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Learning by Almost Doing

New Education Methods for Learning about Driving
Automation Systems

Master's thesis in Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abbreviations

DAS Driving automation system

DDT Dynamic driving tasks

LoA Level of automation

SDS Supervised driving system

UDS Unsupervised driving system

Abstract

Driving automation systems (DAS) in cars are systems that can take over parts of the driving control from the driver. There are standardised ways of categorising five levels of automation (LoAs) by defining the control of the car and the where the responsibility of the car lies. There is a problem for driver's and automakers that some drivers are having trouble understanding DAS in the correct way. This could increase the risk that some drivers misuse the DAS because they fail to understand the limitations and functions to a certain degree which causes some safety concerns. There is mode confusion which increases risk for some drivers to misunderstand the modes of automation in their cars. DAS are getting developed even further which leads to more complexity for the driver.

It is in automakers interest to have their drivers use their systems as intended but it is also becoming a demand from outside authorities to provide effective education as DAS is becoming more common and advanced. To support this, the methods of educating drivers needs to be developed in order to be more efficient and motivating in according to human learning behaviour.

Other studies have researched ways to educate drivers by suggesting new methods which have been successful. What this thesis researched was a comparative study of education methods to create a base for what a good education needs in term of being effective and motivating. This was done by creating education concepts which applies different methods of education which were then tested on people to see if they understood the content.

A literature study was first done to establish a starting ground in the subject. A focus on a learning theory in constructivism was used which says that learning is constructed in an individual when they actively participate. To achieve an effective learning method, it needs to create motivation within the learner who will otherwise be bored and find something else to occupy their mind. A certain level of immersion and engagement is required according to learning theory to create an effective learning method. Other methods for creating good motivation within the learner is gamification. It uses elements from games designed to keep the player feeling motivated and rewarded for their work. Two new conceptual education methods for DAS were created and tested. One concept made for simulating the environment of driving in a car with DAS which involves the learner on an active level. They get to watch scenarios from a drivers POV where DAS are relevant. They affect the outcome by making choices that results in different outcomes. The other concept uses gamification in a quiz format where the user progresses through higher levels by completing questions. They were rewarded and could track their progress. In both concepts they got feedback for each correct or incorrect answer resulting in them learning something new.

These concepts were used in a user test with a printed user manual as a comparative baseline method. The test participants were provided with an educational material (Scenario concept, Quiz concept, or User manual) that educated them in DAS. The test involved observation of simulator driving, survey questions, and interview questions.

The scenario concept performed the best in our user test, with the quiz coming second. The scenario concept had good performance when using DAS in the simulator but also on a theoretical knowledge level. It showed that a good method for education is to immerse the learner in real environments where they are actively participating and affecting the outcome. It creates both an effective learning method but also a motivating one where the learner enjoys doing it.

We have created design guidelines with the help of the findings from the concepts which describe how to design effective and motivating educational material for DAS.

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1 Introduction

In today's cars, there are systems which help the driver by taking over certain tasks during driving. These systems are called driving automation systems (DAS) (Watzenig & Horn, 2017). They are described in literature as performing parts of or all the dynamic driving tasks (DDT) by controlling longitudinal and/or lateral steering of the vehicle (Noble et al., 2019). According to SAE (2021) there are five levels of automation, which range from the car assisting the driver in conducting the driving task, to taking over the whole DDT when conditions are met, relieving the driver completely.

DAS are continuously and rapidly evolving and thereby taking over more and more of the drivers' tasks. In studies researching the use of DAS, those who were frequent users of the systems increased their usage time of DAS during a drive (Orlovska et al., 2020). This shows that a big part of drivers actually enjoys these systems, as once they have used it, they continue to do so more than before. Still, many drivers do not keep up with the rapid development of these new systems and do not use (or are not aware of) the systems as evidenced by the lack of and incorrect understanding showed in several studies (Orlovska et al., 2021; Orlovska et al., 2020; Hu et al., 2022; McDonald et al., 2018; Noble et al., 2019). Automakers invest a lot of money on DAS features in order to create safer interactions (Singh, 2015), as well as improving the driving experience and exploring new possibilities (Heineke et al., 2021).

However, while LoAs are technical taxonomies followed by car manufacturers, most drivers have never heard of these levels, but they probably already have them in their own cars, as the market share of vehicles offering some form of automation is steadily growing (Fortune Business Insights, 2020), which poses higher demands on drivers, e.g., knowing what mode is active and how to switch between them in a safe way (Kurpiers et al., 2019; Naujoks et al., 2015). This development, challenges drivers to change their current mental model from where they alone are responsible for the vehicle to one where the burden is shared to some degree. The more advanced the driving automation systems get, the more drivers have to adapt their current usage strategies, and their understanding of the capabilities and limitations of the systems (Beggiato & Krems, 2013). This in turn comes with challenges for car manufacturers regarding the education of drivers, and the communication of safe usage strategies. Traditionally, the printed manual has been the central source of information. It has since generally become more condensed, making the more crucial information easier to find in the manual itself. A lot of information has been transferred to the cars infotainment system, support website, and apps (Volvo Cars, 2023a) as they have become more and more usable. Nevertheless, even though many efforts are made, they are seemingly ineffective. Research shows that manuals are often too long, difficult to understand, and the information is insufficient, and therefore, seldomly read by drivers (Viktorová & Šucha, 2018; Mehlenbacher et al., 2002) According to Bristol Street Motors (2020) only 29% of drivers had read their user manual in full.

Thus, efforts are made into investigating alternative ways of educating drivers, as has been highlighted by (Ogitsu & Mizoguchi, 2015; Shirokinskiy et al., 2021). Simulation of DAS is one approach to make the driver more used to using DAS in real situations (Ogitsu & Mizoguchi, 2015; Sætren et al., 2018). Other attempts are to incorporate gamification which uses elements found in games to increase motivation (Hamari, 2007). Studies show that gamification has potential for good education methods in DAS (Feinauer et al., 2022; Zainuddin et al., 2020), because of their ability to encourage drivers, inspire, and stimulate them. Gamification has the possibility to make it attractive for drivers to learn instead of a chore.

Portouli et al. (2008) showed that between paper instructions and multimedia software tools consisting of video instructions and sound effects, multimedia is more effective. They also showed that additional simulation experience did not increase their knowledge but only their perceived knowledge. An interesting aspect of Portouli et al. (2008) is that the paper instructions and the software tools contained

essentially the same information. The difference is that the software tools utilised several media channels like text, pictures, videos, and sound which then gave the best result. This means that giving information through several channels is preferable and perhaps enough, since the simulation did not present any better education, only perceived education. Other efforts, show that the majority of drivers prefer to learn by doing trial-and-error or talking with friends about it (Harms et al., 2020; Oviedo-Trespalacios et al., 2019).

It becomes evident, that the problem that needs to be addressed when educating drivers for the use of DAS, is the gap between drivers being used to their usual ways of driving and raising awareness for the benefits DAS can yield (Pradhan et al., 2018; Winkle, 2016), and how to use the systems safely (Hagl & Kouabenan, 2020). However, while efforts are being made towards better education strategies, all insights are often very general and do not provide concrete examples on how to address the current issues.

The introduction of progressively more advanced systems of automation (Cusack, 2021) calls for a need to retrain drivers in how they are used to driving with less automation. It is not enough to educate drivers in new systems, but it becomes necessary to making them adapt new ways. Drivers today are used to their way which will change in the future, creating a need to re-educate regularly.

In order to address the aforementioned gap, this thesis aims to develop a set of design guidelines, through a comparative approach of different educational materials, to find out key elements in making a good education for DAS. What aspects makes the education effective, meaning that the driver will learn valuable information, and what aspects will make it motivating to use, meaning to have the driver actually use it.

1.1 Research questions

In order to find out how to best educate drivers this thesis addresses the gap of knowledge in driver education for driving automation systems. Thus, the following research question was formulated:

RQ: How can drivers be educated, in order to meet the challenges that come with the deployment of a progressively more complex driving automation systems?

In order to be able to answer the leading research question, we have formulated two sub-questions that will guide this work:

SQ1: What aspects of learning are effective when re-educating drivers for using DAS?

SQ2: What aspects motivate drivers to use education material for DAS?

2 Theoretical framework

Here the relevant theory for this project will be presented to support the decisions and provide a starting point within the subject of learning DAS. The chapter will cover how Automated driving looks and is classified today as well as mental models and learning theory. This will provide a basis for how the project started and where initial inspiration were taken from.

2.1 Mental models

When this work refers to mental models the definition is “an internal representation or structure that reflects the user’s understanding of the machine. It is the user’s imagination of what something is, how it works, and what happens if you act in a specific way” (Andersson, 2010).

The mental or conceptual model of a product helps the user understand, interact with, and use the product or service if the model is accurate to some degree (Andersson, 2010). The accuracy of the model depends on the user's previous experience with similar products (Ramalingam et al., 2004), and it varies in detail depending on how well the inner workings of the product is understood. The model hierarchy describes the different levels of understanding as situation, task, function, process, and structure (figure 2.1). Drivers learning about DAS does not need to reach a high level of understanding to use DAS safely. It is sufficient for them to understand it on a task level.

The levels of understanding are described by Andersson (2010) like this: Situational understanding is understanding why something needs to be done for example “Why the coffeemaker heats up the water” (Andersson, 2010). Task specific understanding describes how to do something and accomplish a task for example “How to turn on the coffeemaker and prepare the machine to get a cup of coffee”. A functional understanding explains why different parts exist and their function for example “The coffee filter is there to stop the coffee grounds from ending up in the cup”. Process level understanding explains how the different parts work and the inner processes of the machine for example “The switch allows an AC current to reach the pump, heating elements and LEDs to pump accurately heated water through coffee grounds and a filter to produce coffee”. Lastly, a structural understanding means that all the individual parts and how they are connected to each other are known for example “Four M1 screws holds together the bottom plate with the outer shell of the coffeemaker”.

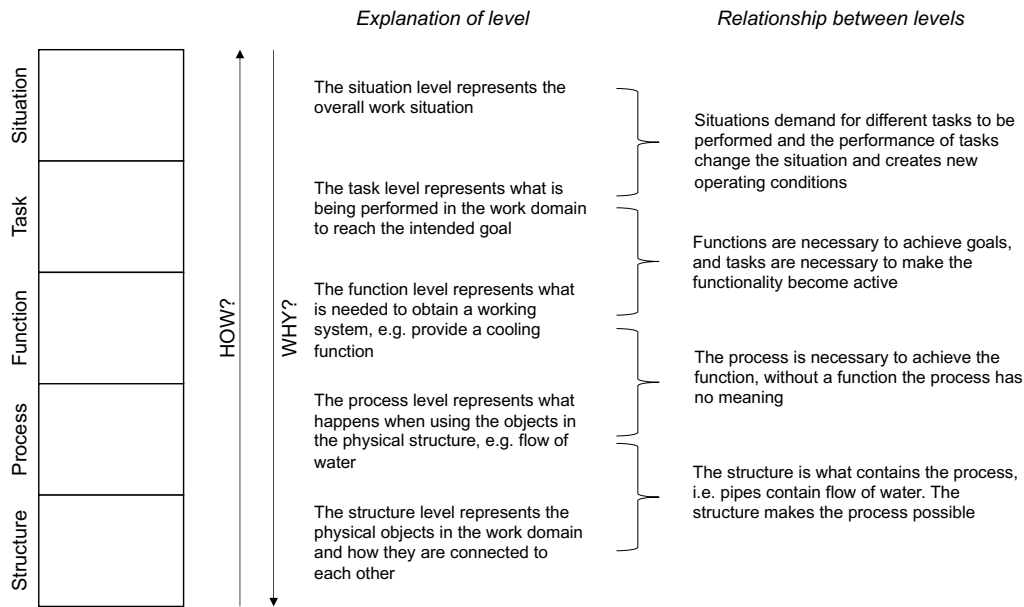


Figure 2.1 Mental model hierarchy (Andersson, 2010)

The five levels of understanding according to model hierarchy describes different types of understanding depending on where on the model the user is. Moving up in the hierarchy answers the question “Why?” And moving down the hierarchy answers the question “How?” (Andersson, 2010).

In driving automation mental models are used as a way to measure drivers’ understanding of the system. A driver’s mental model of DAS can be if they expect the car to drive itself completely in a certain system and if they expect the car to be responsible for the driving. Their mental model is how they think they should start a system and how to turn it off, what certain signals mean and how to respond to them. When automakers design a DAS there is a correct mental model for how the system is supposed to work and be used, however, it can be difficult communicating this mental model to the driver (Endsley, 2019) through design of human machine interaction (Nees, 2020). While DAS is supposed to create a safer driving behaviour, if the drivers’ mental model is incorrect it can lead to misuse. It is common in automation-misuse that it is human error causing drivers to use the DAS outside of their intended use (Parasuraman & Riley, 1997; Biondi et al., 2019) which is caused by inaccurate mental models (Besnard et al., 2004; Endsley, 2017). Using mental models for DAS use is a powerful tool as it gives an estimation of how the driver expects the vehicle to behave in certain situations (Biondi, 2023). Drivers with strong mental models have been reported to respond quicker to critical road events (Gaspar et al., 2020) and was more consistent in their driving, while drivers with weak mental models drove in a more erratic fashion (Rossi et al., 2020).

Beggiato and Krems (2013) studied how drivers converge on a correct mental model through different means. Through simply using the system the mental model converged towards a correct model, even though they may have been misinformed in the beginning or not have gotten all the information. While it is true that a driver learns more about the DAS when using it, it does not necessarily mean an adequate mental model. It also means that for the driver to learn something new they have to make an error and realise what was wrong and then correct their mental model. This creates a method of trial-and-error

which inherently involves making errors causing an unsafe period of use until a correct mental model has been shaped. It is an ineffective way of learning, which should not be used. However, the results indicate that direct usage with the car makes the drivers learn which is still valuable information.

2.1.1 The Process of how perception shapes understanding

A model for understanding a driver in the specific setting operating a car is presented by Novakazi (2020) in figure 2.2 and it will be used in this work to integrate mental models with the active use case of driving. The box named understanding will be treated as mental models in the way that mental models has been presented in this work.

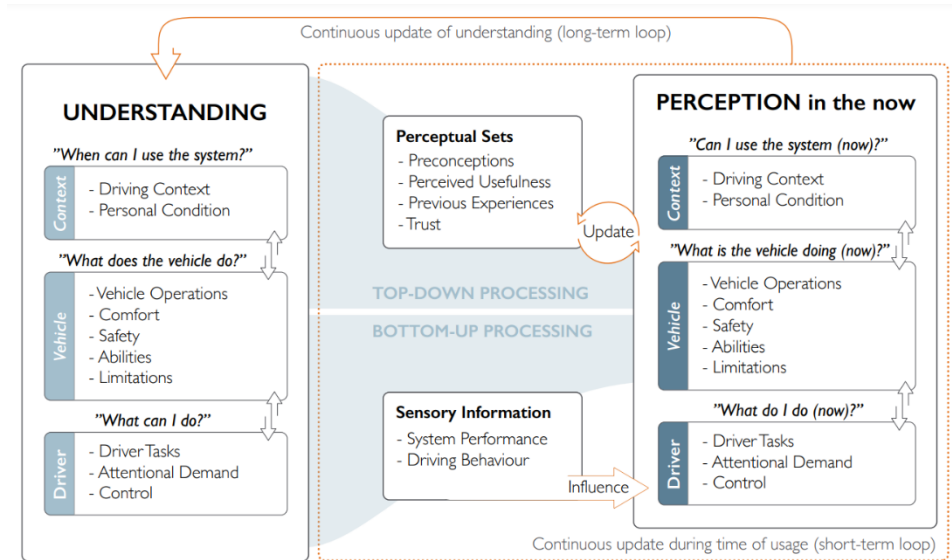


Figure 2.2 Model of perception and understanding (Novakazi, 2020)

The box that is called perception is what the user is aware of in the present moment. The user is aware of mental models and previous experiences related to the task that is relevant but also the sensory inputs. Top-down processing is related to what the user knows and expects will happen and it simplifies the world by “filling in the blanks”. The world is interpreted, and predictions are made based on previous experience. Bottom-up processing happen “in the now” and is driven by inputs or data that the users pick up and reacts to. The data comes from the user’s surroundings in the shape of external stimuli and sensory inputs.

In DAS education, the driver has previous experience and preconceptions which will need to be addressed in some way. The education will have to consider these things and create new perceptual sets through top-down processing that the driver then brings to the actual driving. There, the driver will be affected by sensory information from the car and environment, affecting their perception through bottom-up processing. This is where the two process methods needs to convey the same type of information and not cause conflicts.

2.2 Learning theory

To be able to design a good education platform for DAS, it is necessary to begin at the basics of learning. Constructivism is a learning theory which says that learning is constructed in a person through active participation and engagement etc. (Bada & Olusegun, 2015; Amineh & Asl, 2015) as opposed to that it is formed with the right behaviour and rewards (Pritchard, 2017). It was used as a base to build upon in this

thesis. Constructivism learning can be through social discourse or when the learner experiences something first-hand in a social or solitaire state. Constructivist stance maintains that learning is a process of constructing meaning; it is how people make sense of their experience (Amineh, Asl, 2015). The learning should, according to constructivism, be supported by practical experience and not only in a classroom setting. With Constructivism as an educational theory in mind, the teachers should consider what students know and allow their students to put their knowledge in to practice (Amineh, Asl, 2015). This has been proven a valid strategy outside traditional education as well within certain areas such as video games. Letting the users have small bits of information that is followed by direct implementation of that knowledge to in the end build a skill set for solving complex tasks. Using constructivism learning theory, a good base for DAS education can be built. Therefore, constructivism theory is applicable to DAS education since the driver have to learn complex mental models of how the system works.

2.2.1 Adult learning

General learning theory on constructivism says that a big part of learning is what preconceptions the individual brings with them and their experiences (Bada & Olusegun, 2015). To gain more insight in this, adult learning theory is here looked into since most learning theory is based on educational purposes and therefore on younger minds (Green & Gredler, 2002). Compared to children, adults have more experience of the world that affects their learning and makes them a good candidate to study since their situation is a hyperbole of the general learner. Adults differ in their vast experience, as previously mentioned, but also other things. Russel (2006) says that adults are self-directed, have a strong foundation of experience, are goal and relevance oriented, and are practical. Their source of motivation comes from external expectations, social welfare, personal gain, stimulation, and interest (figure 2.3). White (2021) says that adults have lower patience and will not accept failure as well as children. Adults expect too much from themselves and expect success over night with too much self-confidence. It is also common for them to rely heavily on their own knowledge and experience (Volvo Cars, 2020) where subjects often tried things on their own at first to later need the infotainment system in the car. Adults also have a lot in their attention span like family, work, and social relationships.

Characteristics	Sources of motivation
<ul style="list-style-type: none"> • Autonomous and self-directed • Accumulated a foundation of experiences and knowledge • Goal oriented • Relevancy oriented • Practical • Need to be shown respect 	<ul style="list-style-type: none"> • <i>Social Relationships</i>: to make new friends; to meet a need for associations and friendships • <i>External Expectations</i>: to comply with instructions from someone else; to fulfill recommendations of someone with formal authority • <i>Social Welfare</i>: to improve ability to serve mankind; to improve ability to participate in community work • <i>Personal Advancement</i>: to achieve higher status in a job; secure professional advancement • <i>Escape/Stimulation</i>: to relieve boredom; provide a break in the routine of home or work • <i>Cognitive Interest</i>: to learn for the sake of learning; to satisfy an inquiring mind

Figure 2.3 Characteristics and sources of motivation for adult learning (Russel, 2006)

2.2.2 Experiential learning

When talking about a customer getting to know a product they can learn about it in different ways. More specifically it can be through the producer or by themselves through hands-on experience. The learner, in this case, say that they will perceive the experiential learning better than if they were taught (Hoch & Deighton, 1989). From the learner's perspective, experiential learning means honesty, more trustfulness and better credibility. They are more invested in the learning, they are better motivated, and it makes a more lasting memory. Experiential learning is self-paced, and the learner takes pride in personal efficacy, something that is also common in adult learning theory (Russel, 2006).

From the producer’s point of view, experiential learning means a lack of control which is a drawback (Hoch & Deighton, 1989). Hoch and Deighton (1989) say that there is a difference in learning by describing motivation to learn and familiarity with the product (figure 2.4). Regarding driver’s learning about DAS, they are not motivated and unfamiliar with the product, meaning according to Hoch & Deighton (1989) that the learning is slow to start, difficult to keep up, but manageable by the producer. For drivers in vehicles equipped with DAS, it could be a challenge getting them to learn from own experience in order to get a good quality education, while at the same time teaching safe, correct, and efficient ways.

How motivated are consumer to learn?	What do consumers already know?	What do consumers already know?	
		Little (High ambiguity)	A lot (Low ambiguity)
Highly motivated	Unfamiliar	Learning is most susceptible to management	Learning is spontaneous, rapid, and difficult to manage
	Familiar	Formation of “superstitious” beliefs is possible Existing beliefs inhibit suggestibility	
Weakly motivated	Unfamiliar	Learning is slow to start and difficult to sustain, but is susceptible to management	Learning is difficult to initiate and once started difficult to manage
	Familiar	Complacency inhibits initiation of learning, so experience is unresponsive to management	

Figure 2.4 Classification of readiness to learn (Hoch & Deighton, 1989)

2.2.3 Previous experience and preconceptions

To dip our toes very carefully in the area of neuroscience and how our brains work on a more basic level the field of graph learning will be used to illustrate this. Graph learning on a fundamental level describes data as nodes and that nodes are connected to each other in different ways (Huang, 2019). In figure 2.5 an illustration of graphs interconnectedness is shown. Nodes are connected to each other representing relationship between data points. The nodes are clustered in colour and have different sizes to illustrate difference in data. In DAS the nodes represent the driver’s knowledge and how data points are related to each other. Change in one data point affects the rest of the graph, creating new knowledge, mental model (Ramalingam, 2004), or perception (Novakazi, 2020). The area of interest for this work is especially how the brain changes something that is already known to something new. Re-learning or retraining the brain to adopt to new circumstances happens every time something changes in such a way that it requires a new or altered approach from the user to reach the intended goal (Lynn & Bassett, 2020). This is of interest because of the nature of the task of educating drivers on new systems since most already have complex networks that describe how driving is done. If the drivers are to adopt new functions and willingly change their behaviour it is advantageous to know what kind of hurdles there might be on a basic level.

