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NTNU
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QoE of in-car multimedia use in Traditional and Autonomous Cars

Master's thesis in Communication Technology and Digital Security
Supervisor: Katrien De Moor
June 2022

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Title: QoE of in-car multimedia use in Traditional and Autonomous Cars

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Problem description:

Ensuring high-quality multimedia services in cars today and in the future is crucial to utilize the expanding opportunities related to increased connectivity and new possibilities coming with 5G and beyond. Also, it is an opportunity to explore the different ways of spending the sudden gained spare time in the car. Therefore, developing in-car multimedia services is a growing interest in this research field. Nevertheless, looking at QoE as a central focus in this context is a shortage, also as it is challenging to determine and more complex to evaluate. Investigating QoE in this field demands context-aware research, enlightening several influencing factors and including various disciplines, thus challenging the dominant approaches to evaluate QoE.

Given this context, the thesis aims at researching the Quality of Experience (QoE) related to multimedia use in cars today and in more future-oriented scenarios, e.g., in the context of autonomous cars. What will happen when the driver loses the driving-related responsibilities, and may engage in non-driving related tasks? Will the leftover space become an office, a cinema, or maybe even a meeting room? And what does this imply when the aim is to ensure high in-car multimedia QoE also in the future?

The objectives of this thesis include exploring influencing factors of in-car multimedia, also discussing the suitability of existing QoE evaluation methods being projected onto more future-oriented traffic scenarios. In addition, looking at challenges which may arise related to QoE of in-car multimedia in the context of autonomous cars is a topic planned to explore further. Furthermore, this leads to the formulation of the following three research questions:

1. Explore the influencing factors related to QoE of in-car multimedia.
   - What influences QoE of in-car multimedia services *today*?
   - What might influence QoE of in-car multimedia services in a more *future-oriented* autonomous car context?
2. Evaluating and investigating the suitability of QoE methods used today.

- To which extent may existing QoE evaluation methods be used to evaluate QoE of in-car multimedia in the *current* car context?
- At the other end, to which extent may existing QoE evaluation methods be used to evaluate QoE of in-car multimedia in the *autonomous car* context?

To answer these research questions, a mixed methods approach, being a combination of qualitative and quantitative research methods, will be employed. This thesis also questions the methodology used to evaluate QoE of in-car multimedia, being especially complex in autonomous cars, as the latter do not yet exist in the common everyday picture. The most important methodologies to be used in the research include getting in touch with acknowledged experts in the various fields to be addressed, i.e., QoE, user experience (UX), human-computer interaction (HCI) and 5G and beyond, to mention some. Also, developing a questionnaire to get quantitative data is an appropriate way to get in touch with the users and their perspectives, suggestions and attitudes towards autonomous driving and technology in general.

This, in conjunction with expert interviews, a few user interviews and a literature review provides the initial foundation for answering the research questions.

This problem description is partly adopted from the pre-project summary and introduction.

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Abstract

When the COVID-19 pandemic hit, everyone were suddenly encouraged to ride their cars to and from work instead of riding the bus, train or tram. This resulted in fewer bus crowds and more traffic jams since we were all bringing the car to work, despite the negative climate impact that follows with driving fuel cars. This enlightens the fact that cars and traffic are a big part of the everyday life of many people, for the purpose of saving time, for convenience and full flexibility of arrival/departure times. In-car multimedia services are widespread, and constantly evolving, as car manufacturers offer increasingly complex and technological services to their users. It is important to ensure the quality of these services in conjunction with the driving scenario, and this is were Quality of Experience (QoE) becomes relevant.

Quality of Experience (QoE) is a holistic quality measure taking into account the overall experience related to a service, and in this case the driver/rider using the in-car multimedia services. To explore the most important influencing factors of in-car multimedia services with regards to QoE, several method approaches were initiated. A user survey, user focus groups, expert interviews and a diary study were conducted in conjunction with a literature review to get a deeper insight into user needs, limitations and challenges related to the topic in both traditional and autonomous cars. The findings show that age, gender, amount of passengers, sound quality and weather conditions were some of the important influencing factors considering in-car multimedia services. Furthermore, these insights are attempted projected onto the more future-oriented scenario where cars will transition into fully autonomous cars, in order to gain knowledge on how the reception of these vehicles will effect the users and their habits using in-car multimedia services.

In order to ensure high-quality in-car multimedia services also in the future, researchers need well-suited methods for this purpose, and for the ever-changing context of the autonomous (and the traditional) car context. There are a great variety of existing and well-established QoE evaluation methods which are suited for specific services. Using literature review and expert interviews as research methods, the suitability of these methods are revised and explored, in order to conclude with a suggestion that could create a holistic methodology approach to both current and more future-oriented research.

