
Att ha egenskaper att kunna utföra en specifik syssla/uppgift
Det man kan
Neutralt: fjärrkontroll TV
Negativt: kontrollbehhov
Positivt: att kunna kontrollera sig själv på ett adekvat vis i olika sammanhang
Kontroll beskrver någons förmåga att direkt eller indirekt styra någon eller något. En person som koncentrerar sig på att köra bil har direkt kontroll över bilens styrning. En övervakningskamera ger samhället indirekt kontroll genom att skrämma folk till lydnad.
Control - ability
Styra, se till att något fungerar
Att ha förmåga att se till att någonting sker utifrån planen / på ett sådant sätt som man tänkt sig
Att veta vart man hamnar när man påbörjar något.
Att jobbet blir klart i tid enligt plan
Kontroll över 20 barn i en barngrupp. Kontroll att kunna fläta en fläta fast miljön kan vara stressig och stundtals kaos. Kontroll över situationen så att alla känner sig säkra.
Options
Ngn som styr ngt. övergripande koll på läget
TVdosor jag väljer vad jag vill se på tv.
Det är en sån jag håller i (spelkontroll), som låg väldigt lämpligt på bordet framför mig då jag höll på med detta.
Kontroll, en bild på en övervakningskamera. De används för att ha kontroll över vad som händer på en sta
gator och torg.
Overview
Kontrollera ett hälsotillstånd


Social
Mormor med sovande barnbarn i famnen
Kärlek, syskon, familj, släkt, vänner m.m.
Beteende som uppstår när individer umgås
Vi har en egen sorts relation jämfört med vad jag har till andra. En icke uttalad, men en lika självklar.
En fantastisk relation som är givande, berikande och uppbyggande.
Social koppling mellan individer
Relation, en bild på ett par i soffan. Den kanske viktigaste relationen är den man har med sin partner. Ofta under många många år.


Relation between two or more
När man älskar jobbet
Förhållandet mellan två parter. Kan vara hur man förhåller sig till en person, ett djur, en sak eller fenomen.
En relation beskriver ett samband mellan två individer, grupper eller saker.
Förhållande till ngt el. ngn / bra eller dålig
Jag har en bra relation med människorna (flickvän & syster) samt ölburken i denna bild.
Ett förhållande mellan ex: -människor & djur/ting/företelser
- ting
- företelser
- abstrakt - livet döden

Appendix B: Information Film Used in User Study

Toyota safety sense 2.0 overview | Toyota
Uploaded by Toyota US

Link:
https://www.youtube.com/watch?v=KeUOMaPe3v0&t=136s

Appendix C: Interview Script For the User Study

Hej!
Vi utför den här intervjun för att se hur bilförare uppfattar olika scenarion där förarstödsystem är inblandade. Vi är tacksamma för alla tankar, åsikter och känslor och det finns inga rätt eller fel svar!

Skulle du någonstans vilja skippa en fråga, eller avbryta så är det helt okej!
Du är helt anonym i resultatet.

Är det okej att jag spelar in ljud från intervjun?

Lite allmänt om vad du tyckte om uppgiften som helhet

1. Vad tyckte du om uppgiften? Hur kändes det att göra den?
2. Var det lätt/svårt?
3. Var det något som gjorde dig osäker?
4. Väcktes några tankar, känslor som du inte tänkt på innan?

Steg 1: Om orden och val av bilderna
Hade du hört dessa ord innan?
Prata lite om orden och hur de tänkte när det valde bilderna- låta dem förklara.

Steg 2: Systemen ACC + LTA, Bookleten

Först prata om systemen ACC + LTA, sen prata om hur de har svarat i bookleten.

Förstår du dig på systemen/funktionerna som innefattas i förarstödsystemen?

Hade du någonsin hört talas om dessa system innan?

ACC
Känner du att du har fått någon uppfattning om hur den adaptiva farthållaren fungerar?

Ja; Kan du förklara vad som sker?
Nej; Vad känner du skulle hjälpa dig förstå?
Vill du förstå vad som händer?

Brukar du använda farthållare?
Under vilka förhållanden?
Är det en vanliga farthållare, eller en adaptiv (som anpassar avståndet till framförvarande bil)?

Känner du dig trygg med att använda den adaptiva farthållaren?
Ja; På vilket sätt? Vad är det som gör att du känner dig trygg?
Nej; Vad skulle få dig att känna dig trygg när du använder farthållaren?

Skulle du säga att du lämnar ifrån dig kontrollen över hastigheten när du slår på den adaptiva farthållaren?
Ja; Hur vet du att bilen fortfarande håller sig inom den lagliga hastigheten?
Nej; Varför inte? Hur kontrollerar du fortfarande hastigheten om du inte har foten på pedalen?

Om du blir påkörd av en person som har sin adaptiva farthållare aktiverad, vem skulle du då skylla din smärta på?