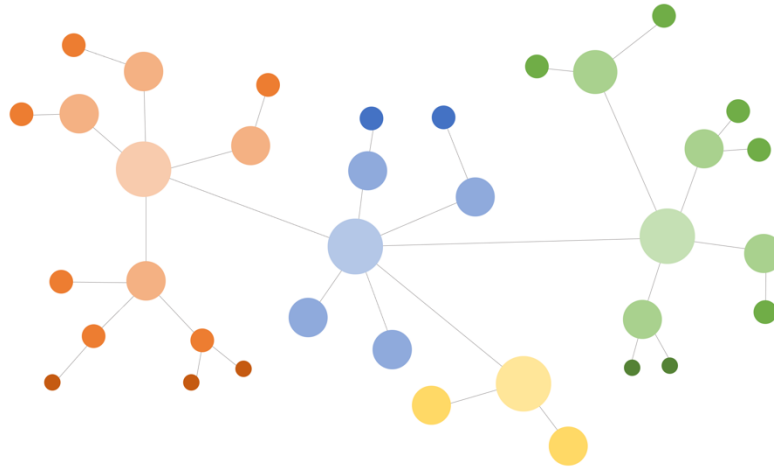


Figure 2.5 Connected nodes representing graph learning (Woodie, 2016)

Early results indicate that, when observing a sequence of stimuli that shifts from one transition structure to another, people’s learned representation of the first network influences their behaviour in response to the second network, but that these effects diminish with time. This gradual “unlearning” of network structure raises an important question for future research: Rather than investigating how network properties facilitate learning—as has been the focus of most graph learning studies—can we determine which properties make a network difficult to forget? (Lynn & Bassett, 2020).

Previous experience and preconceptions are also factors to consider since they influence a driver’s understanding of DAS (Novakazi, 2020). Drivers have a preconception or mental model of how they think DAS work, which evidently (Beggiato & Krems, 2013) is inaccurate. A big part of learning drivers how to use DAS correctly is getting them to forget, unlearn, or understand their misconceptions.

2.2.4 Gamification

Gamification refers to a development found in several domains that uses game elements to achieve motivational benefits, playfulness, creativity, and engagement among other things (Hamari, 2007). It is commonly used to facilitate changes in people’s behaviour. Games are a form of entertainment meant for people to have fun, relax, or spend time together. Their inheritably fun nature has made them a good medium for learning new things. Gamification has since become a method in design to make menial tasks more fun. Gamification in education, and DAS specially, has been shown to be an effective way to teach (Zainuddin et al., 2020). It is supposed to increase the motivation to learn by creating fun learning elements that makes the user not realise that what they are doing is actually learning. Feinauer et al. (2022) says that gamification as an education method is a great way to teach DAS. It is supposed to give more motivation, trust, and mental model formation. All of this sounds very promising to this thesis, since motivation to learn is one of the most critical things when designing education methods. Gamification could solve the motivation problem.

3 Methods

In order to find out new education methods, the domain where education could be applied needed to be established first. A user journey was constructed as a starting point. Three main concepts were then created during an idea generation. The ideas were tested in a workshop to find flaws and new inspiration. After this there were still three concepts that were further developed. Concept number three was developed to the prototype stage for user testing, however, after its pilot test it was deemed too distracting and would not give valuable results. After the pilot test, this concept was dropped and is not part of the result. It is still present in this method chapter.

3.1 Benchmark

As a starting point, the current available methods of education in DAS needed to be made. To summarize what kind of educational methods automakers are using today, a benchmark on the most common brands was made in table 3.1. The benchmark looked for traditional as well as novel ways to educate. However, no novel ways were found except for a few. Educational methods found in the benchmark were paper manual, digital manual, digital manual in app, information on website, video tutorials, and in-car information; Volvo Cars (2023b); Mercedes-Benz (2019); Tesla (2023); Toyota (2022); Audi (2023); BMW (2020); Volkswagen (2023); Kia (n.d.); Hyundai (2023); Cadillac (2021); Ford (2023); Honda (n.d.); Nio (2023); Xpeng (n.d.); Peugeot (2022); Opel, (2018); Mazda (n.d.). Besides the traditional methods, a lot of research have included simulation as education material, so it was added in the benchmark. There were a few automakers that offered some new ways like a simulator of their car, but nothing that specifically was about educating the driver in systems. It should be mentioned that just because a method of education is not mentioned in this benchmark, it is not necessarily because the automaker does not provide that method but only because it was not found in the research.

Table 3.1 Benchmark showing the current common methods for automakers to educate drivers

OEMs	Paper instruction (manual)	Digital text	Website	Video tutorials	In-car learning elements	Simulations
Volvo Cars	X	X	X	X		
Mercedes	X	X	X	X		
Tesla		X	X			
Toyota	X	X		X		
Audi		X	X	X		
BMW		X	X	X		
Volkswagen		X	X			
Kia	X	X	X	X		App that allows simulated use of the vehicle. Not specifically DAS
Hyundai		X	X	X	X	
Cadillac	X	X		X		
Ford		X	X			
Honda			X			
Nio		X	X			
Xpeng		X	X	X		
Peugeot		X	X	X		Interactive user manual that uses phone camera
Opel		X	X			Interactive user manual that uses phone camera
Mazda		X	X	X		

The result of the benchmark concluded that there are very limited methods in car education in general and DAS specifically. Further, there were few existing methods to consider when generating ideas, and only the concept of driving simulation presented as a novel idea.

3.2 Idea generation

The idea generation included the user journey, brainwriting, workshop, and analysis. It generated three ideas that were later tested with users.

3.2.1 User journey

A typical driver has a user journey centred around when they drive their car with additions to what happens before and after. By mapping this journey, opportunities where learning can take place can be found. The user journey for one day, or one drive, contained four phases distinct from each other. They were derived from analysing a typical drive and what happens before during and after the drive. The phases were created by what makes them different in terms of context and environment.

A complete user journey is found in table 3.2 which contains the four phases with actions, context, problem space, touchpoints, motivation, opportunities, and reach.

Table 3.2 User journey of a driver centred around driving a car

Journey steps	Before drive	Pre drive	During drive	After drive
Actions	Being at home Being at work Leisure away from home	Shopping Longer journey Commuting Weekend trip Setting travel destination Finding playlist Setting up mirrors/chair	Listening to music/radio Talking phone/passenger Following map Driving (steering, accelerating) Focus on road Change settings	Checking notifications and messages Getting ready to leave car
Context	Home Work Outdoor Other facilities	Car	Car Traffic City Highway Passengers	Car Parking lot
Problem space - What can I do? - When can I use the system? - What does the vehicle do?	Lack of appropriate mental models Lack of training devices Lack of motivation to learn Lack of knowledge about conditions and limitations Lack of access to easy educational resources	Lack of appropriate mental models Lack of training devices Lack of indications about the availability at start of drive Lack of awareness about appropriate functions at start of drive Lack motivation in trying new functions Lack of indications or suggestions about functionality	Lack of knowledge about the meaning of symbols and indications Lack of awareness towards new symbols and indications Lack of mental resources to try and educate while driving Lack of effective ways to communicate with the driver without breaking their focus Signals and indications are communicated in other places than the driver expects or does not notice	Not reflecting on the drive and improvements Missing feedback about when functions could be utilized Missing or misinterpreting ques and signals from the system Does not steer the driver towards a mental model that supports DAS Not presenting statistics to driver about the drive in a constructive way
Touchpoint	App Web	Infotainment Phone/app Car	Infotainment Phone/app Car	Infotainment Phone/app Car
Motivation	Prioritizing other stuff (more fun stuff) Not enough time Busy with life Opportunity to explore cars functions	If not in a hurry, there is an opportunity for exploration Ex. setting up music or learning about DAS First priority is to get going Often little/no time for exploring the cars functions	Driver distracted by driving High motivation to use DAS when aware Driving could be boring, fun way to learn motivating Instead of listening to music or radio	Getting to work With time over, there is opportunity for exploring car
Opportunities	Web Email AR App VR Image based Podcast Quiz "Bandersnatch"	Level up through SAE levels Video walkthrough on HUD or infotainment on unused functions Pop-up infotainment Walkthrough of DAS functions Audio visual ques on learning resources	Audio guide on how to use DAS Audial ques when DAS available Infotainment notifies when DAS available and suitable Leveling up through SAE levels Track the learning curve	Statistics and feedback Show DAS usage Show potential improvements with DAS Safety Relaxing Reverse w/ trailer Show improvement over time Show simple representation of drive performance
Reach	Notifications through email Notifications through app	HUD Car Phone/app Infotainment Audio	HUD Audio Car Infotainment Audio	HUD Car Phone/app Infotainment Audio

Phase 1: Before drive

First is before drive, it takes place outside the car which could be at home, at work, on a bus, in school, basically wherever during a normal day. This phase covers the biggest time span and possible locations. The options available here are massive since education could be applied anywhere where the driver is. Any mediums like a computer, phone, book, or game could be used to convey education except the car itself. It is also the phase least connected to the car which makes learning harder since it is without the proper context which is important when learning.

This phase would best take advantage of the moment of acquisition of the car when the driver is motivated to learn about what they just bought.

Phase 2: Pre drive

The second phase is pre drive, it takes place in the car but just before they drive away. It is a small window of opportunity since most of the time the driver simply gets in the car and drives away. There is always a small moment when the car is starting when the driver is susceptible for information, but most drivers have their focus elsewhere and won't be perceptive enough. Sometimes this phase could be longer if the driver is not in a hurry and are willing to explore the car in some way before they take off.

This phase has a short time span. Usually, the driver drives away quickly after getting into the car. It has the right context for real experience with the car. This phase needs to find the right moment when the driver would have time. It could probably not work on its own since it could not provide with enough education for the driver. It is also confined to the limits of the car, meaning that it can use the car such as the infotainment system and the real controls or a phone. A computer is not a viable option for this.

Phase 3: During drive

Third phase is during drive, it takes place when they are driving, and the driver is the most distracted.

This phase could have a long or short timespan since it is dependent on the drive. The context is the best in this phase since it is exactly the right use context (driving in a car). This context also comes with the most amount of distraction elements and safety risks. A lot of focus goes to driving the car and there is not much left over to be able to focus on some type of education. Theoretically, this phase should be the most effective given the learning theory that says learning is best done when doing. The learning would be completely confined to the cars systems. It cannot include the use of a phone or anything similar. The driver cannot look away from the road so the learning should be audio-based with other small elements like lights and haptics. The best application would be on longer drive periods when the driver is bored, and automation systems are suitable to use.

Phase 4: After drive

Lastly, the fourth phase is after drive, it takes place in the car after the car has stopped at the destination. Again, most drivers are on their way to something by now and won't have time to sit in the car to explore systems. After the fourth phase when the driver has left the car, they are now in phase 1 again, before drive, until they get into the car again making the journey into a cycle.

This phase also has a short time span. As in phase 2, the driver probably does not have time to sit in their car for a longer period of time, unless the driver is perhaps waiting for someone in their car. In this type of scenario, the education method needs to compete with other entertainment factors like a phone. The phase does have the right context as phase 2 and can use the cars systems and the phone. This phase has a unique opportunity to give feedback after a drive. Feedback gives an opportunity for reflection on their performance which is also good for learning.

The phases illustrate where in the driver’s journey education can be applied. Each phase has its strengths and weaknesses. There are huge amounts of time and opportunity in Before drive which means that anything can be done there. At the same time, it also lacks the real driving environment which the other phases have. The other phases are either brief or requires a lot of focus when you are driving. By examining the phases, it is easier to determine what is possible, feasible and promising when generating concepts.

3.2.2 Brainwriting

The user journey was used as a base to find opportunities for drivers to learn. The method brainwriting was used which involves silently sharing ideas written down (VanGundy, 1984). Brainwriting was used as a process for its ability to generate ideas on a short time, while keeping the idea generation structured and at the same time possibly eliminating production blocking and loafing around (Paulus & Yang, 2000). Brainwriting was used to frequently generate ideas for learning in the four previously mentioned phases. Phase 1 offered the broadest type of learning available since it can take place anywhere outside the car. Most traditional learning happens here, and it can happen in almost any form. The other phases were more constrained and limited in what mediums they can use.

The complete result of the brainwriting is found in appendix A. Examples are shown in table 3.2/figure 3.3:



Figure 3.1 Brainwriting result

3.2.3 Expert workshop

To evaluate the concepts before the user test, a workshop with experts in user education related areas was held. To do this, three concepts was further developed to be presented in the workshop where the experts could voice their opinions and concerns for further iterative development.

Three conceptual methods were chosen from the brainwriting. This first elimination phase was made with theoretical basis. First of all, the phases pre drive and after drive were deemed too short and too difficult to find motivation to learn. Given that it takes some engagement from the driver to learn, it will be too hard to use the short timespan to motivate the driver. Motivation is a highly prioritized factor which makes these phases unsuitable. What is left to choose from is before drive and during drive. Before drive has a lot of freedom regarding when the education is supposed to happen. Here, two concepts utilizing fun and enjoyment was chosen. One concept which had multimedia elements and simulated real driving situations, creating a mix from the results of Portouli et al. (2008) where multimedia education was effective, and simulation was only perceived as effective. The other concept for its gamification aspects which are supposed to be effective in DAS education (Feinauer et al., 2022).

Concept 1

Previous literature in DAS learning showed that multimedia and interactive learning methods resulted in better learning while simulation did not result in better learning in addition to multimedia learning (Portouli et al., 2008). This led to a concept dubbed Scenario. It showed scenarios from a driver's point of view inside a car where the viewer encountered situations involving DAS and made appropriate choices and received feedback by having the scenario play whatever would happen if that choice was made. This primarily took place before the drive (Phase 1) but could theoretically be placed in the car in the centre display while parked.

This concept took advantage of theories claiming that interactive learning is effective (Amineh & Asl, 2015), use multimedia learning and it got close to a simulation, since the driver experienced "real" scenarios without having to operate the controls of a simulator (Portouli et al., 2008).

Concept 2

Gamification has been shown to be effective in learning regarding DAS (Feinauer et al., 2022). In their study they used a quiz-based learning method with lots of other gamification aspects incorporated as well like progress bars, badge level-ups, and scoreboards. The Quiz concept made a game of learning about DAS by offering different levels of difficulty and player badges. This concept took place before drive but could also theoretically be used in the car centre display.

Concept 3

In according to constructivism learning theory, learning is very effective when the user gets first-hand experience (Hoch & Deighton, 1989; Amineh & Asl, 2015). Therefore, a concept in which the driver learns while driving with DAS should be effective. The only medium that the driver can take in while driving is sound based with some light and symbol indications. This concept used a voice assistant which gave instructions on DAS and was responsive to the driver's questions and eventual mistakes.

Workshop

The workshop was held with the aim of evaluating the concepts before the user testing with practitioners from relevant fields. The participants in the workshop were from the departments of User Information, Safe Experience, Product Validation, and Functional Architecture & Simulation. They had experience with designing for users and could therefore come with comments on how they thought the concepts would work if implemented.

They were presented the concepts at first and then in groups discussed each concept one by one. The workshop found out if the concepts were promising, if they needed tweaking, or if they were bad for reasons only these experts knew.

The workshop was structured in five phases:

1. First, the participants were given a brief in the email invitation explaining what the workshop was meant for and the agenda.
2. Second, when the workshop began, the participants were given an intro presentation on what work this thesis would be about and what has been done previously. The complete workshop including the intro presentation is found in appendix B. The intro presentation explained where we as students came from and our education, what our research question was, why we are researching this subject, our literature review and its findings, our aim, scope, time horizon, a timeline of what has been done and will be done after this, and finally what we want from them during the workshop.

- Third, the concepts were presented one at a time. Each concept was explained on how it worked, describing the functions and what the user did to learn. It was explained why this would work, naming relevant literature and references. It was explained when and where this would work, suggestions on when during the user journey they would use this concept. An example of presenting concept one is shown in figure 3.2.

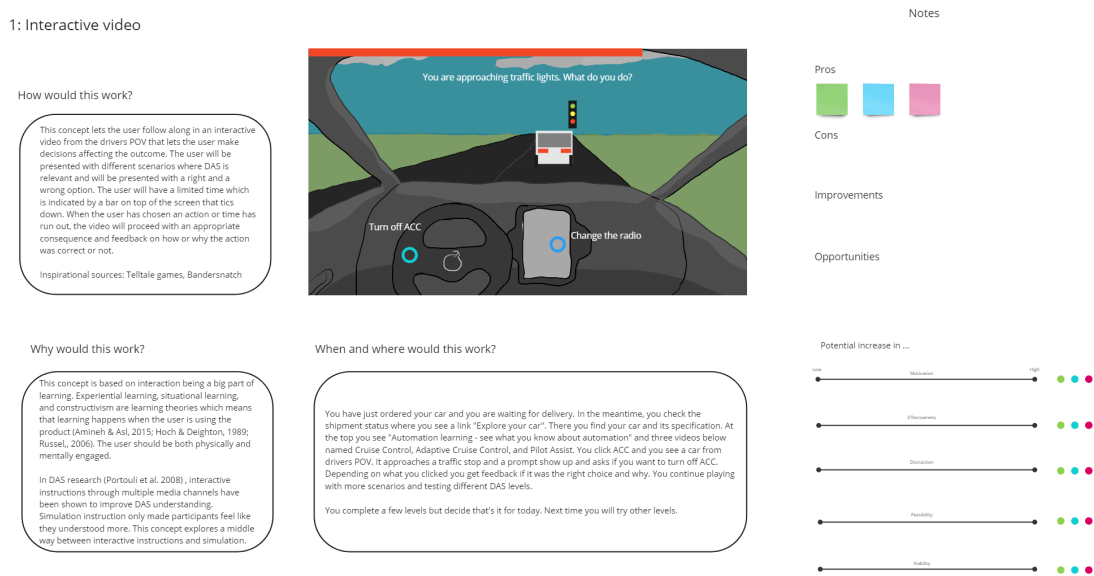


Figure 3.2 Example of the concept 1 workshop presentation

- Fourth, after the presentation the participants were separated in two groups which were moderated by us students. We sometimes had to steer the conversation and discussion away from irrelevant subjects. They looked at each concept one at a time and write down thoughts they had on notes. Each person got a colour assigned to them to later be able to distinguish their thoughts. They went through Pros, Cons, Improvements, and Opportunities and then placed themselves on Likert scales measuring Motivation, Effectiveness, Distraction, Feasibility, and Viability. This is found in figure 3.2 to the right.
- Fifth, the workshop ended with their general thoughts to see if they had more to say that had not been covered during the workshop.

The KJ method was used to analyse the data from the workshop. It is a method which gathers data points in clusters which are then named to establish important factors (Kawakita, 1991). First, all data from each participant for each concept was gathered in one place. The result for each concept were summarized from the notes and scales to see what the participants thought of them.

The results from the workshop suggested that concept 1 was promising and would probably perform well as an educational resource. Concerns were however that it was not the real experience of driving and lacked the real controls of the car. It needed more immersion to make up for the lack of realism. Concept 2 were thought of as lacking in motivation. Workshop participants suggested that it would not be enough with just a quiz to keep drivers entertained. It needed more encouraging elements to keep the driver entertained. Concept 3 had concerns that it would be annoying in some situations but was seen as promising and interesting as a concept. For the best result it should be complemented with other elements

apart from sound like light and haptic feedback. The full analysis from the workshop is found in appendix C. The results of the feedback are incorporated in the final concepts which are presented in chapter 3.3.

3.3 Final concepts

The final conceptual methods before creating the prototypes were defined with the help of the previous workshop. The concepts were redefined and polished in accordance with what the expert participants have expressed. The concepts were to be redefined one last time when making the prototypes because of limitations in the software used.

The three concepts were realised with prototypes created mainly in Figma. Figma is a software where you can do graphical layouts that can be made into interactive prototypes. It can look like websites or apps depending on how you make it look.

3.3.1 Concept 1: Scenario

The first concept was named Scenario. The basic formula could remain the same since it was considered an effective, motivating, and not distracting method.

Prototype

To create a prototype for this concept there needed to be a lot of footage of situations where the driver uses DAS. This footage was captured from a simulator that Volvo Cars has developed. The simulator lets you drive a Volvo car on trafficked roads where the other cars are programmed to drive around. It consists of three maps: City, Highway, and Country Road. The City map has a town with city traffic like traffic lights, stop signs, and roundabouts. It also has a highway which loops around the city. The Highway map is a broad highway which is mainly straight with some turns. The Country Road map has smaller roads with more sharp turns. Using these maps, footage was gathered to then be used in Figma where an interface could be made.

The video footage was then combined with an interface that the user could interact with. An example of a scenario is shown in figure 3.4. The interface consisted of a time bar that indicated how much time the user has left to make a choice. This was an animated progress bar that started full and gradually reduced itself to zero. The time for this time bar was set to 18 seconds to make sure that the user had time to read the prompt and figure out what to do. To indicate where the user could interact with the car, there were blue circles on areas like the buttons, the steering wheel, the centre display of the car, and so forth. There was also text next to the circles that described what the action would do, for example, “turn on SDS” or “Keep steering”.