Sammendrag

Da COVID-19 pandemien inntraff, ble alle brått anbefalt å kjøre bil til jobb fremfor å bruke kollektiv transport som lenge har vært anbefalt tilkomstmetode på grunn av de negative klimaeffektene til bilkjøring. Dette resulterte i færre fullstappede busser, men også lengre køer og generelt flere biler på veiene. Dette forsterker det faktum at biler og trafikk fortsatt er en stor del av hverdagen til mange, for å spare tid og for å ha full kontroll og fleksibilitet når det gjelder avgangs- og ankomsttider. Multimediatjenester i biler er utbredt, og i konstant endring, på grunn av at bilprodusenter i økende grad tilbyr komplekse og høyteknologiske tjenester til kjøperne sine. Det er viktig å sikre kvaliteten til disse tjenestene på en sånn måte at bruken av tjenesten samspiller med kjørescenariet, og det er her Quality of Experience (QoE) kommer inn i bildet.

Quality of Experience (QoE) er en holistisk kvalitetstilnærming som tar i betraktning den helhetlige opplevelsen relatert til en tjeneste, og i dette tilfellet sjåføren/passasjeren som benytter seg av multimediatjenestene i bilen. For å undersøke de viktigste påvirkende faktorene for multimediatjenester i bil med tanke på QoE, ble flere metoder utført. En spørreundersøkelse, fokusgrupper bestående av brukere, ekspertintervjuer og en dagbokstudie ble initiert sammen med et litteraturstudie for å sammen oppnå en dypere forståelse for krav brukeren har, samt begrensninger og utfordringer relatert til temaet i både tradisjonelle og autonome biler. Funnene viser at alder, kjønn, antall passasjerer, lydkvalitet og værforhold er noen av de viktige påvirkende factorene når det kommer til multimediatjenester i bil. Videre ble disse innsiktene forsøkt projisert på det mer fremtidsorienterte scenariet hvor biler vil være helautonome, for å få økt kunnskap rundt hvordan mottagelsen av disse kjøretøyene vil påvirke brukerne og deres vaner rundt bruk av multimediatjenester i bil.

For å kunne sikre at multimediatjenestene for bil holder en høy kvalitet også i fremtiden, trenger forskere velegnede metoder utviklet for dette formålet, og for konteksten til de tradisjonelle og autonome bilene som vil være i konstant endring. Det er stor variasjon av eksisterende og veletablerte QoE evalueringsmetoder som er egnet for sine spesifikke tjenester. Ved bruk av litteratursøk og ekspertintervjuer som metoder, er egnetheten til disse metodene revidert og undersøkt, for å kunne konkludere med et forslag som kan frembringe en holistisk metodologitilnærming til både nåtidens og mer fremtidsorientert forskning.

Preface

The thesis was written at the Department for Information security and Communication Technology (IIK) at the Norwegian University of Technology and Science (NTNU). The author followed the study program Communication Technology and Digital Security with specialisation in Information security.

The main contributor of my work, Katrien De Moor, has been the guiding star this year. Having digital meetings with her allowed me to stay in Molde while writing the thesis, which I am grateful for her being comfortable with. I want to thank her for all her help, supportive words and for her engagement in this thesis and its topic. Also, I would like to thank her for all her effort put into contacting experts from her network to part-take in my expert interviews. The experts taking their time from busy work schedules is an act of kindness, which I am ever grateful for. Their perspectives and supportive words meant a lot. In addition, I am grateful for all the valuable contributors in the various user studies - without them taking their time, this thesis would be nothing.

Tuva Larsen
Trondheim, 10th of June 2022

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List of Acronyms

ACC Active Cruise Control.

ADAS Advanced Driver Assistance Systems.

AR Augmented Reality.

CIF Context-related Influencing Factor.

EMA Ecological Momentary Assessment.

HCI Human-computer Interaction.

IF Influencing Factor.

NSD Norwegian Centre for Research Data.

NTNU Norwegian University of Science and Technology.

QoE Quality of Experience.

SIF System-related Influencing Factor.

SPSS Statistical Package for Social Sciences.

UIF User-related Influencing Factor.

UX User Experience.

VR Virtual Reality.

Chapter 1
Introduction

Despite the negative climate impact, transportation by car is still a part of the daily routine in many households [Lar21]. Developing and finding different ways to entertain oneself while sitting in the car has been on the agenda of researchers all over the globe, and for a long time. The use of multimedia services is widespread to kill spare-time during car rides [PRB16]. Network-based activities in cars will likely also further increase as the development of cellular technology reaches new heights with greater complexity and less latency.