Om polisen skulle stanna dig för fortkörning när du har den adaptiva farthållaren aktiverad, vad säger du som försvar?

Är du fortfarande ansvarig för framförandet av bilen när du använder den adaptiva farthållaren?
Varför?

LTA
Känner du att du har fått någon uppfattning om hur väghållningsassistansen fungerar?

Ja; Kan du förklara vad som sker?
Nej; Vad känner du skulle hjälpa dig förstå?
Vill du förstå vad som händer?

Har du använt en väghållningsassistans förut?
Om ja, under vilka förhållanden?

Känner du dig trygg med att använda väghållningsassistansen?
Ja; På vilket sätt. Vad är det som gör att du känner dig trygg?
Nej; Vad skulle få dig att känna dig trygg när du använder väghållningsassistansen?

Skulle du säga att du lämnar ifrån dig kontrollen över bilen när du slår på väghållningsassistansen?
Ja; Hur vet du att bilen fortfarande håller sig inom rätt fil?
Nej; Varför inte?

Om du krockar med en bil som har använt sin väghållning assistans, vem skulle du då skylla din smärta på?

Om polisen skulle stanna dig för märklig väghållning när du har väghållningsassistansen igång, vad säger du som försvar?

Booklet:
Var det något specifikt scenario som du la extra tanke på?
Var det någonstans du inte förstod riktigt?

(Kolla igenom var plupparna skiljer sig åt)
Exempelfrågor:
Varför har människan mer ansvar här?
Hur tänker du med förmåga här?
Vem har bilen relation till i detta scenario?
Varför har bilen kontroll?

Instruktionsboken/manual: Om du ska använd en ny bil, läser du instruktionsboken, så du vet vilka begränsningar systemet har? För om du inte läser instruktionerna hur vet du att du använder systemet rätt annars? För bilfirman har ju ansvar att ge ut tydliga instruktioner hur bilen fungerar men du som förare har också ansvaret att använda systemen rätt..

Avsluta med:

Tror du att du lämnar ifrån dig ansvaret när du slår på de här systemen?

Skulle du känna du dig tryggare att köra om du använder dessa hjälpsystem?

Tack för att du tog dig tid och ville medverka i studien!

Appendix D: Workshop Script

Introduction

Hi everyone!
Hope you are safe, and have had a nice Easter. And thank you for the homework you all did! We are glad to have you for this workshop today, and we believe that it will be both fun and interesting to hear what you have to say!

The workspace we are using is right now empty, but as we move along to the different tasks - Ida will fill it with different tools.
I will try to explain each of the steps, before we start doing anything. If there is something unclear or strange just ask!

The thought is that it is you that will perform the different steps, both alone and together - this I will explain later. We are just here to guide you and help out.

You are free to try out any of the tools to the left, such as notes, text, shapes, arrows and pen. You are also welcome to draw by hand or find images on the web to upload on the workspace.
And remember, there are no right or wrong answers! :)

Do you have any questions right now, or shall we start?

1. Discussing the last statements of the homework (ca 15 min)
As a warm-up, we would like you to discuss the last 5 statements in the homework you did. It is not necessary to mention how you answered, if you do not wish to do so. Rather what went through your mind when you answered it, and maybe motivate why or why not one should agree.

In the first task, we will discuss the homework and how you answered the last 5 statements. We take one question at a time where everyone can explain why they have answered as they have done.

The 5 statements:
"I understand what happens when the ADAS is activated"

"I feel safer when the ADAS are activated"

"I am still in control over the vehicle when the ADAS are activated"

"The vehicle is responsible when the ADAS are activated"
"I am always responsible for the vehicle, even then it drives by itself."
2. Assign quotes to personas (ca 15 min)

Do you all know what personas are? Otherwise, it simply is fictional characters that are supposed to capture different users. The ones we see here differs in age, technology interest and way of driving the vehicle.

The quotes have been extracted from several of the interviews we have done with potential users.

We ask you to, together, try to assign as many as you like to each of the personas by pulling the quote to the persona. If there happens to be a quote that you feel suits more than one, you can just copy it and place it on both.

If there are any quotes that you do not understand or do not feel suits any of the personas, you can ask us or just leave them.

3. Brainwriting (ca 40 min)
So, with the different quotes fresh in mind - we are now moving into the three different brainwriting sessions. Each session is 7 minutes, followed by discussing the different thoughts that might have appeared.

Let's start by each of you zooming into one of the empty brain writing spaces that we have prepared. This way, you won't be disturbed by any of the others thoughts during the first 7 minutes.

Do you all know how to add post-its? And to write on these?
So, are you ready?
7 minutes starts now.

OK! Now we can zoom out again!
Anyone that would like to start sharing what they've come up with?

To sum up the discussion, we ask you to together choose the three most interesting thoughts that have been discussed under this task.