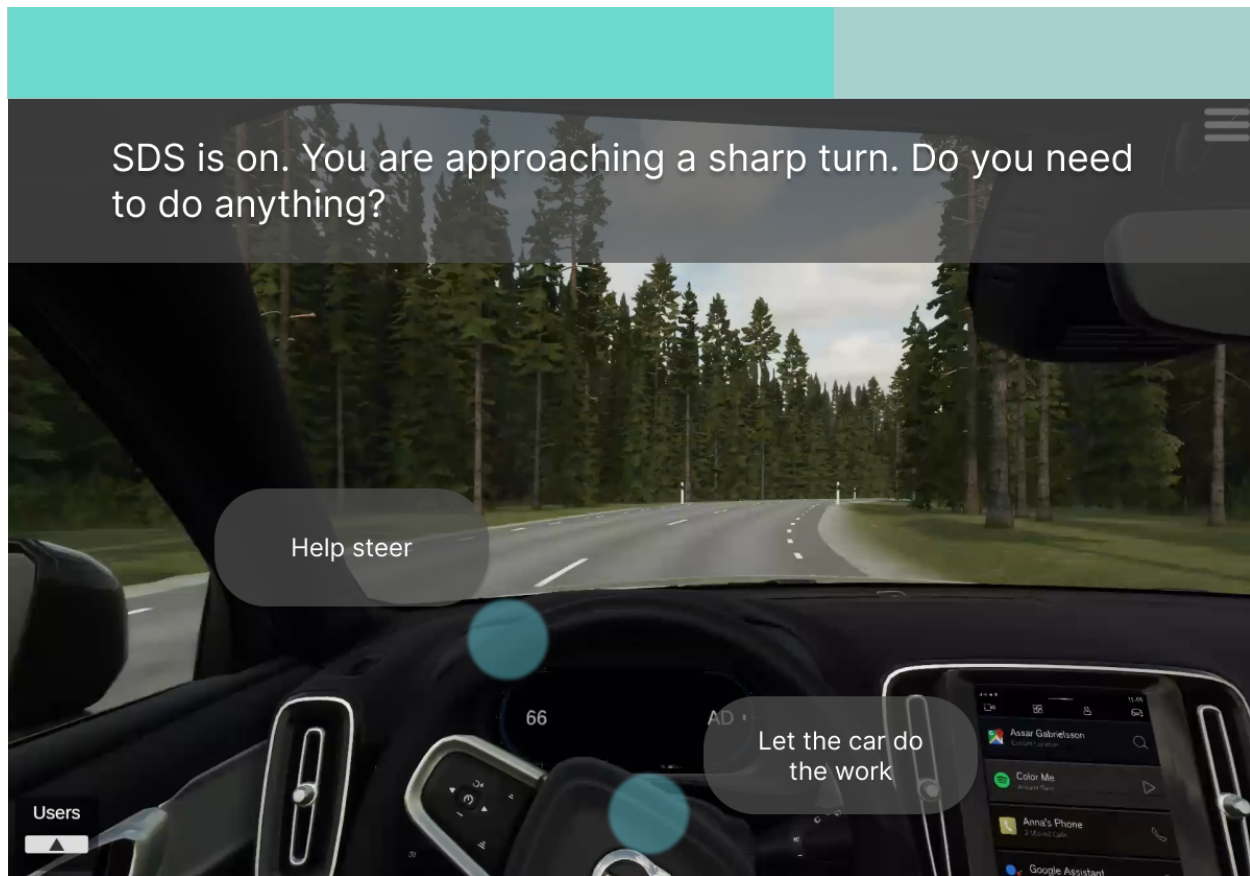
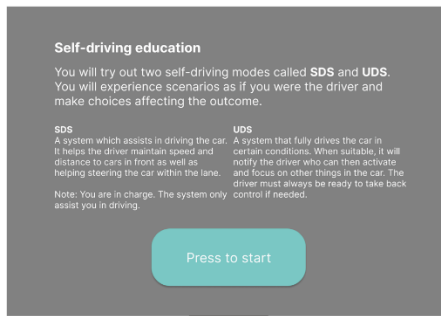


Figure 3.3 Example from prototype of concept 1: Scenario

The prototype worked like this: The user starts with an intro describing what they are about to do and is given a brief description of the two systems. When they press start, they are given their first scenario which begins with them seeing a car driving from the driver's point of view. After a few seconds the interactive interface appears with a prompt. Now, the time bar, prompt, and circles appear for the user and their task is to read the prompt and decide on what they think is the right choice. Note, sometimes no action could be correct by letting the time run out. For example, when driving in dense city traffic they could choose to not activate any system which would be a correct choice. The prompt contained some form of information about the situation (weather conditions, traffic conditions, descriptions of the road, and other things affecting the driving) and a command or a question that the user responded to by clicking one of the circles. Depending on if the choice was correct, they were met with feedback. They got a positive response like "Good job!" or "Smart!" as well as an explanation of why it was correct. If they answered wrong, they got a response like "Wrong" as well as an explanation of why it was incorrect. A flow chart of the prototype is shown in figure 3.5.

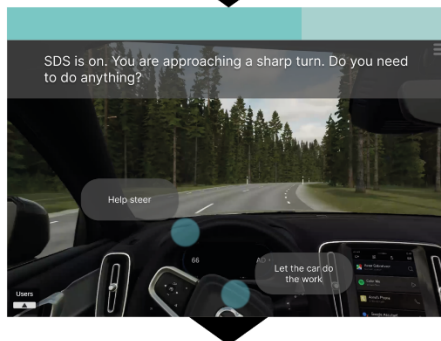
After this they clicked to the next scenario and continue until the end which congratulated them for completing the whole material.



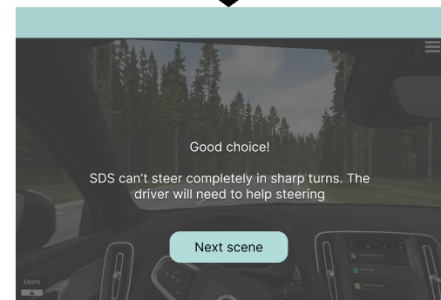
Starting page
Briefing of education method
and systems



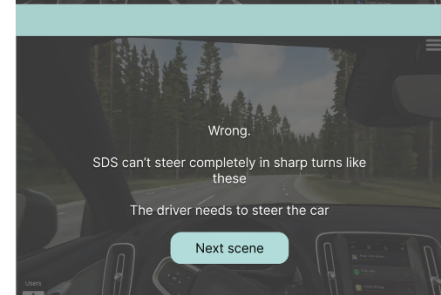
A scenario starts playing. The video starts automatically with no other prompts



After a few seconds a prompt appears with information and interaction elements



When a choice has been made a feedback frame pops up with either "Good choice!" or "Wrong" with additional explanation



Pressing next scene, starts the next scenario

Figure 3.4 Flow chart for concept 1 Scenario

3.3.2 Concept 2: Quiz

This concept, named Quiz, was considered a good educational resource but could be a bit boring, i.e., not motivating enough. It needed to be more fun and make the learning more enjoyable and less of a burden. To do this, sound effects and progress bars was added to the concept so that the user is rewarded a lot with sound effects which keeps them motivated to keep using it. The progress bar is useful for the user so they can keep track of their progress during the quiz and have a clear indication of how far they have come.

Prototype

This concept was completely made in Figma. The first thing the user saw was an introduction explaining what they were about to do and a brief explanation, like in concept two. Then they were met with a starting page showing that there are three levels but that only level one is available now. The user also saw their progress, they started as a beginner when they had not completed any level. This is shown in figure 3.5. The user could get explanation of their badge level by pressing “i”.

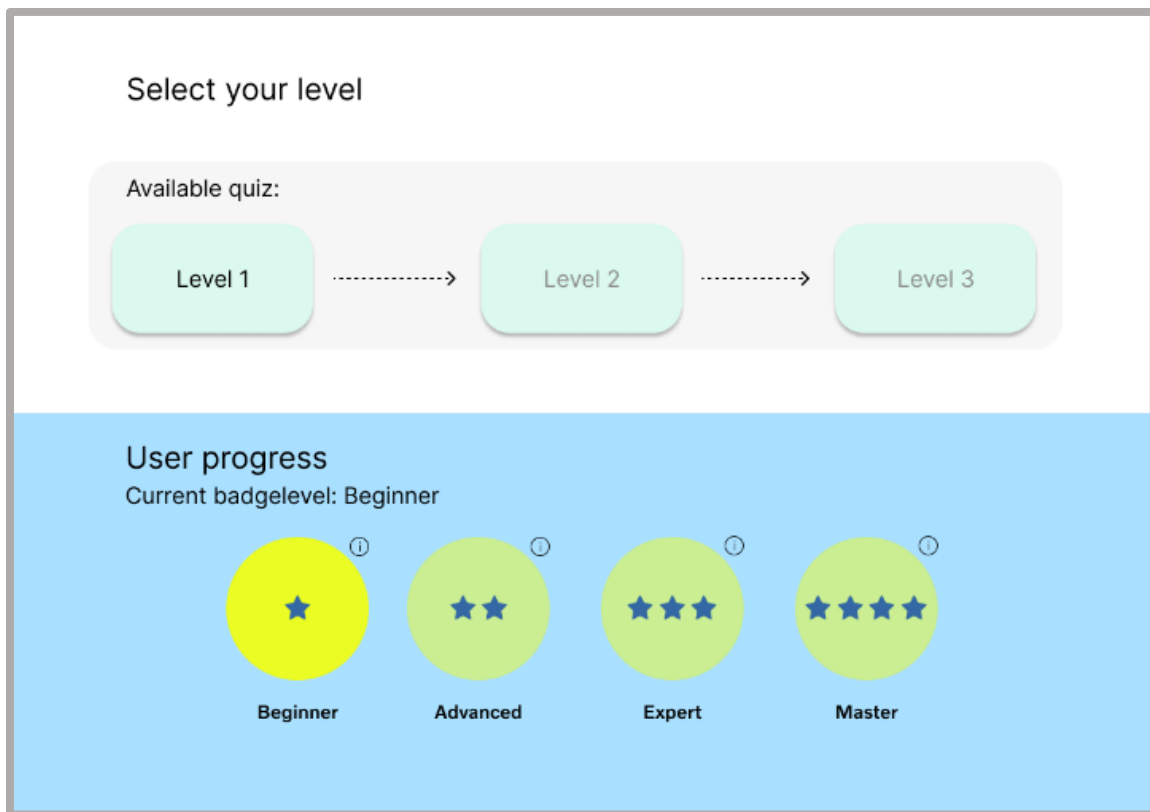


Figure 3.5 Concept 2 starting page showing available levels and User progress

When the user selects a level, the quiz begins. The user gets a question with four alternatives with one correct alternative (figure 3.6). If the user answers correctly, they are met with a sound indicating success and a blue pop-up window saying “Correct!” and with additional feedback of why and how they were correct. If the user answers wrong, they are met with a sound indicating an error and a red pop-up window saying “Wrong.” and additional feedback on why it was wrong, and what the correct answer was. The correct and wrong feedback is shown in figure 3.7. Then the user can continue with the next question. As the user progress with the question, a progress bar is shown at the top to indicate how many questions are left.

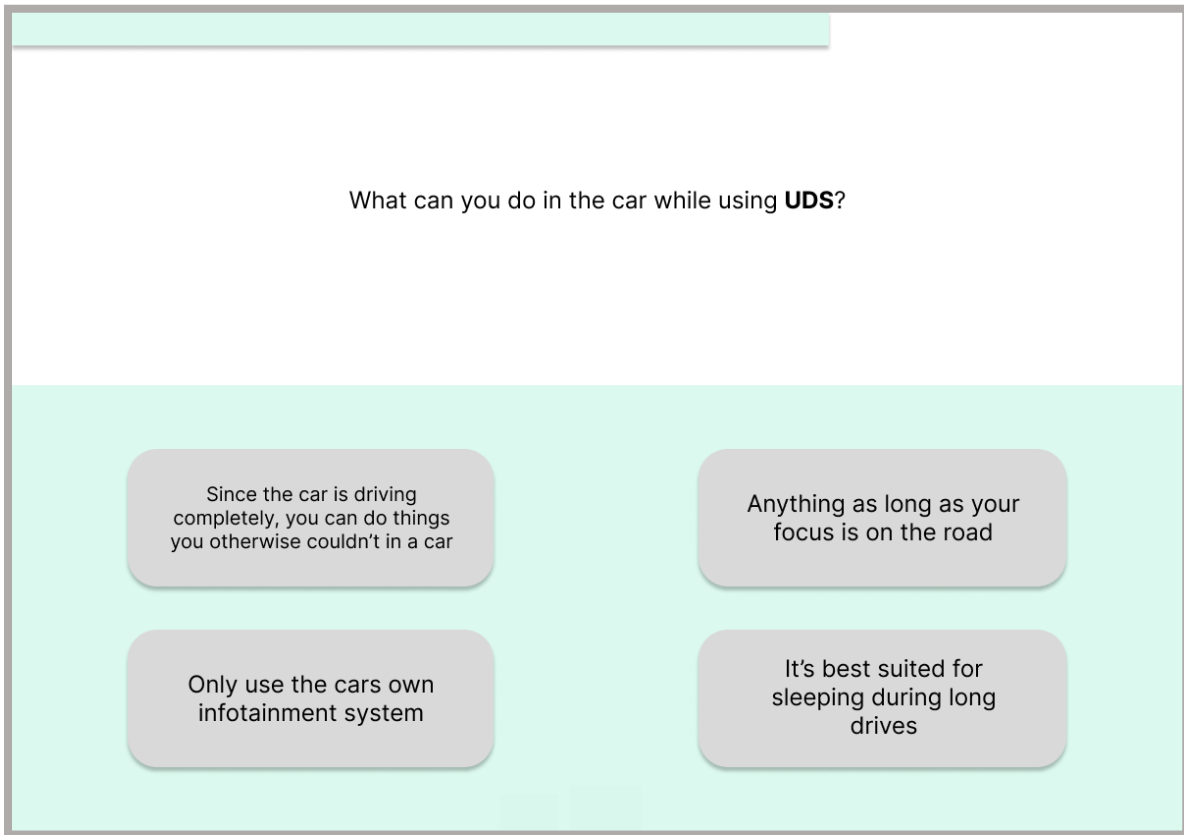


Figure 3.6 Example of concept 2 question

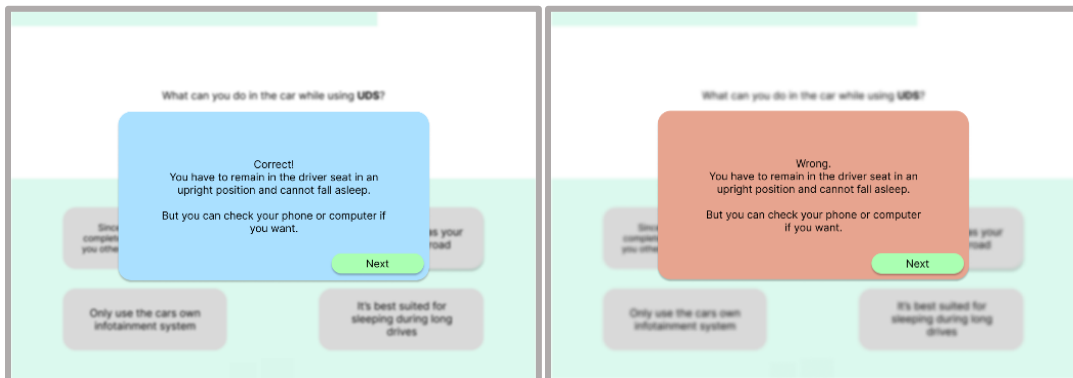


Figure 3.7 Feedback for question, correct (left) or incorrect (right)

When the user has completed a level, they are taken back to the start page where they are rewarded with an advancement in their user progress. A pop-up window appears immediately displaying their current badge level (figure 3.8). The user can click away the pop-up showing the start page again, but now showing level one as completed and that level two is unlocked (figure 3.9).

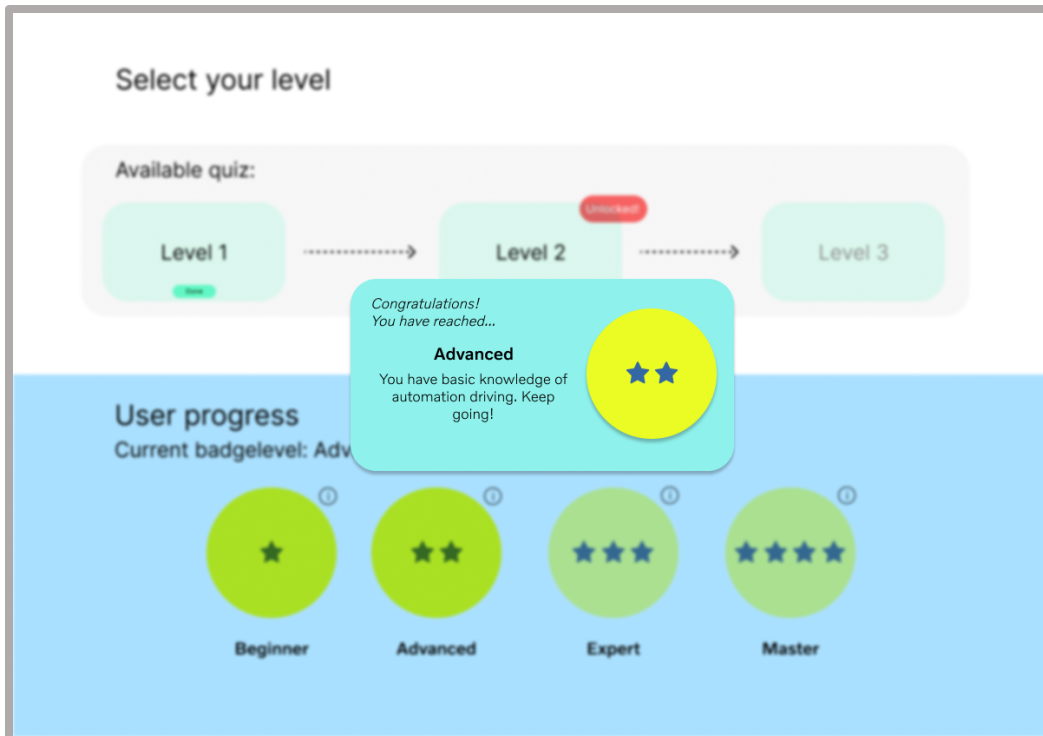


Figure 3.8 Starting page where the user has completed level 1 and advanced to a higher badge level

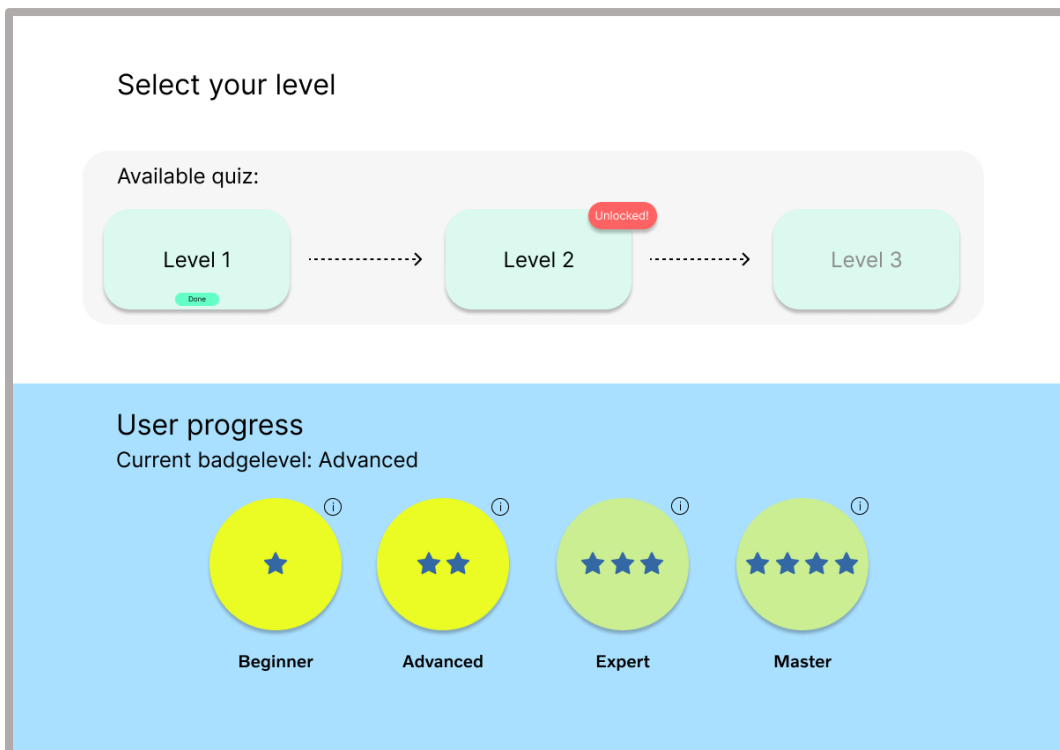


Figure 3.9 Starting page showing the progress of completing level 1 and indicating that level 2 is available

3.3.3 Concept 3: Voice guide

The final concept was named Voice guide. The workshop suggested that it would not be too distracting considering what else the driver can handle in the car while driving. After further consulting with automotive sound experts on how the concept could be realised it was decided that it used pre-recorded lines of text using a text to speech software which informed the driver who could navigate through different segments of the text. This concept was performed while the user is driving, and we sat next to them with the pre-recorded messages on a computer. If the driver had questions, we were also able to write real-time messages.

Prototype

A text to speech software was used to create voice lines for the instructions. These were then imported in Figma where they were connected to buttons. This created a soundboard that works like when you press a button on the screen it will start playing the voice lines (figure 3.10). The instructions were divided into segments so that it was less overwhelming for the driver when listening and easier for them to navigate through the segments.

1 "Hello and welcome to the audio guide for SDS"

2 SDS is a system that helps the driver by keeping and adjusting speed while keeping the car in its lane. There are limitations to this system and it is ultimately the driver that is responsible for the vehicle while the system is in use.

3 SDS can not detect street signs, traffic lights, or roundabouts and it can not see pedestrians or animals so you will have to steer clear of them. SDS can struggle to make sharp turns so you will have to be ready to steer if one is coming up. This means that SDS is best used outside of towns and cities where signs, people and sharp turns are limited

4 The conditions for when SDS is appropriate to use is if there are clear lane markings on a highway with good weather. You as the driver needs to keep your hands on the wheel at all times since it is you who is responsible for the vehicle.

5 Make sure there are clear lane markings on the road and the sight is reasonably clear without heavy rain or snow. There should not be a heavy trailer connected and the drive does not include any steep inclines.

6 To begin please look at the buttons on the left side of your steering wheel to get an overview. Locate the middle button on the left side with a symbol that looks like a steering wheel with two hands controlling it. To activate SDS you press the button.

7 Press the middle button that you located earlier and adjust the speed by pressing plus or minus. To deactivate the function you can press the same button or simply use the brakes.

< UDS

1 "Hello and welcome to the audio guide for UDS"

2 UDS is a system that when it is available will drive the car for you! The system can be used on specific roads which it will track and notify you of automatically but it cannot be used on unsupported roads.

3 When UDS is used you can do other things in the car since the car is completely responsible while driving in UDS.. You can socialize with other passengers and use your phone or computer if you want. Remember that you must be ready to take back control if needed. And sadly enough you can not sleep while using UDS.

4 The system will let you know when it is available. To activate it you have to press two buttons on the steering wheel and then the car will confirm you have activated it.