Furthermore, cars become more complex as time goes and technology evolves. Active cruise control (ACC) where the car itself monitors the speed, and even autopilot are functionalities already implemented in many cars, making it even more tempting to dive into a great TV-series while on the road (if the car is completely autonomous, that is). Considering the amount of existing research zooming in on autonomous cars, the age of driving cars might be coming to an end, replacing *driving* with *riding*. It is no longer unrealistic to foresee future roads consisting of mainly autonomous cars [Lar21].

To be able to ensure high-quality multimedia services in a future scenario where autonomous cars make up the vast majority of the traffic situation, the whole context must be included in the quality assurance process. Not only must the human-computer interaction (HCI) be a top priority, but the outside environment (often non-controllable) must also be a part of the equation. This further leads us to the introduction of the term Quality of Experience (QoE), a concept addressing several perspectives beyond only the physical, measurable performance parameters.

This thesis will be building upon and extending the work from the pre-project [Lar21] submitted fall 2021, and focuses on exploring influencing factors and challenges of in-car multimedia, in addition to considering to which degree traditional QoE evaluation methods might be used within this field.

1.1 Motivation

Seeing the amount of cars on the road in rush hours, the wear-down of asphalt roads due to high traffic, or the lines up towards ski resorts in the winter holidays, the fact that people are driving cars is non-negotiable. In all kinds of situations where one needs to be transported, choosing the car is the easiest option for many, whether if it is for running errands or leaving for work.

Car commuting, being the action of driving a car to and from work, is still a popular choice even in places where public transport infrastructure is fully developed, highly available and also convenient [PMM+16]. 36% percent of employed Norwegians work outside of their own municipality (Norwegian: kommune), making it likely that some of them choose to commute by car [SSB2]. Hence, a lot of time each day is spent in the car for many people.

Furthermore, other types of travels also happen in favour of using the car. Statistics Norway presented that 81,7% of all travels in Norway happened by car in 2020 [SSB1]. Keeping in mind these numbers being measured during the pandemic, where less use of public transport and flights was encouraged, the year 2019 is not far behind with its 75,6%. Hence, the amount of time spent in the car is high whether or not a global pandemic is scaring people away from public transport.

Keeping in mind these statistics and the amount of car commuters in rural areas where the car trips are often longer, the car is a place where a lot of time is spent by a lot of people. As a consequence, the accumulated spare-time one is given in a car ride is mostly filled doing some sort of activity. Researchers have not surprisingly found that the use of multimedia is widespread, whether it is scrolling on social media or streaming a TV-series [PRB16].

To be able to positively influence the future research on in-car multimedia, several disciplines must be considered and there is a need to look at the overall quality of the experience (QoE). There are several definitions of what QoE is, but in this thesis the definition used will be *the degree of delight or annoyance of the user of an application or service*. However, it is currently unclear to which degree different factors play a role and how, both today and in more future-oriented scenarios. The context of driving and riding cars is often also non-controllable, creating an unstable and varying environment for researchers developing in-car multimedia services and aiming to evaluate their quality. Social psychology, the more design focused field of User Experience (UX) in addition to the umbrella field of Human-Computer Interaction (HCI) are all disciplines needed to be able to develop the most pleasant and helpful in-car multimedia functions. Each of these research fields are - independently - not sufficient to create a good service, meeting users' requirements. However, the different perspectives and contexts taken into account when the fields join would create a

more inclusive and high-quality service.

As technology evolves and becomes more complex, also the field of autonomous/driverless cars has gained attention. Their promises includes less car crashes, due to human error being the main contributor for traffic accidents today [HOH19]. The fact that the driving responsibility will in the future most likely rely on the car and not the human, leaves the human with no choice but to sit down and have a spare time while the car is moving. As previously stated, this amount of time is quite excessive for many, and especially the ones relying on cars for commuting. Finding well-suited in-car multimedia services and info- and entertainment systems is crucial for ensuring this time well spent, from a sociopsychological- and economical perspective.

1.2 Objectives

As mentioned, this thesis will further work on the overall topics from the pre-project [Lar21]. This includes exploring influencing factors of in-car multimedia, also discussing the suitability of existing QoE evaluation methods being projected onto more future-oriented traffic scenarios. In addition, looking at challenges which may arise related to QoE of in-car multimedia in the context of autonomous cars is a topic planned to be further explored.

Hence, the objectives and research questions are presented in the following.

1. Explore the influencing factors related to QoE of in-car multimedia.
   - What influences QoE of in-car multimedia services *today*?
   - What might influence QoE of in-car multimedia services in a more *future-oriented* autonomous car context?
2. Evaluating and investigating the suitability of QoE methods used today.
   - To which extent may existing QoE evaluation methods be used to evaluate QoE of in-car multimedia in the *current* car context?
   - At the other end, to which extent may existing QoE evaluation methods be used to evaluate QoE of in-car multimedia in the *autonomous car* context?