4. PNI (ca 15)
OK! So now let's try to evaluate these favorite thoughts that you have chosen. We will do this by using a method that's called positive negative interesting - that is, you will discuss all positive, negative and interesting aspects on each of the ideas.

Is it something specific that you want to explain?

Thank you!

Appendix E: Interview Script Car Sales Representations

1. Kan du berätta lite om de automatiserade systemen? Vilka funktioner som finns utrustade samt hur de fungerar?

2. Vad finns det för begränsningar hos dessa system?

Appendix F: Interview Script Locomotive Pilot

1. Vill/kan du ta en bild på “instrumentpanelen”?

2. Vad har loket för “säkerhetssystem”?
Nödbroms?

3. Kan loket “köra själv”? Fungerar det som autopilot, eller kan du välja en kombination? Vid olika väder/ställen?

4. Hur ser dessa system ut?

5. Brukar du hålla på med något annat när du kör tåg? Om ja, vad?

6. Brukar du kunna släppa kontrollen när du kör?

7. Ser du några skillnader mellan att köra bil och tåg?
Har du annorlunda ansvar i tåg resp. Bil?

8. Kan du som lokförare hållas ansvarig i fall av en olycka? Om du har gjort allt i din makt (följt signaler, trafikledare)?

9. Känner du att du har en auktoritet som förare? Vem är det som bestämmer? Tåget, du, trafikledare eller kombination? Vem har sista ordet?

Appendix G: Interview Script Aircraft Pilot

1. Vill/kan du ta en bild på “instrumentpanelen”?

2. Vad har plan vanligtvis för “säkerhetssystem”?

- Hur ser symbolerna/meddelandena ut?

3. Kan planet “köra själv”? Fungerar det som autopilot, eller kan du välja en kombination? Är det olika vid olika väder/ situationer så som planets stigning, nedstigning, inflygning?

4. Hur ser dessa system ut?

5. Brukar du hålla på med något annat när du flyger flygplan? Om ja, vad?

6. Brukar du kunna släppa kontrollen när du flyger?

7. Ser du några skillnader mellan att köra bil och flygplan?
Har du annorlunda ansvar i bil resp. flygplan?

8. Kan du som pilot hållas ansvarig i fall av en olycka? Om du har gjort allt i din makt (följt signaler, trafikledare)?

9. Känner du att du har en auktoritet som pilot? Vem är det som bestämmer? Planet, du, trafikledare eller kombination? Vem har sista ordet?

10. Hur skulle du säga att ansvarsfördelningen ser ut mellan första och andrepilot?

11. Kan en av piloterna lämna över ansvar till den andre under en flygning?

12. Känner du olika ansvar över om du flyger människor eller gods? Hur?

Appendix H: Information Used In the Concept Evaluation

Introduktion

I scenariot i detta test så kör du en bil som tillhör **nivå 3,** som definieras som ett semiautomatiskt fordon. Det finns totalt sex olika nivåer, 0-5, där 5 är helt självkörande. I en bil med nivå 3 kan fordonet köra, vilket innebär att så länge de avancerade systemen är aktiverade kör fordonet, inte du. Du förväntas dock fortfarande ta över när bilen stöter på omgivningar där systemet inte fungerar korrekt, vilket kan vara pga. väder eller trafikmiljön.

En **take over request (TOR),** visas under resan i form av symboler och ibland text, när villkoren för systemet inte är uppfyllt. Detta innebär att systemet når sina begränsningar och ber användaren att ta över körningen av bilen. I denna situation har användaren en begränsad tid på sig att reagera innan systemet inaktiveras.

Scenario

Du är på väg hem från jobbet och kör på motorvägen. Det automatiska systemet (AS) är aktiverat och den gröna symbolen är synlig på displayen bakom ratten. Allting verkar gå felfritt och smidigt. Du tittar ner på din mobiltelefon och börjar skriva ett meddelande till din vän angående kvällens planer.

Eftersom du kör ett semiautomatiskt fordon tittar du då och då upp på vägen för att vara redo att ta kontrollen efter att ha fått en notis från systemet. En TOR i form av en symbol är synlig på displayen bakom ratten eftersom det är en kö 800 meter framför dig. Din uppmärksamhet flyttar sig dock mellan mobilen och vägen.

Förklaring av orden ansvar och kontroll

Ansvar: Att ha ansvar kan förklaras som att vara ansvarig för situationen, de handlingar som utförs och konsekvenserna av dessa handlingar.

Kontroll: Förmågan att ha kontroll kan förklaras som att ha en form av översikt som att övervaka en situation eller en process där man har alternativ att välja handlingssätt.

Head-down display & Head-up display

En take-over request (**TOR**) presenteras med hjälp av symboler och ibland i kombination med text.

Dessa visas på **head-down display (HDD)** - displayen bakom ratten.

Ibland kan även de visas på **head-up display (HUD)** - en transparent display som projicerar informationen på vindrutan.