5 The system will let you know when to take back control of the driving with sound notifications. If you do not take over the driving the system will stop the car by the road in a safe way. To deactivate the system and continue the drive manually you press the same two buttons as before.

SDS >

Figure 3.10 Concept 3 soundboard of instruction segments

3.4 User testing

The goal was to have three concepts tested for how well they educate drivers. They were measured and compared to each other by having the participants learn from the educational materials, then use the DAS and answer questions about them. The results from these measurements were then used to find out differences in the concepts on effectiveness and motivation.

The user test was planned as follows:

1. The participants were first presented with educational material,
2. then drove in the simulator,
3. then did a survey,
4. and finished with an interview.

There also needed to be a standard test to establish a baseline, which all concepts could be measured against. This baseline needed to be a basic type of education, so a printed user manual for the current automation system was used. In step one they were presented with either the concept Scenario, concept Quiz or the baseline User manual. Concept Voice guide was presented during the simulator as it was designed to be done while driving. They were given a laptop where the prototypes could be used or a printed version of the manual. They were given a moment to themselves to finish the material. Most of the time they figured out how everything worked, but sometimes they needed initial guidance for the concepts. Those who read the manual were instructed to read it with as much or as little thoroughness they felt like. It was important that the participants did not feel pressured to study the material before the simulator as if it was a test, since that is not how they would have read it in real life. They were told to imagine that they wanted to look up the DAS in their car and was presented with the manual and should read it like they would have in that situation. If they felt that some information was unnecessary, they were allowed to skip or skim through it.

The simulator drive was observed with cameras for performance evaluation by monitoring their behaviour and steering wheel interaction. The surveys measured theoretical knowledge. The participants were asked to answer statements with agree or disagree. The interviews asked them questions specifically on the educational material they were presented. Their opinion on the educational material and what they would have wanted instead was asked. A detailed protocol for the test is found in appendix D.

3.4.1 Definition of education material

Before making the concept prototypes, the content of the educational material needed to be defined. The driver needed to be educated in functionality of DAS and mode awareness. To make the educational materials equal in content the manual was the base of the content. Since the manual is an already made resource, it was used to extract material about the functionalities and limitations of the DAS. In addition to this, other common errors made when using DAS was added to the new concepts.

They had a possibility to convey even more information compared to the manual, given that they were designed for a specific purpose and system of the car. The manual need to cover all aspects of the car and be complete. In the real world, the concepts would complement the manual being the base of all instructions and the new concepts could educate the driver as effectively as possible on specific topics. Still, it is important to note that the new educational material would have the same liability as the manual. They also have a unique opportunity to convey information the manual cannot, because of the type of medium it uses.

The educational material was focused on two different levels of automation, SAE (2021) Level 2 and Level 4. Level 2 is defined as partial automation (speed control and assisted steering) and level 4 as high automation (car drives itself completely when notified). For the purpose of the thesis goals, two systems

were defined: a level two supervised DAS and a Level 4 unsupervised DAS. Level 2 and Level 4 was chosen for testing because they are different from each other. They are on each side of SAEs (2021) regarding high and low level of automation, meaning that in level 2 the driver is responsible and in level 4 the car is responsible. The stark difference in the systems makes them suitable for this user test since it creates a challenge for the driver to be able to have the correct mode awareness of them.

Level 2: Supervised Driving System (SDS)

The level 2 system was named for this thesis Supervised Driving System (SDS). It is part of the low-level automation in SAE standard (SAE, 2021) meaning that the driver is still technically and legally driving the car. It maintains speed, adapts to the car in front, and assists with steering the car within the lanes (SAE, 2021). It is available at all times, and it is up to the driver to activate it without the car notifying them. It needs clear lane markings on the road to work and cannot detect traffic signs, traffic lights, roundabouts etc. The driver is as responsible for the car when using SDS as they are when driving completely by themselves. It only assists with driving the car so the driver cannot do anything in the car that they could not do normally, for example use their phone or take their focus off the road.

Level 4: Unsupervised Driving System (UDS)

For this thesis a conceptual idea for a level four system was used, named Unsupervised Driving System (UDS). According to SAE (2021) in a level 4 system the car is completely in control which means it will maintain speed, adapt to traffic, completely steer the car, and is also responsible when used. It is part of SAE higher-level automation systems, and it notifies the driver when it is available who then decides if to activate it. When activated, the driver can do other things in the car like use their phone, watch a movie, or socialise with others in the car. The driver still has a responsibility to be able to resume control when the car notifies them, so the driver cannot sleep while using UDS.

3.4.2 Simulator

The test participants drove in a simulator as a part of the test. The software was from the same type of simulator used when capturing footage for one of the concept prototypes. They drove in the City map (figure 3.11) where they started in a city, drove out on the highway for some time, and then exited the highway to drive back into the city.



Figure 3.11 Simulator driving environment

The simulator utilized a rig which consisted of a steering wheel which had the correct buttons for SDS and the level four system. It also had a real adjustable driver's seat and pedals. The whole simulator drove like a car with an automatic gearbox.

The simulator had one built in automation system which worked like UDS (completely steering the car by itself when activated). This automation system was used for both SDS and UDS and the difference was only the driver's interaction with the system. The systems could only be used on the highway part of the

drive since they did not work in the city because of limitations with the simulator. UDS will when activated drive the car completely, meaning steering the car and keeping the speed. SDS will keep the speed and assist with the steering, but the driver needs to keep their hands on the wheel and help steer. In the simulator SDS and UDS behaved exactly the same but in SDS the driver must keep their hands on the wheel and actively steer, while in UDS they could let the wheel go.

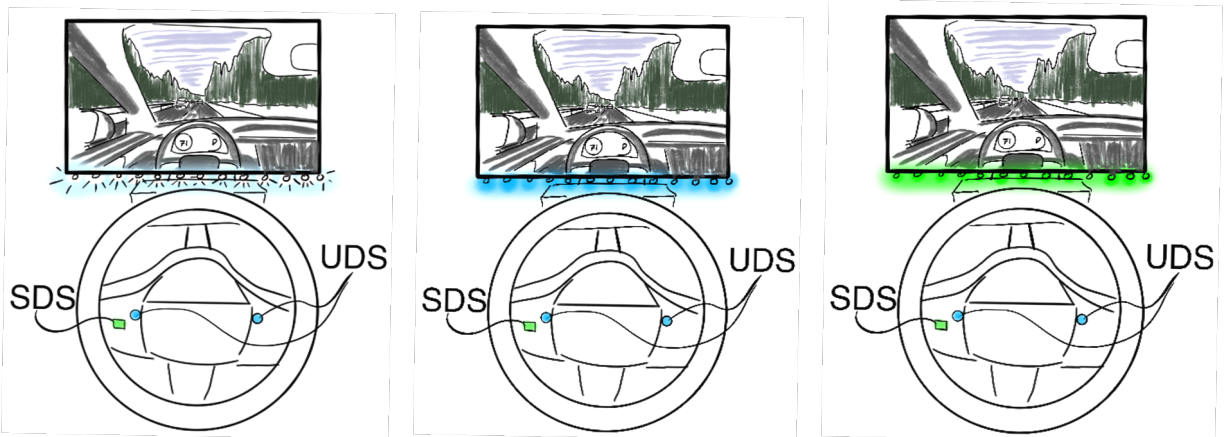


Figure 3.12 Simulator rig from driver POV showing light indications and wheel buttons

In order to simulate the automation systems and everything around them, the Wizard of Oz method was used where all the systems are manually controlled by us. The driver had a wheel without functioning buttons. When they pressed the buttons, we activated the system. To simulate which system was active a light strip was added to the simulator as well as sounds to indicate notification and activation. To illustrate that UDS was available or that it should be turned off, a pulsing light was used with a notification sound (figure 3.12 left). When it was activated, a turquoise light was turned on with a success sound (figure 3.12 middle). When SDS was activated, a green light was turned on (figure 3.12 right) without sound since there is no activation sound for that in a real car.

3.4.3 Participants

The participants for this study needed to be unfamiliar with DAS. They could not have a lot of experience driving with DAS or knowledge about DAS (i.e., working with DAS). Therefore, a screening was made to filter out people like this. A survey collecting demographic information and asking about their experience and knowledge level on DAS was used (appendix E).

Those that had low level of DAS knowledge and low experience was given a link to book a time slot, and those that were too experienced did not proceed.

A total of 48 people used the screener survey, where 27 people were eligible for the test and answered that they wanted to sign up for a user test. A total of 20 people participated in the test. One of those people was a pilot for concept 3 Voice guide which was deemed too distracting to feasibly test. All in all, 19 test could be used for data collecting: 7 for concept one, 7 for concept two, and 5 for the baseline test. An overview of the test participants is shown in figure 3.13-3.18.

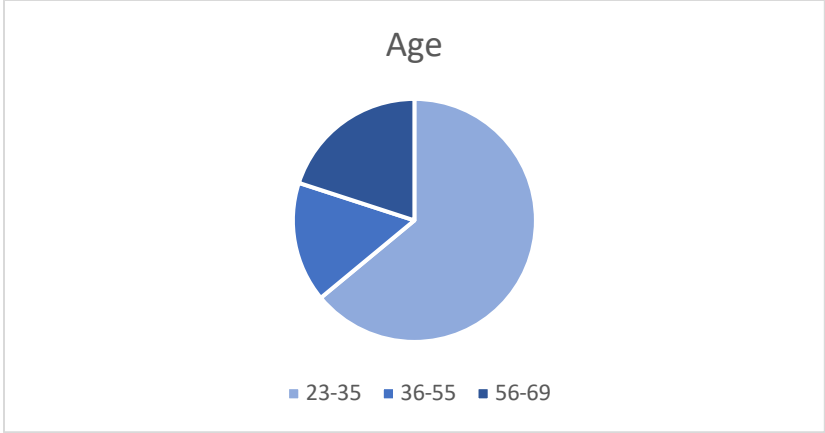


Figure 3.13 Participant demographics on their age

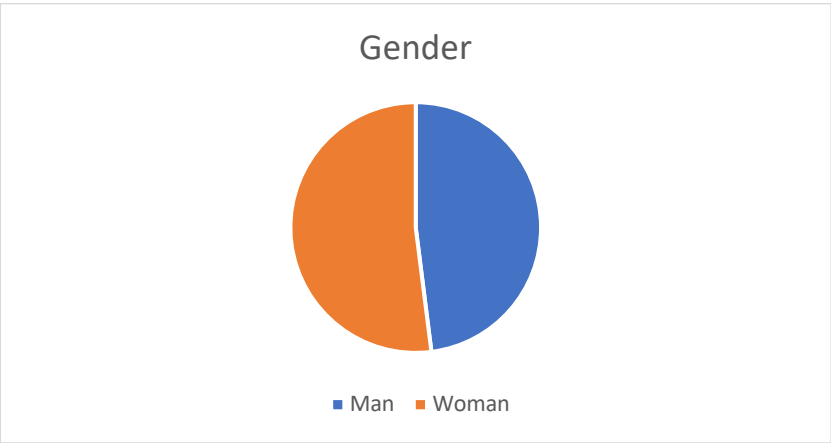


Figure 3.14 Participant demographics on gender

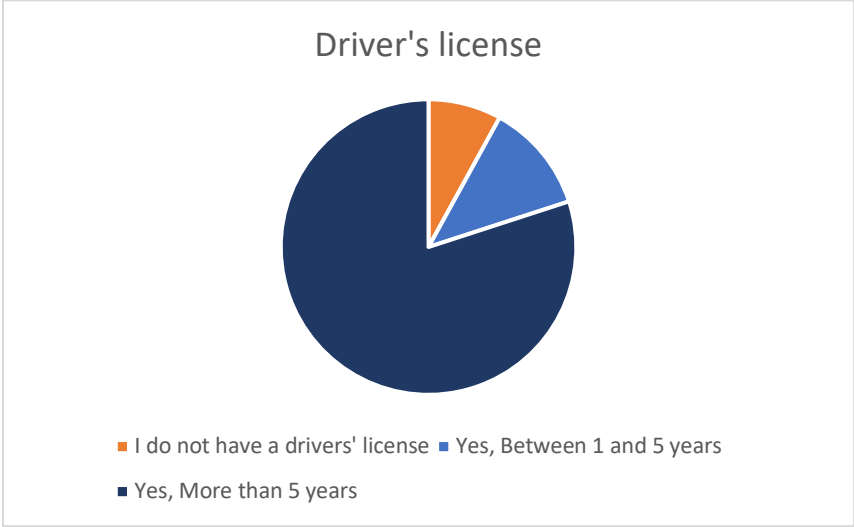
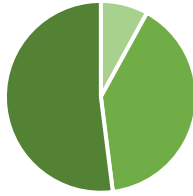


Figure 3.15 Participant demographics on driver's license

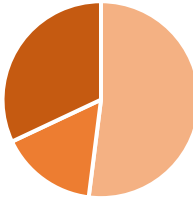
How much knowledge do you have of DAS?



- I don't have any knowledge about driving automation
- I have a little knowledge about driving automation
- I have moderate knowledge about driving automation

Figure 3.16 Participant information on DAS knowledge

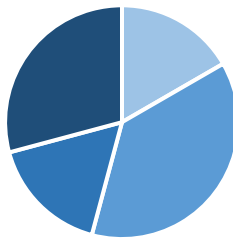
Do you have a car with DAS?



- No, I don't own a car with such systems
- My car is equipped with Cruise Control (CC) or Adaptive Cruise Control (ACC)
- Yes, I own a car with such systems

Figure 3.17 Participant information on car with DAS ownership

How often to you use DAS?



- I have never used it
- I have tried it but I don't use it
- I use it for specific trips
- I use it sometimes

Figure 3.18 Participant information on DAS usage

3.5 Data collection and analysis

The data was collected through a mixed-methods approach facilitating an observation in the simulator, a survey, and an interview post-drive. The observation result gave quantitative information on how they performed driving in the simulator. The survey gave quantitative information on their theoretical knowledge. The interview gave qualitative insights on their opinions and feelings on the education material and concepts.

The analysis of the results was guided by the following hypothesis:

H0: Concepts 1 and 2 are believed to outperform the baseline in both the simulator and survey.

This hypothesis is based upon gamification theories as well as the way constructivism puts learning in a context which will benefit more engaging and interactive methods.

Concept 1 Scenario is built upon constructivism theory that learning takes place while doing and in the appropriate context. They are allowed to make mistakes and reflect on the feedback they are given which should enhance the learning experience. The Scenario concept uses this by showing situations in traffic where the driver interacts with the car on a certain level. The driver must analyse the situation as in a real scenario and then make decisions, engaging them in the situation and thus making the learning more effective. The learner in this concept should then understand when, where, and under what circumstances DAS can be used.

The Quiz concept should work well since it is built upon gamification aspects that should make it fun to use. The learner in this case should feel a sense of wanting to continue doing the education material because of encouraging elements in the concept. Gamification elements should also result in more effective learning so that the learner should have a good understanding of the DAS.

If the hypothesis stands true, the analysis should result in participants in, both concept 1 and 2, having fewer errors, better understanding of limitations and functionality, faster response time, more active use, and more motivation to use.

The following sections will describe the collection and analysis of each dataset in detail.

3.5.1 Dataset 1: Observation

The observation was made when the participants drove in the simulator. They were recorded with two cameras, one recording their body and one recording the steering wheel. The body camera captured things like how they behaved driving and using the systems, for example, where they kept their hands and where they looked. The steering wheel camera captured things like where they interacted with the wheel, what buttons they pressed, and if they kept their hands on the wheel. The screen showing the simulator was also recorded. The composition of the test set up is shown in figure 3.19. Camera 1 was filming the body, camera 2 was filming the steering wheel interaction. The wizard who was controlling the notification system sat behind the driver to the right to be able to see the driver's button interactions. The test leader sat next to the driver to their left and gave them instructions as well as turned on and off the automation system with the keyboard.

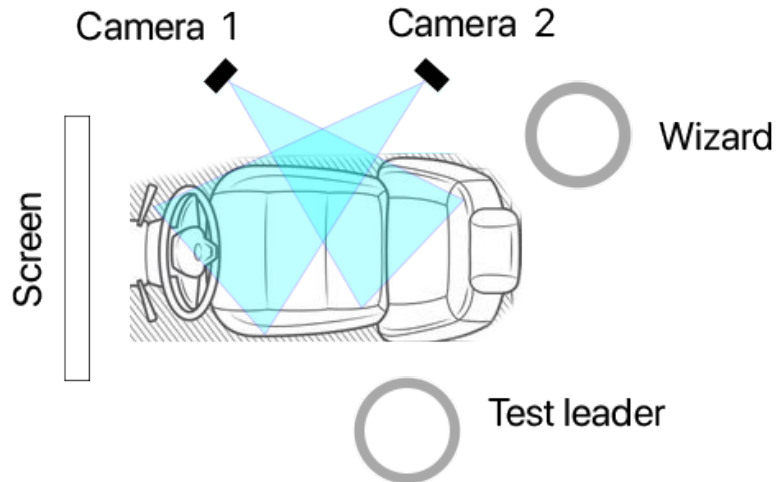


Figure 3.19 Test set-up

Data collection

The data collected from the observation was quantitative and it was collected according to table 3.3. The data points were either a positive value or negative value, meaning that a higher number of positive values indicates better performance and vice versa. The positive values have a weight of 1 and negative -1. The exception is superfluous use, which means that the user is not doing something wrong but is doing unnecessary things that shows a lack of understanding of DAS. This is why it has a value of -0,5 instead of -1 to show that it is not as bad as an error, but it is still not the desired behaviour.

Table 3.3 Measurements for Observation

#	Measurements	Definition	Value	Weight
A	Correct actions	Turning on SDS in right conditions Turning on UDS when notified Turning off UDS when notified Correct mode awareness	Positive	1
B	Times activating SDS	Pressing SDS button on highway	Positive	1
C	Times wanting to activate a system	Verbal communication that they want to activate system Trying to press buttons to activate system	Positive	1
D	Errors of omission	Not turning off SDS before city	Negative	-1
E	Errors of commission	Incorrect button press Steering, braking, accelerating while in UDS	Negative	-1
F	Superfluent use	Hands on wheel in UDS Turning off UDS when not notified or told to take an exit	Negative	-0.5
G	Error after notification until activation	Pressing wrong buttons	Negative	-1
H	Time after notification until activation	From sound and light signal to correct button press	Denominator	-

Data analysis

To extract results the average value for each group was calculated. Here each measurement could be compared between the different groups. In addition to this, another data point was created by adding all the positive values, subtracting all the negative values, and dividing with the response time creating a number that reflected the total performance. The formula for this equation is shown in equation 1.

$$Performance = \frac{\sum_{A=i}^G i}{H} \quad (1)$$

During the observation there was one instance of an outlier which performed badly during the simulation. This person made 73 errors whereas other participants made on average 2. This data would skew the result of one of the groups so to avoid this the median value was used on the E measurement (Error of commission) found in table 3.3. The difference in the results was that the average value for E in one group was 1 (median value) instead of 12 (average value).

3.5.2 Dataset 2: Survey

The participants filled out a survey directly after they made the simulation. They answered questions about SDS and UDS on a theoretical level. The survey is found in figure 3.20 and 3.21. The statements were based on the theory described earlier on drivers' common misunderstandings of DAS (Orlovska et al., 2021; Orlovska et al., 2020; Hu et al., 2022; McDonald et al., 2018; Noble et al., 2019) like what you are allowed to do in the car with a system active, who is responsible, when systems are available, etc.

Data collection

The participants also filled in which of the three types of educational material they did by filling in one of four alternatives as seen in figure 3.22. The data could therefore be separated and analysed through different educational methods. Their answers were displayed next to each other in bar graphs which showed the distribution of how each group had answered. A correct answer was added next to the other groups for a reference.

1. SDS	Strongly disagree	Disagree	Kind of disagree	Kind of agree	Strongly agree
I can activate SDS at any time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am responsible for the vehicle while using SDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can watch a movie while using SDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I get information from SDS when I can use it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can be distracted for short amounts of time while using SDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can fully relax while SDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can sleep while SDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can read or browse while SDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 3.20 Survey statements on SDS

You probably got the fastest lap time! Tell us your thoughts on UDS

2. UDS

	Strongly disagree	Disagree	Kind of disagree	Kind of agree	Agree	Strongly agree
I can activate UDS at any time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am responsible for the vehicle while using UDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can watch a movie while using UDS	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I get information from UDS when I can use it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can fully relax while UDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can sleep while UDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can read or browse while UDS is active	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 3.21 Survey statements on UDS

3. Select the education material you did

- Quiz
- Scenarios
- Voice Assistant
- User manual

Figure 3.22 Education material question

Data analysis

All answers were clustered in each group. This way, it showed how each group had answered. It showed if the group had answered unanimously or not and if they had answered correctly. An unanimous answer shows that the educational material was consistent with all of the participants in that group. Correct unanimous answers showed that the participants had a good understanding. If the answers were divided and scattered it showed a flaw in the educational material since it could not be certain that the educational material had taught them or not.

Each group were then compared to each other with how many statements they had wrong and what specific questions were wrong. If they had more wrong answers, they had less understanding and the specific statements showed what type of misunderstandings they had, critical or understandable. This then showed what flaws each respective educational material had, and ultimately which one performed the best.

3.5.3 Dataset 3: Interview

The participants finished their test with an interview on their thoughts about the education material. It was a semi-structured interview, recorded and auto transcribed with Microsoft Office software, consisting of seven questions with additional follow up questions. The full interview is found in the test protocol in appendix D. The questions asked about the following subjects: enjoyment, motivation, trustworthiness, perceived effectiveness, when and where it would be used, and final additional thoughts.

Data collection

The interview was recorded with a microphone and transcribed in real time by the computer. Afterwards, the transcripts were analysed for relevant citations.

One quantitative value from the interview was perceived effectiveness. The interviewee was asked to grade themselves from 1-5 on how well they think they know the systems after the educational material.

Data analysis

The data from the interviews came in the form of citations from the transcripts which were then analysed with the KJ method (Kawakita, 1991) in clusters. Since the interview questions already asked about specific topics, the questions were used as cluster themes in the analysis. The citations were put on post-it notes in Miro and colour coordinated according to which educational material they pertained to.

The KJ grouped quotes from the interviews in different categories based on the interview guide. The categories in the KJ were Motivation, Enjoyment, Perceived effectiveness, Use, Trust, and User journey. After the quotes were sorted and grouped according to the type of test that produced them, patterns started to emerge. The patterns could span over several categories but were always most prevalent in one which led to conclusions about what the main take-aways were for each category. An example of one of these conclusions are from the category Enjoyment where the consensus regarding the manual was that it took too long and that it was boring. The conclusion was then that the educational material should be short and effective and preferably in bite-sized chunks so that the user did not feel the need to spend more time than they were willing at any time. This process was done on all categories and all collected quotes that could be tied to a pattern. The patterns that were not contained within one category needed to be tied to the most relevant one where it was most prevalent to minimize overlapping and unclear guidelines. The categories were then tweaked to better fit the design guidelines, Perceived effectiveness became Effectiveness and Use was removed since the overlap was too great with other categories. These concluding themes were finally turned into the design guidelines that are presented below.

The transcribed interviews were analysed through a KJ analysis that was used as a basis for the development of design guidelines. The developed guidelines aim to support the development of educational resources for DAS.

4 Result

This chapter describes the results obtained from the data collection. It is divided into observation, survey, and interview.

4.1 Observation

The results are visualised in figure 4.1. The Scenario concept is represented by blue bars, Quiz by green, and User manual by grey. The error, superfluent use, and time response values are negative value measurements as seen in table 3.3. It means that lower results are better in these categories, and higher is better in the other: times wanting to activate system, times SDS activated, correct actions, and performance factor.

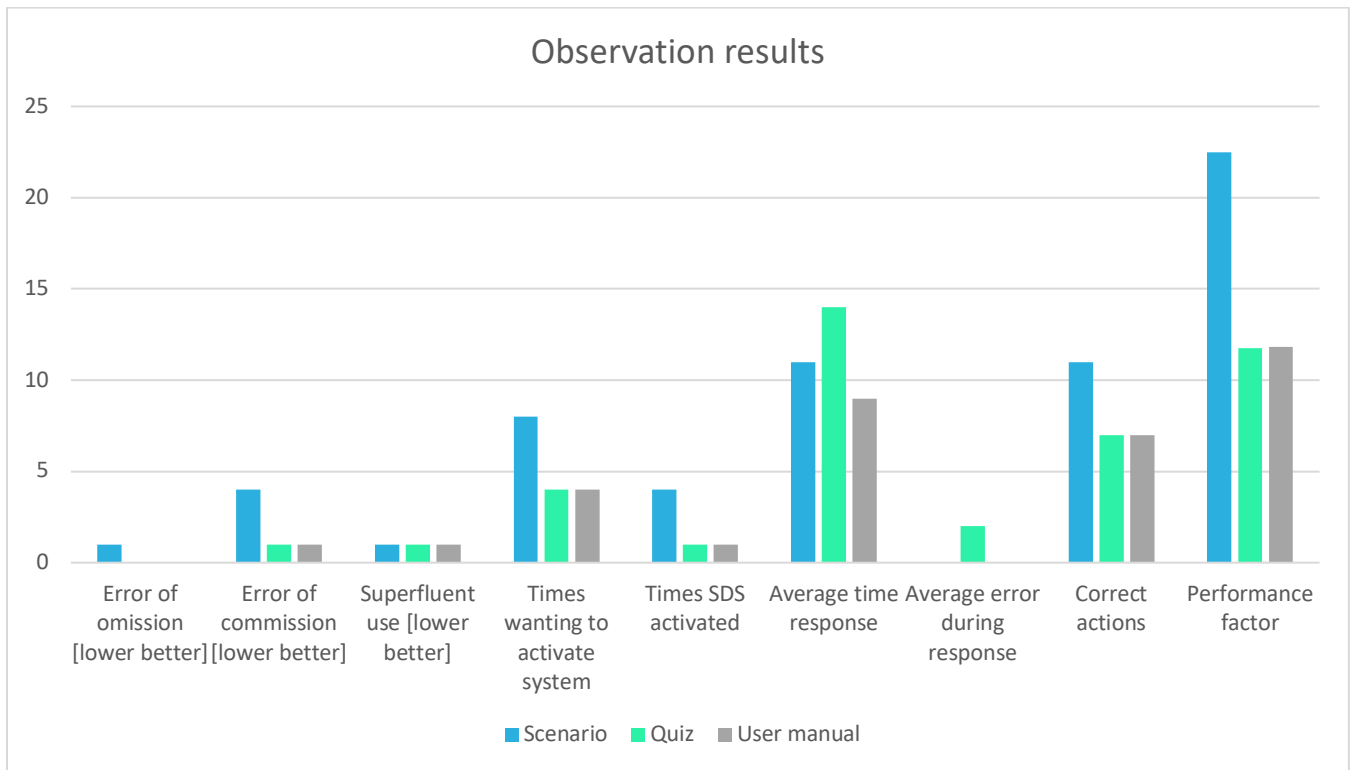


Figure 4.1 Results from observation

Overall, the Scenario concept performed the best. It can be seen in the performance factors which considers all factors and that has good results in each individual measurement. The performance factor is almost double that of the other two methods. Looking on the individual measurements, Scenario had both high in the positive and negative measurements. It had a lot of correct actions but at the same time more errors than the other methods. It also had a lot of times it activated the systems. All of this indicates a lot of interaction with the systems. The driver is engaged with the systems in a way they were not for the other methods. A conclusion can therefore be drawn that the Scenario method increased their willingness to use the systems, which lead to more correct actions but at the same time more errors.

The type of errors the Scenario group made was mostly errors of commission, meaning they did things outside the intended area of use. This was mostly caused by them trying to activate UDS when it was not available. Not a safety critical error since nothing happens when they tried to activate it. More critical if

they had a wrong mode awareness by thinking they activated UDS when they actually activated SDS or not responding to UDS notification to turn it off. What could be critical is if they thought they succeeded in activating UDS and expected the car to drive itself when, in fact, they were driving and were responsible. This type of error of omission did not happen during the observation so the participants avoided being in any hypothetical danger. In addition to this, how the systems work in an actual car is different than what could be done in the simulator as stated in a previous chapter. In a real scenario, the system has more ways to let the driver know what system is active and is able to tell more detailed information.

The Quiz concept and User manual scored similarly, only in response time and error during response did the quiz score lower. Their scores indicate a decent understanding of the system but with passive interaction. They show a low motivation to use the systems, especially SDS which is completely up to the driver to activate without any notification from the car. The User manual did have more graphical elements than the Quiz did which could explain why they performed well in the response measurements.

Why the Scenario concept performed well in the simulator is likely because of its very graphical and interactive ways of education. In this concept the user gets the closest to real life in regard to activating and using the system. This probably gave the user more confidence to use them since they had seen and almost experienced it before.

4.2 Survey

The result is shown in appendix F, showing the users theoretical understanding of the two systems SDS and UDS. Each statement shows how the groups answered labelled with “Manual”, “Quiz”, and “Scen” with the correct answer next to them labelled “Correct”. Orange colour represents disagreement and blue represents agreement with the statement. Of all the groups on average, Scenario and Quiz answered most correct, however, there were statements that contained widespread or some wrong answers. These statements were then deemed incorrect as it showed that some participants still did not know despite having been educated.

Notable statements that every group answered correctly are shown in figure 4.2.

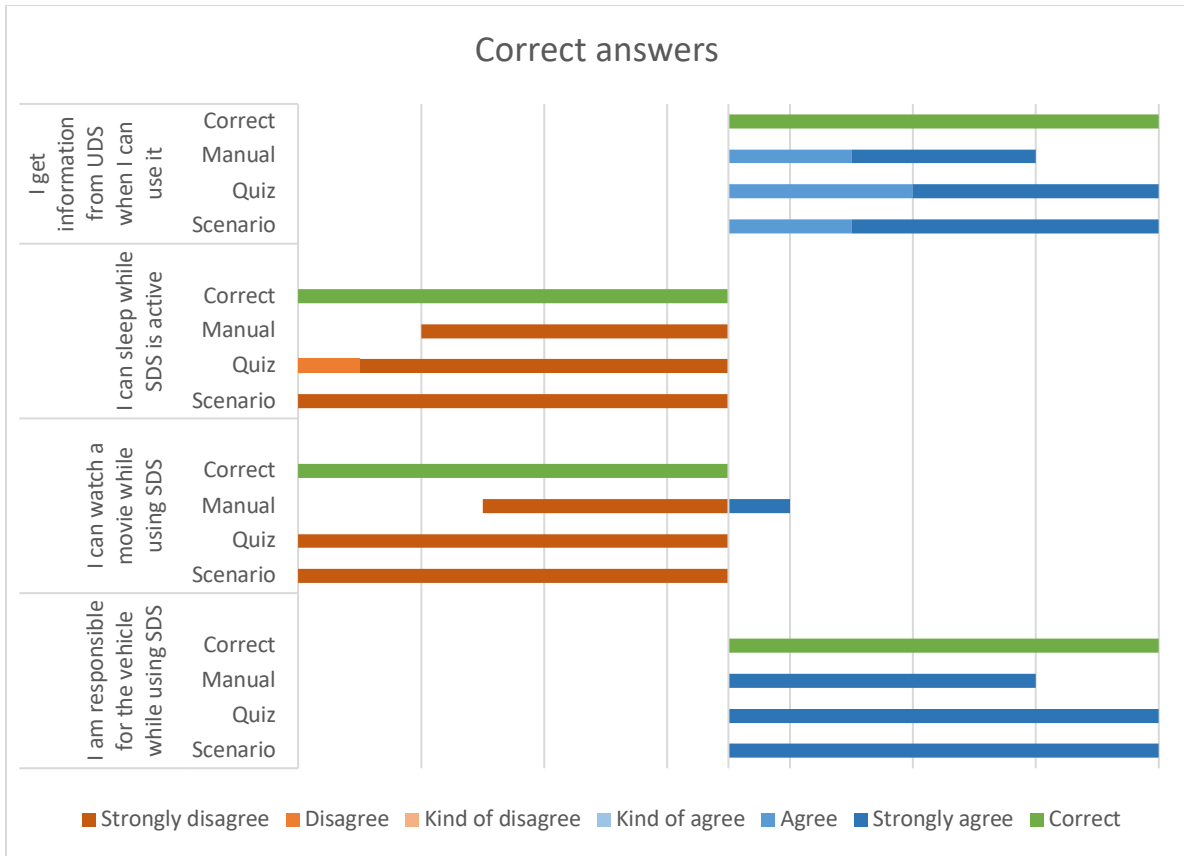


Figure 4.2 Statements that every group answered correctly

These statements are relatively extreme (sleeping and watching a movie in the car) so it is not surprising that they all answered correct.

A statement they all answered wrong is shown in figure 4.3.

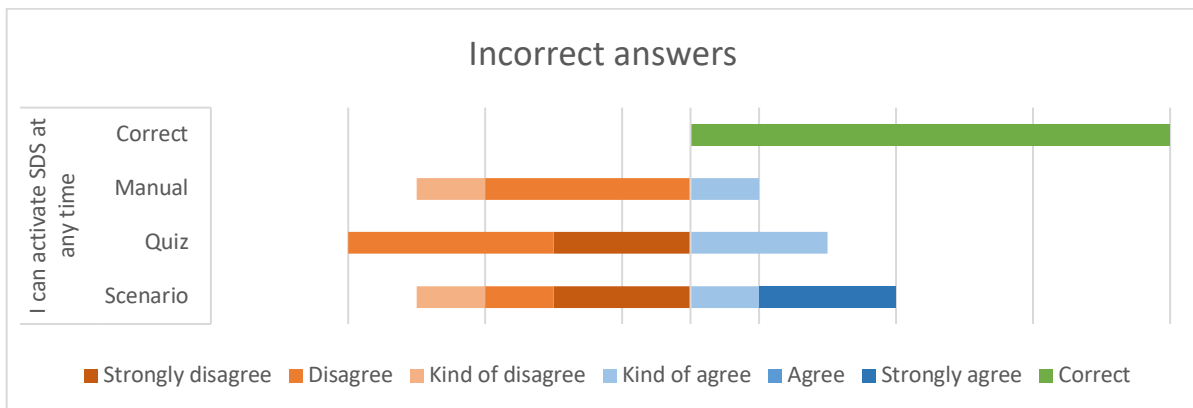


Figure 4.3 Statement all groups answered incorrectly

Why it is correct is because it is up to the driver when to activate SDS. However, why almost all people answered Disagree is likely because they answered that one should not activate SDS at any time.

4.2.1 Survey result: Scenario

The Scenario group performed the best in the survey. They had the lowest number of wrong answers shown in figure 4.4.

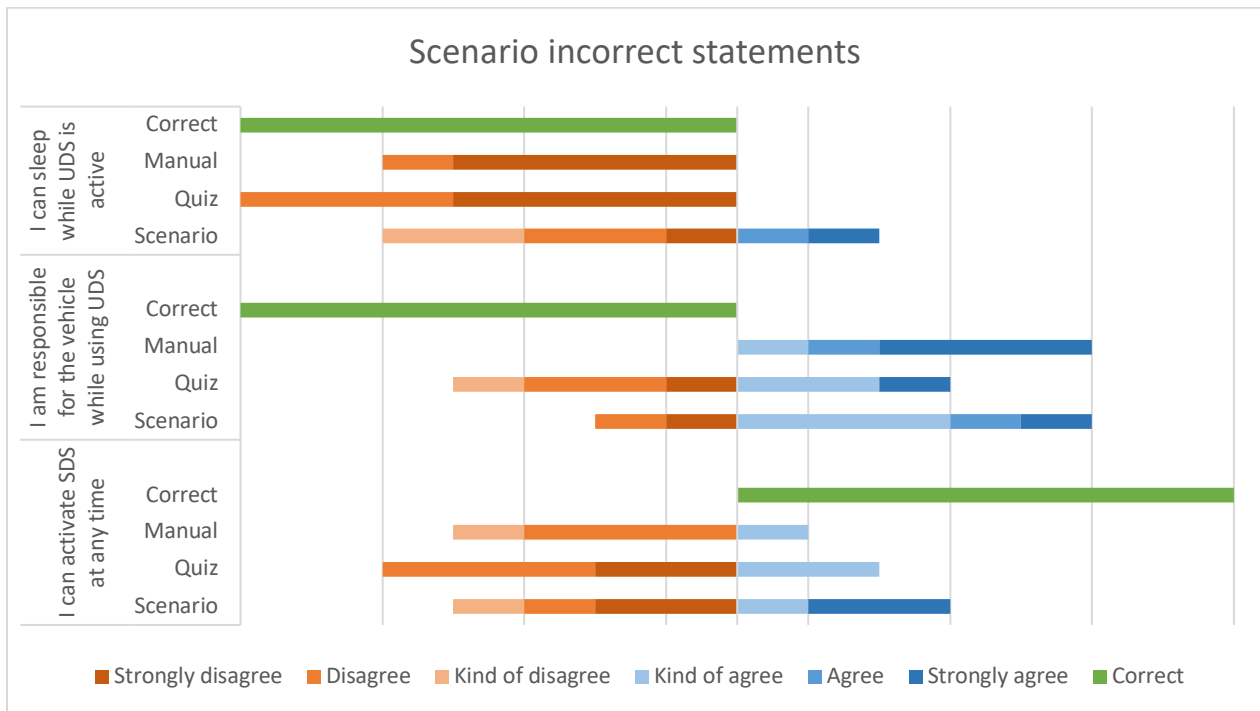


Figure 4.4 Scenario groups incorrect answers

The later one is of concern. The driver is not permitted to sleep using UDS and should be ready to respond to notification to take over the control of the car. The reason for this incorrect answer probably lies in that contrary to the other methods, it was never explicitly stated in the Scenario concept that sleeping is not allowed. It was only conveyed that the driver needs to be able to resume control when told, which involves being alert and therefore not asleep. This is perhaps where the Scenario concept fails, it is not able to convey detailed information since that would mean showing a scenario per detail or trying to convey a lot of details in one scenario which can be challenging. To many scenarios and the user could get bored and lose interest in learning which is not desired. To be able to fill each scenario with enough details while still not being too overwhelming requires a lot of thought for it to not miss any important aspects.

4.2.2 Survey result: Quiz

The Quiz group performed second best of the three groups in the survey. They generally showed a good theoretical understanding. However, their answers were sometimes widespread meaning that the concept had failed in teaching them that particular thing. They answered wrong in figure 4.5.

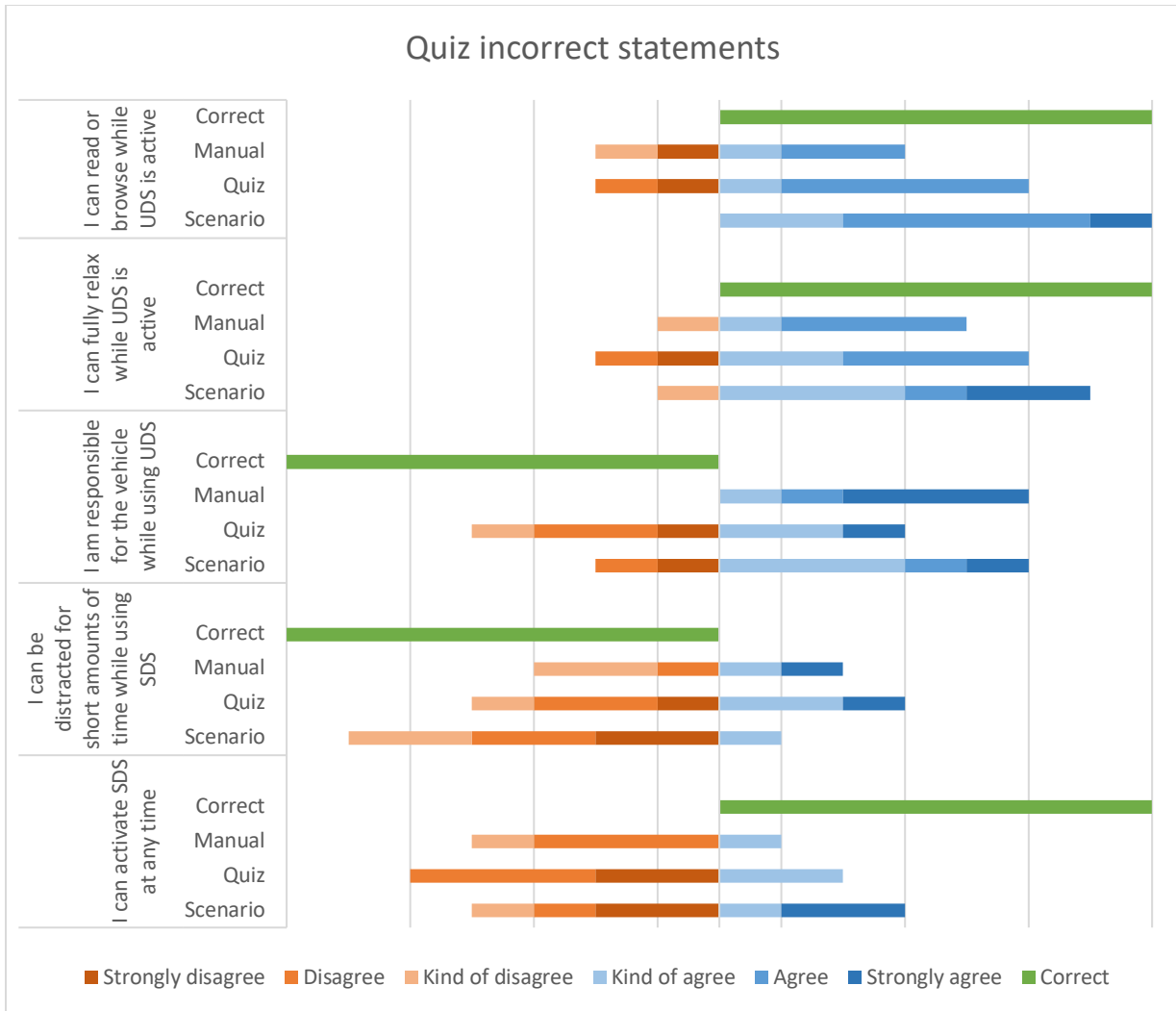


Figure 4.5 Quiz groups incorrect answers

They answered more wrong on UDS questions than SDS. The Quiz does explicitly tell them about things in writing like who is responsible for the car or what you can do when in UDS, but still some participants did not remember that later when they did the survey about 15 minutes later. This means that the Quiz somewhat fails at teaching them about the possibilities of at least UDS. It is a quite effective method of education but fails at showing the new possibilities that are harder to imagine. Things that are not intuitive like fully relaxing as a driver in UDS is hard to convey in the Quiz format but common things like how and when to activate UDS is easier to convey.

4.2.3 Survey result: User manual

The User manual group does tend to answer more incorrect than the others. Those statements are in figure 4.6.

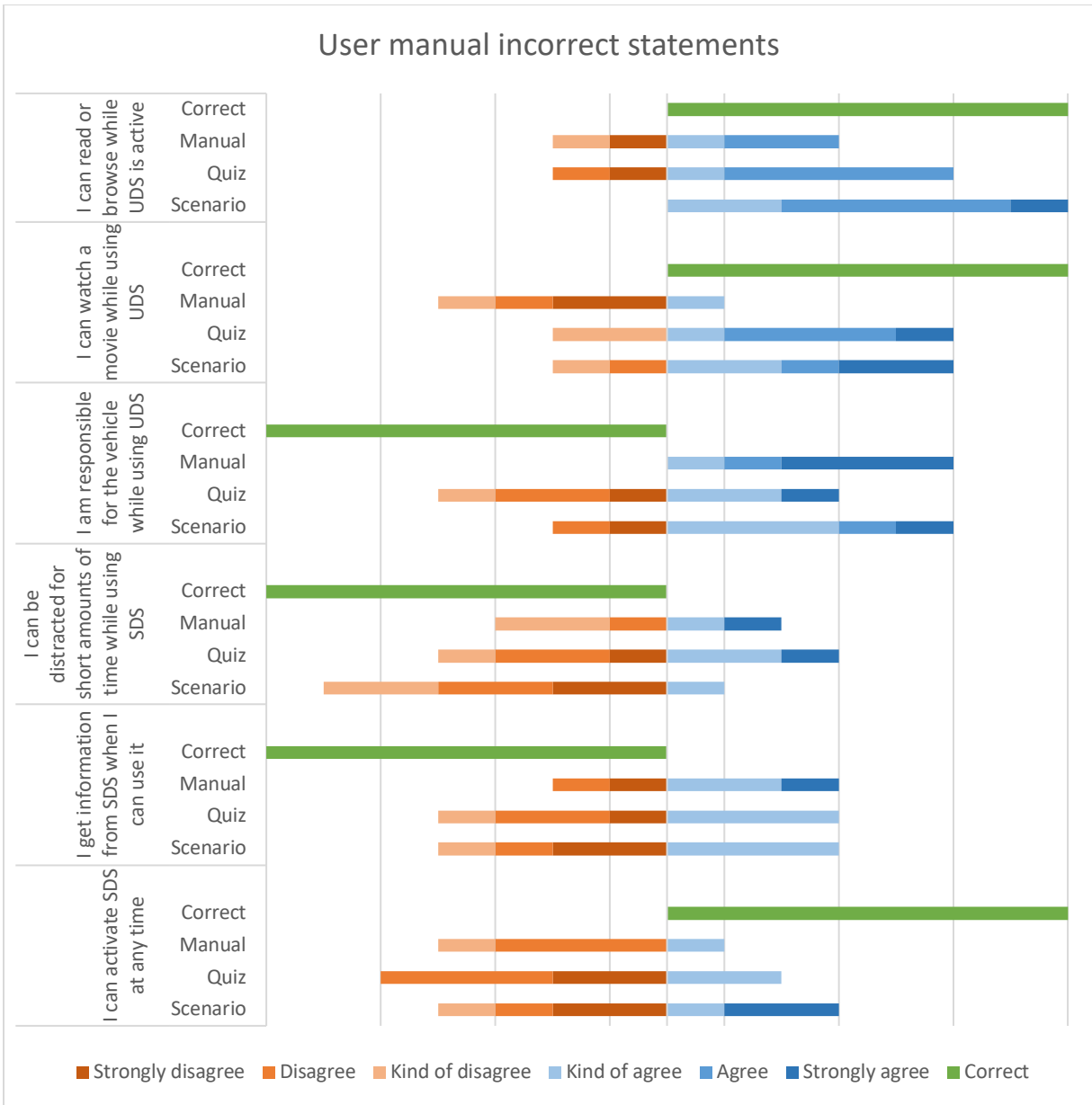


Figure 4.6 User manual groups incorrect answers

Their answers show a passive attitude towards the system, expecting to not be able to do things and waiting for the system to act with them. They do not want to watch a movie in UDS, perhaps unsure of why that would even be possible. It is an extreme thing to be able to do relative to what you can do today so it is not weird that they answered that. The manual is also not the type of medium that encourages those types of behaviours. It focuses more on functionality and limitations given its legal functionality. However, this highlights why another type of education is needed for automakers. They need other types of methods that can more easily explain to the user what the possibilities are. To be able to watch a movie in a car is a huge thing for most people and would be a big factor on wanting to use the system. A new method for learning would give automakers a way to tell their users of their features as a selling point and thus getting them to use the DAS more which also creates a safer driving environment.

4.3 Interview

Below the results of the interviews are described sorted by the identified categories during the analysis. The result from the interview was a collection of transcribed texts which became a KJ analysis that was used as a basis for design guidelines. The guidelines are aimed at the development of educational resources regarding DAS.

The KJ grouped quotes from the interviews in different categories based on the interview guide. The categories in the KJ where; Motivation, Enjoyment, Effectiveness, Trust, and Timing and context.

After the quotes where sorted and grouped according to the type of test that produced them, patterns started to emerge. The patterns could span over several categories but were always most prevalent in one which led to conclusions about what the main take-aways were for each category.

Below, each category is described what it means with some of the quotes from the interviews. The participants are named P# and their respective educational material is stated as well.

Motivation

Motivation in this case means motivation to use the educational material, not specifically using the DAS in the car. It is the first step that will capture the driver. One thing that is important to consider is that the driver primarily wants to try out the system themselves. Their first instinct is to somehow get a hold of the system and learn by trial-and-error. Participants stated that they would like to try out the system themselves. Participants said that it is their preferred way of learning. This means that the educational material needs to mirror this by simulating real use to fulfil their requests. It is also important to make it fun for the driver, since they said that it will make them try it out. Having fun while learning is a powerful tool that can be taken advantage of.

<i>"I would have tried absolutely [...] because it was fun"</i>	<i>P10 Quiz</i>
<i>"I don't know, maybe it's better to try it out yourself kind of"</i>	<i>P17 Scenario</i>
<i>"To overcome the uncomfortableness, I would have wanted to get out and drive"</i>	<i>P14 Scenario</i>
<i>"...maybe like trying it out"</i>	<i>P16 Scenario</i>

Another thing that creates motivation to learn is to present the value of what you are learning. If the education makes it clear what you gain by knowing this, it creates motivation for the driver. The participants said that they would like to be shown what the possibilities are. For example, showing the possibilities for unsupervised automation makes the driver excited and wants to learn more.

<i>"I could see where this could be used. I could see where I can use the [UDS] sections"</i>	<i>P2 Scenario</i>
---	--------------------

“I think if I had more information about what the car could do, and what this actually mean for me potentially. What's in it for me, like the potential.” P20 Quiz

Enjoyment

When the driver has been motivated to learn, another thing is to make them enjoy the material. This is done by making the material short and efficient. The driver should not feel like they are taking on a huge task but something that is more manageable to do in one sitting. The participants that read the user manual said that it felt too long, and the others enjoyed the fast pace of the other education methods.

“No. I mean, I think that it was very lengthy” P5 User manual

“It’s a lot to read. Then you have to skim through and skip certain parts because it becomes too much you could say” P18 User manual

“I liked it [because] it gave a quick walkthrough” P4 Scenario

The educational material also needs to be a bit challenging and not be scared of having the driver make mistakes. It is a part of learning to make mistakes and by making it a bit challenging the driver will have to apply themselves to answer correctly. If not, they will get feedback which should help for the next time. The participants said that they do not get negative feelings when they get corrected.

“It required me to really think. I liked the feedback” P1 Quiz

“It felt that it was okay to make a mistake” P13 Quiz

It also needs to immerse the driver. The educational material needs to engage the driver by making them an active part of the material. Presenting them with information is not enough but they should be actively participating to create a good learning situation. The participants did not want to be a passive observer which only bores them. They enjoyed participating and said it helped them understand.

“It was fun, and it was better than just seeing like a video in front of yourself” P17 Scenario

“It’s easier with the scenarios than just reading an instruction book” P4 Scenario

Effectiveness

Good education is based on repetition. The driver should not be expected to become fully taught after just one sitting. The participants said that after the test most did not feel it was enough. They wanted do go back to what they were wrong about and explore more. They will need to go back and do things again and

especially on the things they were wrong about. The educational material needs to track the users progress and errors to create a personalized learning platform for better learning.

“I have understood a little yes, I do understand much more than before” P11 Quiz

“No, I have not fully understood yet” P1 Quiz

“I don’t think this is enough, it gives you a good appetite for more though” P20 Quiz

Trust

Trust in the material comes by highlighting the possibilities and not limitations. It creates a more distant relation to the systems when the driver is just hearing about what the system cannot do. Participants reading the user manual read a lot of disclaimers which they said was demotivating and created distrust. Disclaimers are still relevant but needs to be expressed with care as to not scare the driver. It is also important to show who is giving this information and clearly present the organisation behind it. Participants said that a big effect on trust is if they know who is behind it.

“It doesn't create a feeling of security when you have many ifs and buts” P5 User manual

“Like, you can use this function, but and then there's like 5 pages of buts” P6 User manual

“Given that it comes from Volvo it should be fine” P11 Quiz

“The brand is everything when it comes to trust” P4 Scenario

Timing and context

The best time for a driver to learn is when they are ordering a car. Participants said that they would want to learn as much as possible during this period since they would be heavily invested in what they just bought. Their motivation to learn is very high since they want information on their property and want to know its worth. In regard to time, they are most likely to be able to use the material for about 10 minutes before they get bored. Most of them want to use it at home during their leisure time, not at work.

“I think when I first got the car” P6 User manual

“Use it when the car is being delivered” P3 Scenario

These conclusions were then turned into the design guidelines that are listed in chapter 5 Design guidelines.

4.3.1 Perceived effectiveness

During the interview, the participants were asked how well they thought they knew the DAS after having gone through the educational material. They were partially asked with an open question on if they thought that they now understand the limitations and features of the systems and were asked to grade themselves on a scale of 1-5, 5 being maximum knowledge.

In figure 4.7-4.9 each participant’s answer categorized in the groups is shown.

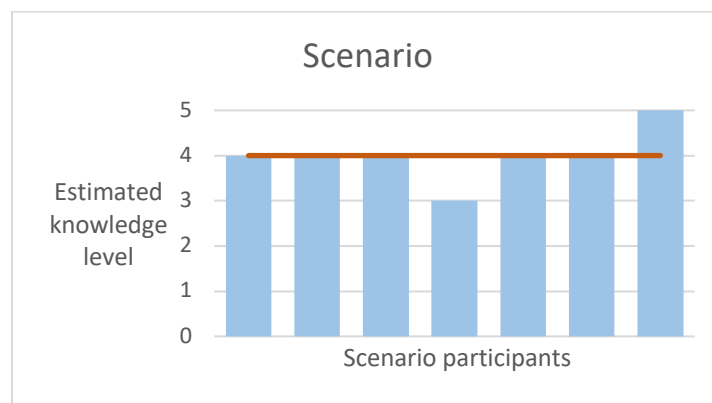


Figure 4.7 Scenario participants answers on their estimated knowledge level on a scale on 1-5 with average value marked by red line

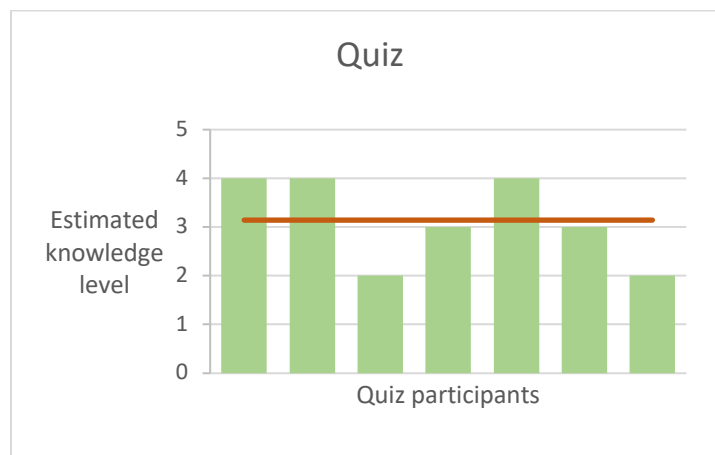


Figure 4.8 Quiz participants answers on their estimated knowledge level on a scale on 1-5 with average value marked by red line

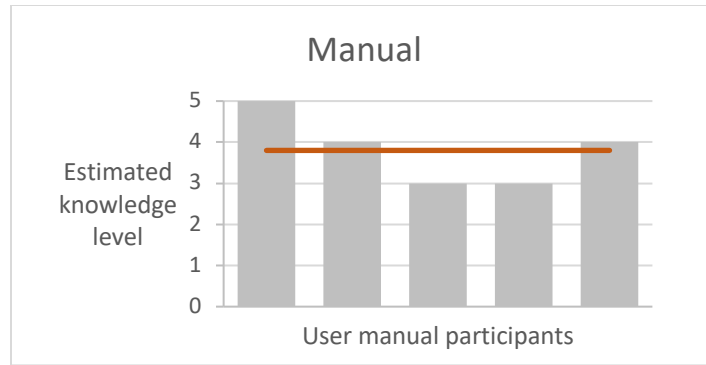


Figure 4.9 User manual participants answers on their estimated knowledge level on a scale on 1-5 with average value marked by red line

The Quiz had a generally lower answer than the other two, meaning that the Quiz participants felt that they had a lower knowledge level compared to what the other groups answered. It is not a huge difference between the groups, but one reason could be that the Quiz was much more explicit in telling the participant when they were wrong. In the Quiz, the participants both got an error sound and a red box saying “Wrong” making it clear for them they answered wrong. They probably remember that they had some wrong answers better than the other groups. Because the Quiz participants were told they were wrong it could have led to them saying that they had low understanding.

The original idea for showing incorrect answers is that it is part of learning to do mistakes and that it is not a big deal if they answer incorrectly. If they had the chance to be able to revisit the questions they were wrong about, they might say that they have a better understanding than before.

The User manual does not have any active communication with the user to be able to convey the same thing as the Quiz. The Scenario concept does not have the same obvious error messages and is probably also easier to answer correctly on than the Quiz. This could then give more confidence than the Quiz.

The Quiz also had badge levels to indicate how good the participant’s understanding were. They gained a badge level for each level they completed which were supposed to give them confidence that they achieved something. At the end they achieved the final level “Master” (regardless of how well they did) which points towards learning progress and that they have a good understanding. Perhaps the participants saw through how the badge levels were gained, that it did not matter how many correct answers they got, and simply did not trust the badge level. A real version could work better, where they would have to get a certain number of correct answers to advance which is showed clearly. Then the impact could have a greater effect.

To conclude the results here, it appears that the Quiz gave the participants less confidence than the other groups on their knowledge level. This might be because of the prototype telling them when they were wrong causing the participants to remember doing more errors, leading to them saying that they have less knowledge. The badge level was supposed to indicate their knowledge level but it did not work as intended. Perhaps a real product that would actually track the progress could give a more trusted indication of their knowledge level.

The other groups Scenario and User manual did not communicate on the same level as the Quiz which could have led to the higher perceived knowledge level. This perceived knowledge level does not have to

be the actual knowledge level. Considering that the User manual group performed worse than the others in the survey, it shows that they overestimated their knowledge level. The Quiz group on the other hand, showed a more real representation of their knowledge level, meaning that it was the educational material itself that was lacking in teaching them.

A higher perceived knowledge means a more confident driver which could be unsafe if their actual knowledge is low. A confident driver which is unknowledgeable makes mistakes that put them and other drivers in danger. What is best sought after is that the driver have an accurate perceived knowledge by knowing their capabilities and flaws which they can then work on to better.

5 Design guidelines

The findings from the tests, were developed into design guidelines, aiming to support designers and developers in the creation of educational materials that engage drivers through motivating and effective means.

Below the five tenets and the respective guidelines are presented in detail.

Motivation

The driver needs to be motivated to learn. Any educational material should be designed so that the driver feels motivated to use it. Otherwise, it risks being ignored.

1. Bridge the gap between the user manual and learning-by-doing
2. Motivation to learn grows when the value of the system is clear
3. Seeing the value needs to be efficient and clear to manage expectations from drivers and promote an accurate mental model
4. Most drivers prefers trial and error and is likely to avoid the manual. The educational material should provide alternatives to real world use to keep the driver safe and comfortable while learning
5. Fun is a powerful learning enabler, and should be incorporated, where it is possible. Users will choose other alternatives if it is not engaging.

Enjoyment

While doing the educational material, the driver benefits greatly from enjoying it. It is more likely to be used and will be more effective if they do.

1. Show the value that the system can bring to the user and what it is capable of
2. Present visualizations of how the system works and how it will look while in use
3. Provide concise and effective educational material in a bite-size format
4. Activate the user by challenging their current understanding and mental model to get them engaged

Effectiveness

The education needs to be effective to make the driver knowledgeable with a solid and accurate mental model.

1. Create material that builds on repetition and continuous learning.
2. Track the users progress and knowledge gaps to help build a better mental model and focus the resources where they are needed

3. Showing the progress of each individual user helps them keep track. Individuals all learn in different ways, so the educational material needs to create personalized methods that show their progress and lets them go back and revisit their mistakes
4. Split the education into parts for easier digestion. Make sure the user is aware of what part they are doing

Trust

It is important to create a trustworthy educational material. The driver should feel confident that what they have learned is true. Otherwise, they could look elsewhere for information making the educational material obsolete.

1. Build up trust and confidence in the system by framing things in what is possible rather than not allowed
2. Use disclaimers with care since it affects motivation and enjoyment negatively
3. Limitations are important but let it not be the focus, the user should learn how to use the system without being told what not to do
4. Make it abundantly clear that the resource is coming directly from the original manufacturer by incorporating logos and slogans where it is suitable

Timing and context

When designing the education, when and where it is used matters. The context affects the educational material, when it is supposed to be used, and for how long.

1. The time that the user is willing to learn and use the educational material is during their leisure time: morning, afternoon, or night. They do not want to do it during their work
2. The average time the user is willing to spend on learning is about 5-10 minutes at a time. Educational material should be adapted in suitable chunks
3. After ordering their car, the user is highly motivated to learn about it and is susceptible for knowledge. Utilize this moment by giving the educational material after purchase
4. The best place to use the educational material is at home
5. Some can imagine themselves using the material in the car, but not as their first choice

6 Discussion

This work set out to investigate different educational methods for DAS and motivational factors regarding education for advanced autonomous systems. The results will be discussed and compared to previous research along with reflections about the different methods and tools used during the project.

6.1 Prototypes, user test, and limitations

The simulator used in this thesis's user test was more immersive than expected. It had a real driver seat and a real steering wheel which added to the immersion. The steering mechanism and pedals were not the controls of a real car, but from a gaming rig. This meant that it was not the most accurate steering experience, but a sufficient one at least. It was more sensitive to input which made most participants uncomfortable in the beginning but adjusted quickly in only a few minutes. The immersion prompted most participants to try and use indicators when turning in an intersection or driving out of a roundabout. Some even tried to look out the side window before turning in an intersection which speaks to how immersed they were in their driving.

To simulate the notification and mode activation, we expanded the simulator by adding a LED-light strip and sounds to communicate with the driver. The three important signals (UDS notification, UDS activation, and SDS activation) could then be conveyed with the help of sound indications accurately enough that no participant misunderstood the signals. Noteworthy, the signal system was sufficient for this test although it was not as accurate as it would have been in a car. A car would be able to convey more than just light- and sound-based information, making it easier for the driver to use the systems. What is important to note here, is that this test did not measure the DAS but the educational material. It is therefore not of utmost importance that the simulator had accurate signals. Theoretically, the simulator could have worked completely different than it would have in a car as long as the participants learned from the education. What is important is that the signals worked as intended and that it allowed the participants to use the DAS as they had been taught.

The activation and deactivation of SDS and UDS was done by a command from a keyboard that was placed out direct line of sight from the driver. It was only one of the participants that asked if we were the ones activating the functions and not the buttons on the steering wheel. Almost all participants seemed to assume that the buttons were working correctly and that they were the ones in complete control of which function was active.

The simulator had one flaw which was that it had no force feedback, which means that the steering wheel should give feedback to the driver. For instance, if you turn right, the wheel should then move back to its starting position automatically. The wheel used here did not turn back automatically which meant that the driver had to do it manually themselves. This also meant that the wheel did not move when it should when using the DAS. For instance, if you activated UDS the wheel should move as if it were steering but in this simulator it did not move. It should be noted that this is not true for all systems as there are technologies where the steering wheel does not move while driving. The wheel not moving caused some confusion for some drivers sometimes when they took back control and the steering wheel was not centred, causing the car to swivel a bit.

Further, the prototypes were not as refined, and could have benefited from iterating the conceptual phase more. For instance, the Quiz made it seem like the participants would be able to track their progress and see their mistakes. In reality, there was no way to collect that data with the prototype using Figma. This meant that the participants automatically advanced to the next level and could not see their statistics which many of the participants expressed that they wanted.

Another issue was that the prototypes were limited in what types of interactive actions that Figma allows for. The participants were limited by only being able to click on single objects. It would have been preferable if multiple objects could be interacted with at the same time and if they could be hold for a few seconds rather than just a click. It would have helped with creating a better representation for what the participants were supposed to do in the simulator.

Another thing to consider is that the user test was limited to a simulator rather than the real experience in a car driven on a real road in traffic. The simulator was indeed immersive, but it cannot replace the context of real driving. Driving in a real car would have provided better context for the participant, but it would not have given the same control of the test environment as the simulator.

Finally, the number of participants was smaller than desired. More participants would have given a stronger statistical result. Seven participants for the new concept groups and five for the baseline test is not the best foundation to build conclusions on. Given the requirement that they could not be experienced with DAS led to a struggle in finding suitable participants since the group of people that was invited worked at Volvo. The optimal participant would be someone with a driver's license but no experience in DAS whatsoever, but it was hard to find at Volvo. Luckily enough we found 20 kind people that agreed to participate in our tests and the trends that were spotted in the educational material were coherent and consistent.

6.2 Voice guide

The third concept that was developed as a prototype was not included in the final user test since it performed less than good on a pilot test. This might seem like a harsh judgement to completely cut it out after only one test, but this decision was made based on what was learned from the participant- The Audio guide proved to be too distracting while also not managing to provide much learning during the short drive that was the test setup. The performance was the worst out of all the other tests, and it was clear during the drive that it did not suite the scenario. This does not mean that there is no hope for concept three but to really evaluate it the whole test setup would have to change. The drive took around 10 minutes which was a good amount of time for the other concepts but concept three would need more and perhaps a little less traffic. The driving part should resemble a longer trip where boredom plays a bigger part and focus can be put almost entirely on what is being said. The concept takes advantage of the fact that the learning will happen in the context of actual use and without visual distractions. In theory, concept three should be an effective and preferred way of learning.

Constructivism learning theory says that learning is best done by doing (Amineh & Asl, 2015) and the preferred way of learning from self-experience (Hoch & Deighton, 1985) so therefore learning while driving in the car on a real road would be best. This was also expressed by many test participants, that their preferred way of learning was by trial-and-error. A voice guide would let them do it their preferred way in a safe manner by observing them, guiding them, and helping them in real time. It would also provide immediate feedback to them after they have made some error. This gives them minimal time to reflect on their feedback and opportunity to retry, making their learning much faster.

If the Audio guide was more like a voice assistant where the driver could ask for information instead of being told a pre-determined script, it could be even less distracting. When the pilot test was done the driver had to focus on what was being said with limited control of the type of information that was given. If the driver requested information, it would be more like having a discussion with another person in the car which most drivers can do when driving in a relatively stress-free situation without too much effort.

Future technology improvements could also improve the learning concept. Lidar, which is an upcoming technology within automation (Warren, 2019), offers much better accuracy than before (Csanyi & Toth,

2007). This does of course mean that the DAS operates better, but also that the car can give more feedback to the driver of the surroundings. The car can communicate more precise things about why DAS is available or not in these specific conditions. For example, the car can see what type of road it is driving on. Before, the car could only give feedback on when it works or not, but with lidar technology it could answer why as well. Lidar can also be used inside of the vehicle and can get much more accurate depictions of what the driver is doing. The car could then also give feedback on how they are behaving, if they are doing the wrong actions, or behaving incorrectly. The car could become one step towards being someone helping you in the passenger seat.

6.3 Implications for the design of education material for DAS

The literature review in this thesis points towards methods like gamification and theories like constructivism as suitable grounds to base an educational resource regarding DAS on. The material the drivers need to learn is practical and based in a familiar setting but it also requires the driver to construct an appropriate mental model regarding limitations. This ties in with how constructivism describes learning and how it is a social, interactive, and context-based activity which does fit better with methods that really envelopes the user in the experience. Many studies said that learning is more effective with more interactive elements (Noble et al, 2019; Portouli et al., 2008; Zainuddin et al., 2020) which has been seen as well with the Scenario concept. It performed well in the tests and showed that it was an effective method of education. The literature also said that learning while doing is effective (Amineh & Asl, 2015; Hoch & Deighton, 1989) as well which the Scenario concept tried to simulate.

Personal learning in according with learning theory describes the variation in learners and how different approaches work for different people which is something that needs to be taken in to account when developing an educational resource. Everyone is different in some ways, and this includes learning. What might work for one does not necessarily work at all for another. The personal aspect of learning creates a need for resources with diversity in how the information is delivered. Multiple channels like text, speech, images, and video can be combined to cover a wider scope of learners. The difference between paper instructions and using multimedia is evidenced by constructivism learning theory, which claims that interaction with both body and mind is necessary. Using multimedia is a better way of engaging the driver and therefore achieving better learning. The use of several of the channels in one concept such as the Scenario in combination with a focus on delivering a fun experience creates a good platform for a lot of different learners, as proven by our test results.

Regarding gamification in education of DAS, there has not been the same type of results as seen in literature. Feinauer et al. (2022) showed that gamification in DAS education would lead to better motivation, trust, and mental model formation. The Quiz concept was made inspired by these promising results but were not reconstructed in this test. Only motivation was seen to increase with the quiz as shown in the results. The Quiz concept did not increase trust compared to the other concept or the baseline. It was also less effective than expected. It did not perform better in the simulation, but it did perform better than the baseline in the survey suggesting that the mental model formation was good on a theoretical level. Still, it was lower than the Scenario concept which performed the best overall. One explanation for this discrepancy between this study and Feinauer et al. (2022), could be the different approaches in research. Feinauer et al. studied the impact of gamification specifically in DAS education. This thesis did a comparative study of different ways to educate drivers in DAS. Feinauer et al. had a more developed prototype with more gamification aspects than what was possible in this thesis due to limitations of the prototype. This probably made the Feinauer et al. prototype of higher quality than ours which could have led to a more effective learning method. What this prototype could not do was for instance track user progress and provide actual personal data. This prototype had to fake progress made by the user and lacked authenticity and detail. One way to make the Quiz more effective is to incorporate more multimedia like images, video, and sound.

The user manual contains a lot of disclaimers to ensure that the system is used in the correct way. These disclaimers work as a legal tool to clearly communicate how the system is supposed to be used and what the limitations are. It is part of the reason why the user manual contains as many pages as it does, and it is something that everyone expects when opening such a document. Too many disclaimers and limitations have been shown to create negative bias and distrust towards DAS (DeGuzman & Domnez, 2022). This has also been confirmed by the results, namely that reading too much about what the system cannot do leads to distrust in the system but also that it lowers their motivation to use the system. It is a little like being stuck between a rock and a hard place where disclaimers have a negative impact on use while being a necessity in the most prevalent guide for use.

Trial-and-error was in literature showed to be a preferred way of education (Harms et al., 2020; Oviedo-Trespalacios et al., 2019). When the participants were asked how they would prefer to learn, or what they probably would have done, a very common answer was that they wanted to do it by trial-and-error. This confirms with the studies about driver's preferred way of learning, but also highlights the importance of good education for the driver. Trial-and-error can lead to incorrect mental models and unsafe behaviour, but it also points to other possible solutions. If trial-and-error is bad since it might cause danger, but it is how a large part of the drivers want to learn, then simulation of trial-and-error is needed to avoid dangerous situations. The approaches towards bridging the gap between trial-and-error and manuals in this project have been the Scenario concept which touches on simulation while still being contained within certain pre-determined situations. In accordance with what research says about trial-and-error the Scenario concept performed the best and got the most solid mental model out of the concepts tried.

Lastly, it was found that repetition is needed in education. Participants expressed that they wanted to do more repetitions and specifically on what they answered incorrect to be sure that they did not have any knowledge gaps. The need for repetition to create accurate mental models is also found in literature. Forster et al. (2019) says that a repetition of five times is needed before the driver is fully trained.

6.4 How could design guidelines be used

One of the deliverables for this project was design guidelines and the other was the concepts that was developed during the project. The design guidelines have been presented in a previous section along with how they were created and on what they are based. The use of the guidelines however has not yet been mentioned and they might seem general in some sense, but they are aimed towards the development of educational resources within DAS or automobile industry. Within the area of DAS however they can be used for completely different concepts than the ones presented in this project. The basis for the guidelines were as mentioned the interviews during the testing and the patterns that emerged during the KJ-analysis were general in the sense of educational resources, not just comments regarding a single concept. Because of these more general comments on aspects regarding the material the guidelines will be of help for anyone trying to create a user manual or other resource for education within DAS. A practical implication might be that an educational tool for a specific feature needs to be developed because it is being promoted heavily in marketing. The feature is complicated and technical in its conception, but the actual use is much simpler, however there are certain aspects around limitation that needs to be effectively communicated. To be able to deliver this educational tool in a way that will not scare the user away from trying out and learning the feature, these design guidelines can help create a fun and attention-grabbing educational resource.

6.5 Societal, environmental, and ethical aspects

The use of cars in society today is something that is expected whether it is in a big city or a rural town it has become a part of how society functions. The expedience and comfort of owning or leasing a car is still today viewed as a standard part of life for most people and not some luxury that only a few could afford.

This is only to say that cars are and have been affecting the way we live for generations and the environmental impact has not gone unnoticed. This thesis talks about DAS and how to educate drivers in that, but it also incentivizes the use of cars. Although cars are becoming more sustainable through electrification, it is still a major contributor to pollution, climate change, and occupying space for other travel modes (Haustein, 2021). Automation is however a way to solve these problems, making the use of automation important.

There is however a shift in how society and people view cars, and it is happening right now. The old way of owning and taking care of your vehicle is being shifted towards viewing cars as just another pay-as-you-go option for transportation where you do not need to own or lease a car to have one readily accessible when you need it (PWC, 2016). This in conjunction with the rise of electric cars are shifting the way society views cars and the concept of owning transportation. Completely self-driving systems are not yet driving around the streets but they will be in a couple of years if current trends stay on course (Mercedes-Benz Group, 2023). Adding advanced systems to a product that might have a user that only drives the car once brings a challenge in how to safely train and educate before use. The material must be efficient enough that a one-time user will use it before getting to wherever they need to be while using DAS. Some of the benefits of using DAS compared to human driving is that it is safer and more fuel or energy efficient since the system can be programmed for optimal driving compared to a human driver which is affected by all sorts of things (Andersson et al., 2014; Garza, 2011). DAS is able to react much quicker and is never distracted which makes it good at avoiding accidents caused by a distracted driver.

The impact of developing more efficient educational resources aimed towards DAS will be noticed in the new way of using cars and the shift towards mobile application-based renting (PWC, 2016). If drivers cannot see themselves reading the user manual to understand DAS, then they probably will not use the system or endanger themselves by trying to learn it by trial and error. With more efficient and motivating ways to learn the use of DAS will hopefully go up and create a safer and more energy efficient society.

DAS in cars is becoming a new phenomenon for drivers. It is becoming a completely new way to interact with cars that we have only imagined before. This phase shift will cause some concern for drivers, who will have to learn to use these new systems. This thesis has talked about the issues of not being aware of what the DAS is capable of and what is permitted for the driver. Misuse can cause accidents, like thinking your car is in full self-driving mode when it actually is not (Orlovska et al., 2021; Orlovska et al., 2020; Hu et al., 2022; McDonald et al., 2018; Noble et al., 2019). This highlights the importance of good and effective education material that drivers want to use. Designing good education material leads to better use of DAS and therefore safer use causing less accidents.

The educational material needs to both train the drivers in using the systems in the right way as well as build a solid mental model where the limitations and possible dangers could lie in using such a system. The ethical concerns regarding AI and its decision making in impossible situations where someone is going to get hurt but it is up to the AI or DAS in this case who that someone will be (Caballero et al., 2022). It could be a scenario where a big animal, like an elk walks into the highway and the car needs to correct its course to avoid it. There are cars behind and a motorcycle to the side so no good option remains. The system could brake as hard as possible, collide with the cars behind and still possibly hit the elk, swerve to the left and hit the motorcyclist but miss the elk or turn right and go off the road in over 100km an hour. An impossible decision where someone will get hurt no matter what is chosen but a choice will be made, and the driver will have to live with experiencing that choice.

DAS in cars also risk becoming a luxury feature that only more wealthy people can afford (Haustein, 2021). If this would be the case, it could lead to a segregation between drivers with and without DAS in their cars. Those with DAS are safer than those without which could lead to better insurance premiums and less accidents.

7 Conclusion

To conclude this thesis, the research questions stated in the introduction will be answered.

SQ1: What learning methods are effective when retraining drivers for using DAS?

The best concept in terms of effectiveness of a theoretical and practical understanding in this thesis was the Scenario concept. The mental model that the Scenario concept produced performed better than the other two when looking at the survey results. It combines an interactive game-like experience with a solid basis since the driver sees how the system would work in a real scenario. The direct feedback after each step corrects and reinforces parts of the mental model connected to that step.

This means that immersive, engaging, and entertaining methods are effective when educating drivers in DAS. It creates a good mental model which makes them operate the car in a safe manner. It also leads to more active and frequent use with the DAS by the driver's own volition.

SQ2: What aspects motivate drivers to use education material for DAS?

The interactive and gamification parts of the concepts was appreciated by the participants in the tests and all participants stated that they would use a similar type of resource if it was available to substitute the user manual. The degree to which they would replace the manual varied some depending on how well the concept worked for each participant but it was still regarded as a "fun" alternative. The Quiz brought up concerns for some participants around not knowing what they should be knowledgeable of, and the Scenario had similar comments but to a lesser degree. This points towards where the next steps should be and what is lacking can be mended by adding a way for the drivers to track their progress but also their gaps in knowledge. A way for the driver to clearly see what the current status of their understanding is and what should be done before they can start driving with the systems. The User Manual was seen as long and too descriptive making it feel the opposite of effortless. Some passages in the manual were skimmed and skipped because they did not feel relevant, or it repeated itself. Reading was not a captivating medium either which led to participants not feeling immersed.

Aspects such as being fun and short makes learning feel motivating. The drivers have a preferred way of learning which should be resembled in the education. Presenting the material in a way that the drivers want (trial-and-error, testing for themselves, use in real situations) by letting them get as close to it as possible creates motivation to use. A certain degree of simulation creates a fun and captivating feeling for the drivers. The education should also challenge the driver by not letting them be a passive observer, but an active part of the education.

RQ: How can drivers be educated, in order to meet the challenges that come with the deployment of a progressively more automated driving automation system?

Creating an educational resource that uses several different media like text, sound, images, and video might be how to reach users, but it all comes down to execution and how these channels are implemented. The best performing concept that was tried in this project did implement all these media types, but it was also a game and simulation type of experience that tried to pull the drivers in and challenge their understanding of DAS. There can of course be other ways of implementing these channels and per chance even a way to make it a "proper" game that anyone could play and enjoy.

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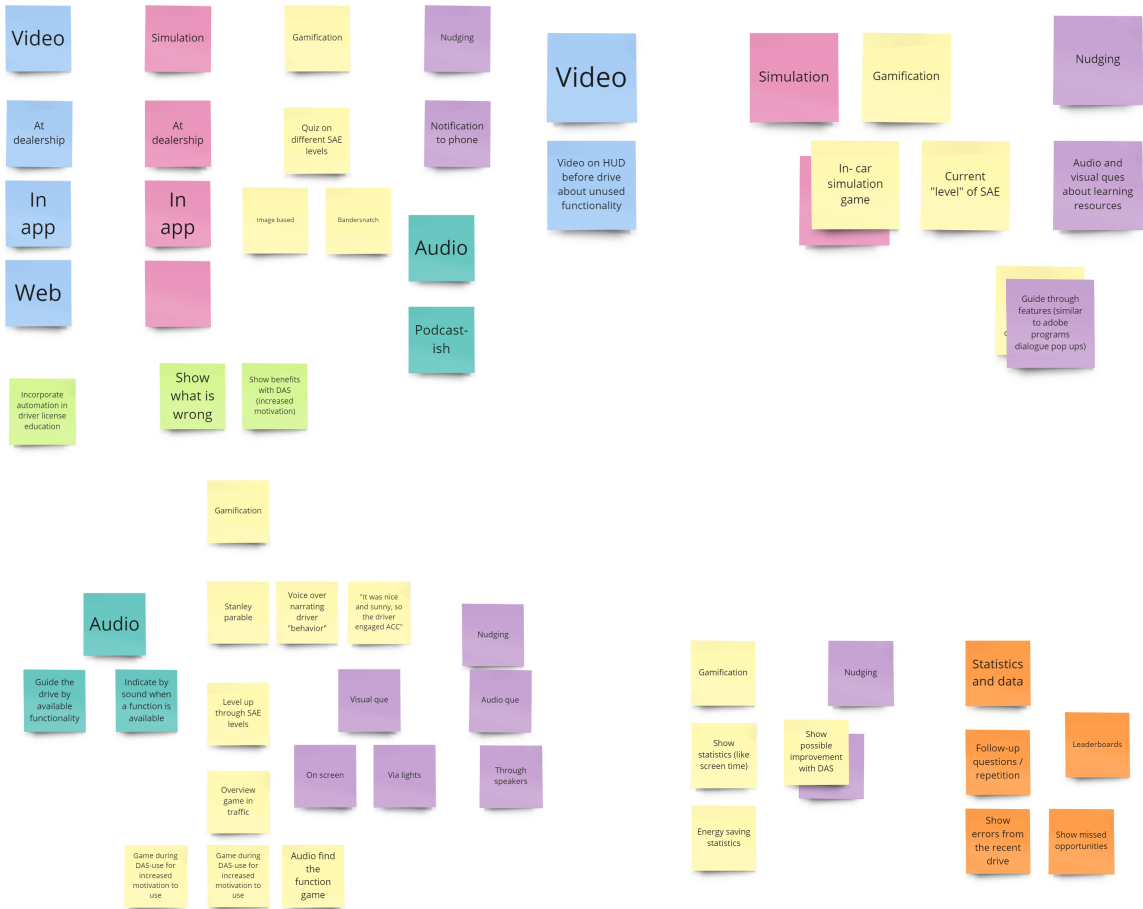
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9 Appendix

A. Brainwriting result



Before drive, outside car

- Video
- Simulation
- Gamification
- Nudging
- At dealership
- Notification to phone
- Quiz on different SAE levels
- In app
- Image based
- Bandersnatch video
- Audio
- Podcast
- Show what is wrong
- Show benefits with DAS

Pre-drive, in car

- Nudging
- Video
- Simulation
- Gamification
- Video on HUD before drive about unused functionality
- In- car simulation game
- Current “level” of SAE
- Audio and visual ques about learning resources
- Guide through features (like adobe programs dialogue pop ups)

During drive, in car

- Audio
- Visual que
 - On screen
 - Via lights
- Guide the drive by available functionality
- Indicate by sound when a function is available
- Audio que
- Level up through SAE levels
- Through speakers

After drive

- Gamification
- Nudging
- Statistics and data
- Show improvement with DAS
- Show statistics (like screen time)
- Follow-up questions / repetition
- Energy saving statistics
- Show errors from the recent drive
- Show missed opportunities

B. Workshop

Workshop: Introduction

Adam Bengtsson
Alfred Vestberg

Chalmers, Industrial design engineering Msc

1. Master thesis during the spring
2. We are researching new ways to educate drivers about driver automation systems (DAS)

Why are we doing this?

- It is a problem today that a lot of drivers are not aware of the DAS in their cars (Noble et al., 2019)
- A large amount of drivers that are aware of the systems still do not use them
- It is becoming a requirement from NHTSA to effectively educate drivers

Part of the NHTSA requirements

Consumer education programs are encouraged to cover topics such as ADSs' functional intent, operational parameters, system capabilities and limitations, engagement/disengagement methods, HMI, emergency fallback scenarios, operational design domain parameters (i.e., limitations), and mechanisms that could alter ADS behavior while in service. They should also include explicit information on what the ADS is capable and not capable of in an effort to minimize potential risks from user system abuse or misunderstanding.

Literature review

Learning theory

- Learning takes place in a context (Amineh & Asl, 2015)
- Everyone has preconceptions and previous experience (Amineh & Asl, 2015; Lynn & Basset, 2020; Novakazi, 2020)
- They have an initial mental model of how a system works (Novakazi, 2020)
- Unlearning and relearning is how we change our mental model (Lynn & Basset, 2020; Novakazi, 2020)
- Motivation is important and difficult to achieve (Russel, 2006; White 2021)
- Reflection afterwards is needed to change mental model (Hoch & Deighton, 1989)

Education in DAS

- More interactive ways results in better mental model (Portouli et al., 2008; Beggiato & Krems, 2013)
- Gamification has been shown to be effective learning method (Feinauer et al., 2022)
 - Better motivation
 - More trust
 - Better mental model formation



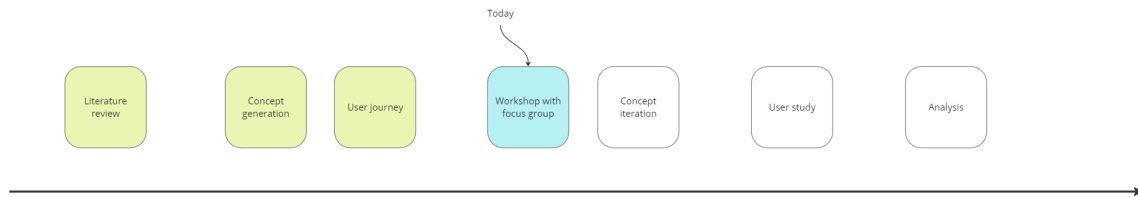
Aim and scope

Our research questions has converged towards how to educate drivers in a safe, efficient and motivating way

The aim of the project is to develop some interesting concepts as well as design guidelines which will provide a starting point for further projects within this area

The time horizon for this project is not sensitive to what is feasible today, nor is it a part of any PI or deadline so try to keep an open mind

What we have done and will do



What do we want from you?

What we want from you is your experience and expertise and you will be able to communicate this through the following:

1: Post-it notes



2: Grading scales



3: Short discussion at the end of the workshop

You will be placed in one of two groups and you need to pick a color for your notes and scales that you will use for all three concepts. The colors need to be different within the groups.

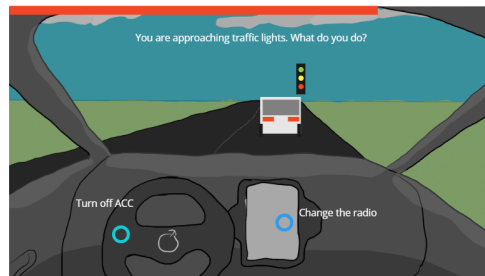
Concepts

1: Interactive video

How would this work?

This concept lets the user follow along in an interactive video from the drivers POV that lets the user make decisions affecting the outcome. The user will be presented with different scenarios where DAS is relevant and will be presented with a right and a wrong option. The user will have a limited time which is indicated by a bar on top of the screen that tics down. When the user has chosen an action or time has run out, the video will proceed with an appropriate consequence and feedback on how or why the action was correct or not.

Inspirational sources: Telltale games, Bandersnatch



Why would this work?

This concept is based on interaction being a big part of learning. Experiential learning, situational learning and constructivism are learning theories which means that learning happens when the user is using the product (Amineh & Asl, 2015; Hoch & Deighton, 1989; Russett, 2006). The user should be both physically and mentally engaged.

In DAS research (Portouli et al. 2008), interactive instructions through multiple media channels have been shown to improve DAS understanding. Simulation instruction only made participants feel like they understood more. This concept explores a middle way between interactive instructions and simulation.

When and where would this work?

You have just ordered your car and you are waiting for delivery. In the meantime, you check the shipment status where you see a link "Explore your car". There you find your car and its specification. At the top you see "Automation learning: see what you know about automation" and three videos below named Cruise Control, Adaptive Cruise Control, and Pilot Assist. You click ACC and you see a car from drivers POV. It approaches a traffic stop and a prompt show up and asks if you want to turn off ACC. Depending on what you clicked you get feedback if it was the right choice and why. You continue playing with more scenarios and testing different DAS levels.

You complete a few levels but decide that's it for today. Next time you will try other levels.

Notes

Pros



Cons

Improvements

Opportunities

Potential increase in ...



2: Quiz

How would this work?

The concept aims to enable users to quiz themselves on DAS systems and more specifically the Volvo functions. The quiz will display at the top if the weather conditions are appropriate for different DAS systems. This is to encourage the users to open the application and if they have the time they can do a little quiz. The quiz will consist of yes and no questions and a brief explanation will be given after each question to give direct feedback to the user.

Why would this work?

This concept takes advantage of the gamification method which is good for motivation. It makes whatever you are doing more fun than it usually is. In DAS education research (Feinauer et al. 2022), gamification has been shown to increase motivation, trust, and mental model formation. By using game aspects, showing feedback on your score, and your progress, the user should be more motivated to learn about DAS and improving their score.

When and where would this work?

Johan is in the middle of his morning routine before work and is planning on driving today but is contemplating if he can try out the pilot assist function today. He has heard about it but not done any research of his own yet so he opens up his Volvo app and checks if there are any quick guides. He finds the user manual but is a little stressed at this stage since he needs to get to work on time and does not feel like he has the time to sit down with a manual. He also finds a quiz in the app which he opens up to see how much knowledge he is lacking. The quiz informs him that the conditions today are well suited for pilot assist and poses the first question "Can pilot assist be used in heavy traffic situations?". He guesses and keeps on going through the questions until he is ready to leave home. The quiz informs him and makes him comfortable with the idea of using pilot assist at the same time as it spikes his curiosity. Whilst in the car he ponders if he should use pilot assist but refrains for now since he has not yet read the manual but he is eager to try it out on the way home!



Notes

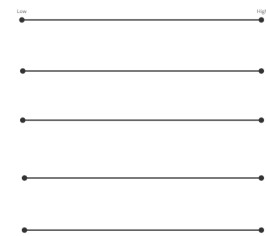
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Notes

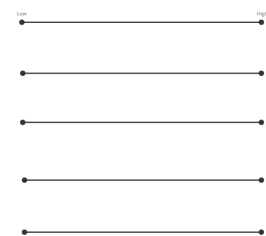
Pros

Cons

Improvements

Opportunities

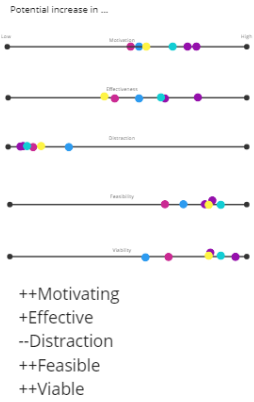
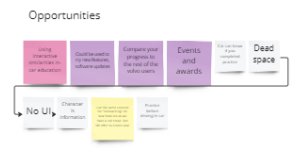
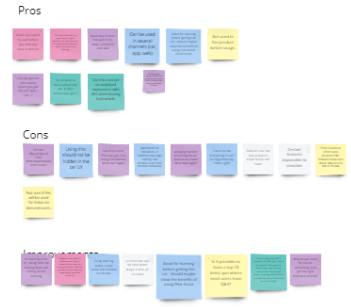
Potential increase in ...



C. Workshop result

1: Interactive video

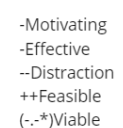
Good concept for learning before you have access to a car
Lacking the "real" experience of driving
Worries about the encouragement of usage of functions
Possibilities and opportunities can be seen



Concepts

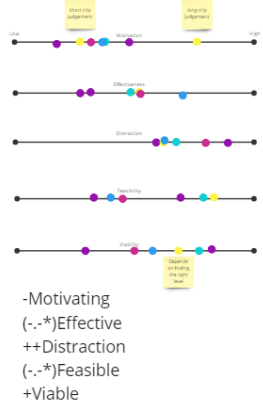
2: Quiz

Good for introducing the users to functionalities and limitations
Concerns around time and motivation to get users to engage
Implementation of some sort of awards and tracking of the users profile would improve the concept

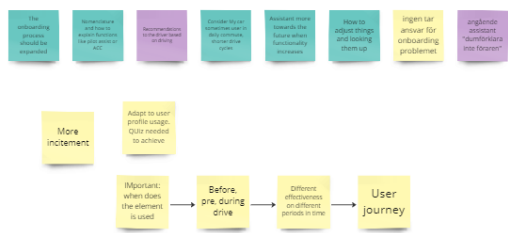


3: Edutainment

No big concerns around the safety of using while driving
Seen as a promising tool to help users while driving
Concerns about it being annoying and disturbing other passengers
Promising during longer drives
Audio needs to be complemented with other sensors like lights and haptics



General thoughts:



D. Test protocol

Test protocol

1. Test walkthrough
2. Education material
3. Simulator brief
4. Simulator test
5. Survey
6. Interview
7. Off-record discussion

Before the start of the study, the participant is welcomed and on the way to the test area they are asked (in addition to the initial survey) of their experience with ADAS to make sure they are suited for the test. Then they sign the GDPR document to give consent to use their data.

Test walkthrough

Thank you for helping us out and taking the time out of your day. Today you will begin by doing some educational material*, then you will drive in the simulator in a simple route, then you do a survey, and finally an interview.

**Unless they are doing concept 3: You will begin by sitting in the simulator and then we will present you the educational material while you are driving.*

Educational material

Four total education methods. Concept 1,2, and the baseline were all done before the driving simulator and concept 3 were done while driving in the simulator.

Quiz

You will use this iPad. You can start by just reading this first page and ask me if there is something you don't understand. So, on this start page you can see your available levels and your current knowledge level here. Feel free to begin level 1 whenever you want. I won't be able to help you with any of the specific questions but maybe I can make sure you have understood the question right.

- Participant use iPad
- Participant is instructed to read first page, questions?
- The instructors supervise during the first question, so they are not using it incorrect
- Then the participant is left alone to complete all levels
- If they have questions during, instructors won't tell them but only do what you think is best

Scenarios

You will use this laptop. You can begin by reading this first page. Ok, so I'll show you how it will work on this first scenario. The video starts automatically. After a while you get this overlay which prompts you with a task or information, and you make a decision by clicking these blue spots before the timer has run out. Sometimes not clicking anything is a decision as well. Make sure you click the next scenario to the right in the column, otherwise the videos won't start properly.

- Participant use laptop
- They read first page
- Instructors supervise first scenario so they use it correctly
- Participant left to do rest of scenarios

Voice Guide

This concept begins with the Simulator brief. The Simulator Test is also started and once they are out on the highway the educational material starts.

The scenario of this drive is that you are going to visit a friend in a neighbouring town and to do this you will take the highway. But we are starting off in your hometown where you can get a sense of the car and get comfortable with the simulator environment. You can now start the drive and try to look for a roundabout where the exit for the highway will be. Try to drive as you normally would but we will not be evaluating your adherence to traffic laws.

This is the roundabout, and you can take the exit towards “Backa E6” to get to the highway. Great you are on the highway! Now just get comfortable on this highway and the educational material will start shortly.

The Voice Guide for SDS starts

- *Hello and welcome to the audio guide for SDS.*
- *SDS is a system that helps the driver by keeping and adjusting speed while keeping the car in its lane. There are limitations to this system, and it is ultimately the driver that is responsible for the vehicle while the system is in use.*
- *SDS cannot detect street signs, traffic lights, or roundabouts and it cannot see pedestrians or animals so you will have to steer clear of them. SDS can struggle to make sharp turns so you will have to be ready to steer if one is coming up. This means that SDS is best used outside of towns and cities where signs, people and sharp turns are limited*
- *The conditions for when SDS is appropriate to use is if there are clear lane markings on a highway with good weather. You as the driver needs to keep your hands on the wheel at all times since it is you who is responsible for the vehicle.*
- *Make sure there are clear lane markings on the road and the sight is reasonably clear without heavy rain or snow.
There should not be a heavy trailer connected and the drive does not include any steep inclines.*
- *To begin please look at the buttons on the left side of your steering wheel to get an overview. Locate the middle button on the left side with a symbol that looks like a steering wheel with two hands controlling it. To activate SDS you press the button.*
- *Press the middle button that you located earlier and adjust the speed by pressing plus or minus. To deactivate the function, you can press the same button or simply use the brakes.*

The Voice Guide for UDS begins

- *Hello and welcome to the audio guide for UDS*
- *UDS is a system that when it is available will drive the car for you!
The system can be used on specific roads which it will track and notify you of automatically, but it cannot be used on unsupported roads.*
- *When UDS is used you can do other things in the car since the car is completely responsible while driving in UDS. You can socialize with other passengers and use your phone or computer if*

you want. Remember that you must be ready to take back control if needed. And sadly enough you cannot sleep while using UDS or adjust your seat.

- *The system will let you know when it is available visually by lighting up two buttons on the steering wheel.*

To activate it you have to press the two buttons on either side of the steering wheel at the same time and keep them pressed until a sound notifies you that UDS is active.

- *The system will let you know when to take back control of the driving by a sound as well as a gentle tug on your seatbelt.*

If you do not take over the driving the system will stop the car by the road in a safe way. To deactivate the system and continue the drive manually you press the same two buttons until a sound notifies you. The system can also be deactivated by you pressing the P-button, braking and turning the wheel with two hands.

So now you are done with the educational material. You can continue this highway until we let you know.

User Manual

Here is your educational material. There are two parts, first one is for SDS, second one is for UDS. When you are reading this through imagine reading it as if you had looked up this information yourself and started reading it. You can read as much or little you want depending on how motivated you feel.

- Participants get to read printed versions of PA and A manuals
- Instructed to read in what pace they feel like (however motivated they are)

Simulator brief

When it is time to drive the simulator, the participant gets to sit and adjust the seat to make sure that they are comfortable. Then a brief explanation is given to explain the differences between the simulator and a real-world scenario. The simulator does not have certain functions like turning the wheel when SDS or UDS is turning it and the proper interface of the HUD or centre console. The participant is instead instructed to listen to audio cues and look for certain lights that are provided by a led strip under the screen. The scenario of the test is then presented, and the drive starts.

“Have you adjusted the seat? Do you have a comfortable driving position?”

The simulator has some limitations and differences from a real-world setup, and we will quickly go through what you need to know before we start the drive. To start of the HUD that is visible on screen does show the right speed, but the rest is not relevant or correct in this test so please ignore it. There will instead be certain lights and sounds that will indicate which function is active or available.

- This light (Green light) indicates that SDS is active.
- This light (strobing White light) indicates together with this sound (Sound 1) that UDS is available.
- This light (Blue light) indicates together with this sound (Sound 2) that you have activated UDS, and that the system is in use.
- Finally, this light (strobing White light) indicates together with this sound (Sound 3) that you must take back control of the car and turn off UDS.

Do you have any questions about the lights or sounds? Great then let's move on to the driving!”

Flow:

- Seated, adjust seat
- Brief on controls: steering wheel and pedals
- Brief of notification system: lights and sound
 - o Green light = PA active
 - o Pulsing + sound = A available/not available
 - o Blue + sound = A active
- The dashboard doesn't represent accurate feedback (Always says AD in both PA and A)
- Traffic doesn't notice you
- We don't monitor small traffic violations (running a red light, not stopping at stop signs) because of the simulator

Simulator test

The scenario of this drive is that you are going to visit a friend in a neighbouring town and to do this you will take the highway. But we are starting off in your hometown where you can get a sense of the car and get comfortable with the simulator environment. You can now start the drive and try to look for a roundabout where the exit for the highway will be. Try to drive as you normally would but we will not be evaluating your adherence to traffic laws.

This is the roundabout, and you can take the exit towards "Backa E6" to get to the highway. Great you are on the highway! Now you can choose how you would like to drive, and I will tell you when it is time to take an exit.

-: Highway drive test with ADAS functions start :-

- Indication with light and sound that UDS is available
- Indication with light and sound if UDS is activated
- Indication with light and sound that UDS is to be turned off
- Indication with light that SDS is active
- Indication with sound that hands must be kept on wheel while using SDS

You can take the next exit! Great work and good driving, if you would like to try something in the simulator you can do that now and when you are done, we can move on to the survey."

- Simulator started; they get a feel for the controls to get used to them
- They are guided toward the highway where they will drive for most of the time
- Here they can start PA if they want
- After a while A is available
- They might start correctly, or incorrectly. If incorrect like pressing wrong buttons or not at all, they keep on driving. Alert on availability comes again.
- Alert on A not available comes after a while
- If they don't take back control, A is turned off (not what actually happens)
- Alerts happen 1-2 times more on the highway
- They are given instructions to take next exit into town

Survey

Ok, good driving! Now you will answer some questions on this iPad over here. The first section is on SDS, then there is one on UDS, and at the end you fill in which educational material you did (Quiz, Scenarios, Voice Guide, or User manual).

Interview

Now for the final interview. Keep in mind that the following questions are about the educational material you did before, not on the simulator you just drive in.

- How did you enjoy the educational material?
 - o If not, could you explain why?
- Did the educational material motivate you to use this type of resource and learn about self-driving systems?
 - o What would motivate you to learn about a new system?
- How trustworthy as an educational resource did you find the material?
 - o Would you still follow up with the car manual after?
 - o **If they used the manual** Would you like to complement the manual with something else?
- How well do you think it would make you understand self-driving modes?
 - o Do you think you understood the limitations of the system after the material?
 - o On a scale of 1-5? 5 being maximum knowledge.
- Would you use this resource?
 - o Why?
- When would you use this resource?
 - o When during the day do you think you would use it? (Before drive, pre-drive, during drive, after drive)
 - o Where would you use it? (Home, work, in car)
 - o Would you like to use this in the car?
- Final thoughts of the educational material?

Off-record discussions

Ok, now that we have done everything, we can answer any question you had during the test or other things you are wondering about.

E. Screening form

User testing for ADAS

Thank you for taking the time to fill out this form! This is a part of our research to explore new ways for drivers to approach ADAS. This form helps us establish a baseline understanding of the participants and hopefully you can help us further by signing up for a user study.

Sincerely,
Adam & Alfred

* Required

Demographic Information

1. Do you own a drivers' license?

- I do not have a drivers' license
- Yes, Less than 1 year
- Yes, Between 1 and 5 years
- Yes, More than 5 years

2. Gender

- Woman
- Man
- Prefer not to say
- Prefer to self-describe

5/22/2023

3. Age

- 18-22
- 23-35
- 36-55
- 56-69
- Over 69

Knowledge about Automated Driver Assistance Systems

4. Do you own, or regularly drive a car which is equipped with Automated Driver Assistance Systems (ADAS), e.g. Adaptive Cruise Control (ACC) or Lane Keeping System (LKS)?

Explanation:

- ACC supports your driving activity by keeping the speed and distance to the car in front of you. The system automatically manages the acceleration and deceleration of the vehicle.

- When LKS is activated, it identifies the lane markings through a set of cameras and assists you in keeping the car in the lane by steering the car slightly and maintaining its position in the travel lane. *

- Yes, I own a car with such systems
- No, I don't own a car with such systems
- My car is equipped with Cruise Control (CC) or Adaptive Cruise Control (ACC)
- I am unsure

5. How much knowledge do you have about ADAS?

- I don't have any knowledge about driving automation
- I have a little knowledge about driving automation
- I have moderate knowledge about driving automation
- I have a lot of knowledge about driving automation
- I know the topic of driving automation extremely well

6. How often do you use ADAS? *

- I have never used it
- I have tried it but I don't use it
- I use it sometimes
- I use it for specific trips
- I use it daily

7. Are you interested in participation in a study where you can learn more about ADAS?

- Yes, where do I sign up?
- No thanks

Book a time slot

Follow the link to book a timeslot. Select a slot within the dates: April 11-21

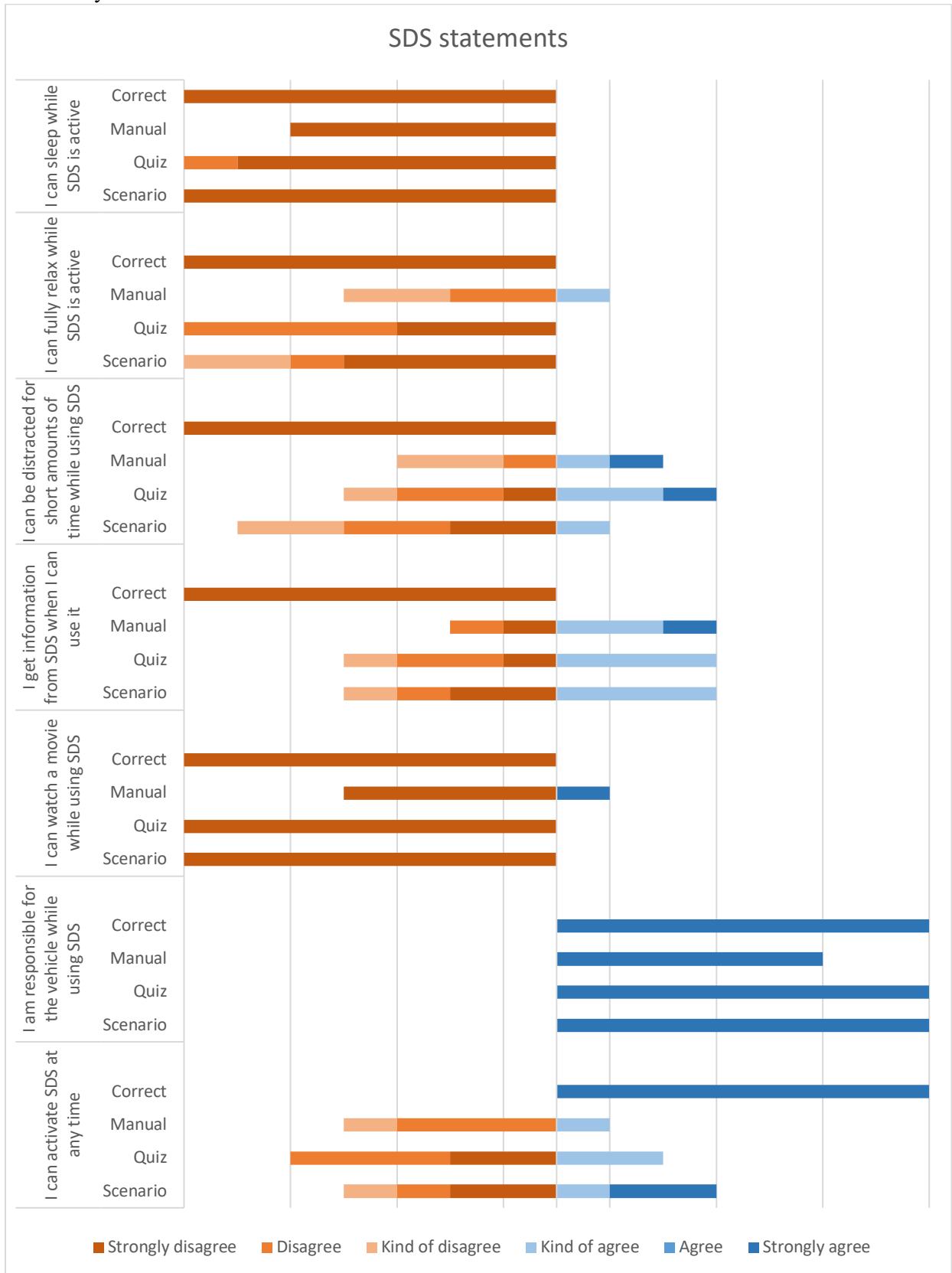
Don't forget to come back here to submit the form!

<https://outlook.office365.com/owa/calendar/Usertestingfordrivereducation@volvocars.onmicrosoft.com/bookings/s/h6plNX1hsEikkosUXaTVew2>
(<https://outlook.office365.com/owa/calendar/Usertestingfordrivereducation@volvocars.onmicrosoft.com/bookings/s/h6plNX1hsEikkosUXaTVew2>)

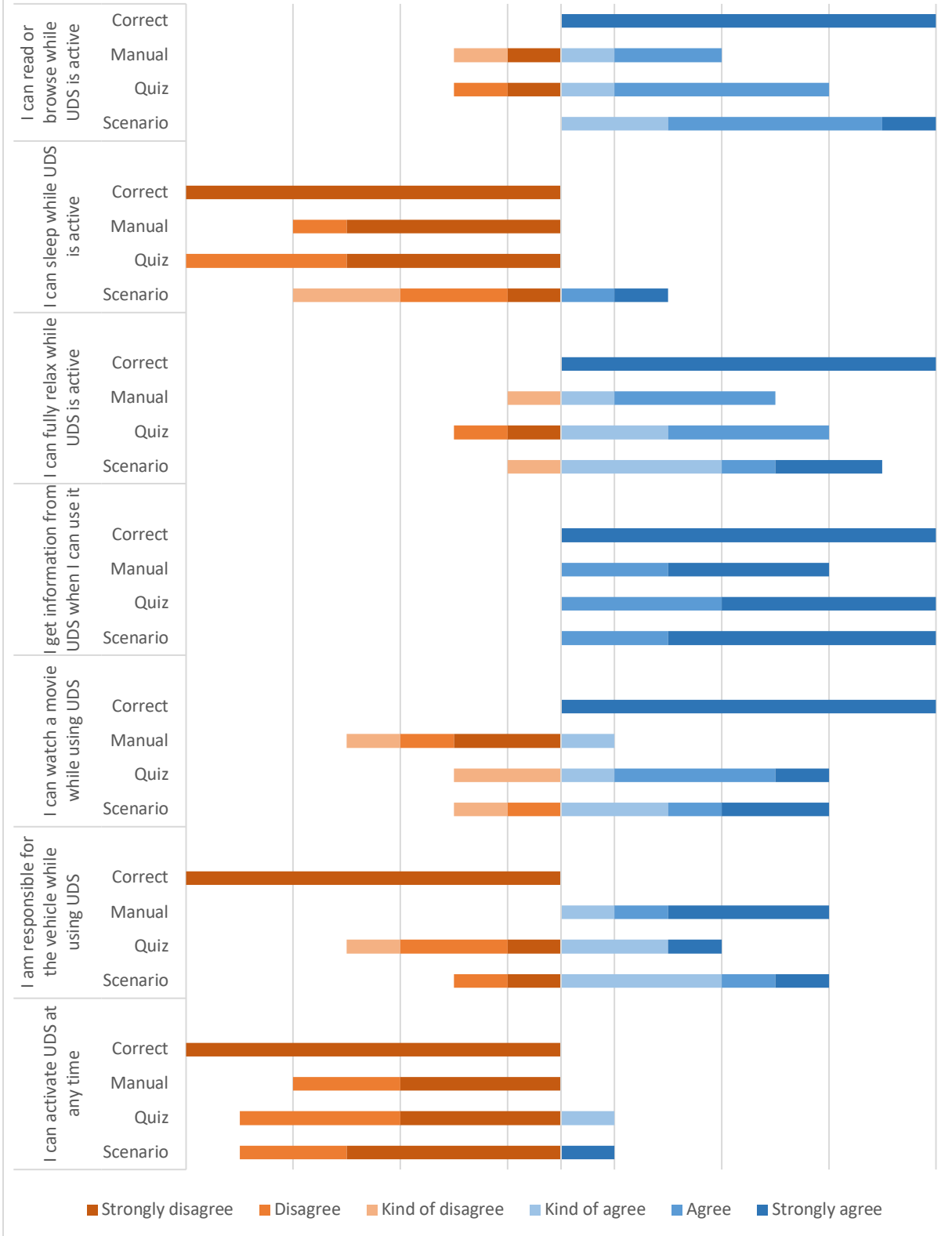
Thank you for your interest but it seems you are too experienced with driving automation

Unfortunately, you don't fit our target group, as we are looking for drivers who are new to these systems. Thank you for your interest!

F. Survey results



UDS statements



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