1.3 Structure of this thesis

The current introduction of the thesis (Section 1) introduced the objectives and their motivation. This is followed by background information on the topic including state-of-the-art and peer-reviewed literature on QoE and autonomous driving. The

methodology is presented in Section 3, presenting a mixed methods approach and how this is planned to be executed. Thereupon, the results of the different empirical studies, using the different methods used, are presented in Section 4. The results are further discussed in Section 5, followed by a conclusion in Section 6 based on the research objectives.

Chapter 2
Background

The average Norwegian car-owner drives 11 000 kilometers per year (2020) [SSB3], making up an average of 30 kilometers per day. Also, as mentioned in Section 1.1, commuting by car to and from work is still a popular choice. As a consequence, drivers and passengers often seek to find a way of staying entertained or informed during a ride, whether it being in the form of music, auditive navigation systems, podcasts, audio books or Bluetooth phone calls with a friend. Ensuring high-quality services for use in cars is an important topic from both a societal and technical perspective, for the enhancement of services in the user's favour, turning the use of the services to an overall positive experience and hence ensuring high QoE. At the same time, the traffic situation today is still dominated by vehicles in need of human intervention to be sufficiently maneuvered, hence being the form of driving that most drivers are familiar with. Furthermore, in newer cars, drizzles of automated functions are becoming more present, and are further elaborated in the following section. Then, the overview moves towards fully autonomous car and user habits and possibilities of in-car multimedia in both current and autonomous cars. Next, the concept of QoE, its conceptualization and evaluation are introduced.

2.1 Automated in-car functionalities

The automated functions of a car, also known as Advanced Driver Assistance Systems (ADAS), is by the National Highway Traffic Safety Administration (NHTSA) split into five categories depending on to which extent a car is autonomous [RSMT14]. The categories and short explanations are given in the following.

- Level 0: No-Automation
  - The driver is in full control of the vehicle, with no assistance.
- Level 1: Function-specific Automation

    - One or more automatic functions. For example brake assistance or auditive parking assist.

- Level 2: Combined Function Automation
    - At least two automatic functions working in unison. Adaptive cruise control and lane centering, for instance. Parking assistance where the vehicle maneuvers the vehicle out of the parking lot only with the human intervention of accelerating and braking.
- Level 3: Limited Self-Driving Automation
    - The vehicle handles the driving situation in more predictable traffic like highways with clear lane markings etc. The driver must be available for resuming the control at times where the traffic less predictable, for example exiting the highway.
- Level 4: Full Self-Driving Automation
    - The vehicle is fully autonomous without the need for human intervention, including parking, accelerating and steering.

In terms of research addressing levels of autonomy and automation, Rödel et al. [RSMT14] also took into account trust and user acceptance (UA) while studying the different autonomy levels, stating that trust and acceptance of ADAS is highly dependent on not only the vehicle but also pre-experience, gender, age and other personal characteristics of the driver. After designing a questionnaire consisting of scenarios with affiliated questions and having 336 respondents, they found that trust decreases when levels of autonomy increase, and justifies this in the fact that people are already well-known with the functions of a non-autonomous car and hence trusts it more. After all, mankind tend to trust what/whom we know best, for better or worse. [KKJ+15] also brings up trust and user acceptance of semi-autonomous cars, but lacking the subjective perspectives and the user perceived QoE.

In the following, some in-car features whom are important for the driving experience and have been increasingly popular in the later years will be presented.

Assistant A type of automated in-car functionality are variations of *assistants*. They are widespread in newer high-technological cars, and could be vocal assistants telling you where to turn due to the navigation direction, or command assistants helping you to call someone (such as Apple's Siri). Other assisting functionalities such as lane assist and parking assist helps the driver with keeping the car within the lane lines and to park, respectively. Parking assistants could be having the car maneuver the steering wheel while parallel parking, or having vocal assistants telling the driver which way to turn, dependent on the manufacturer of the car.

Cruise control Furthermore, a functionality called *cruise control* removes the driver's foot from the gas pedal, and is in fact an old invention from the early 1960's. By using a type of remote control, often in the form of an extra handle on the steering wheel, the driver may adjust the speed up and down. By ticking the handle or by pressing it down or up, the speed adjusts slowly or rapidly. Also, the more advanced *adaptive (or active) cruise control* removes the driver's foot from both the gas pedal and the brake. This functionality adjusts the speed according to the car in front of it (if any).

Autopilot Some manufacturers, such as Tesla [AP], have also launched autopilot functionalities with the limitation of hands-on-the-wheel demands for the human operator to rapidly resume control in case of challenging driving conditions or unforeseen obstacles. Still, this is a groundbreaking step towards a fully autonomous traffic picture.

2.2 Fully Automated cars

Most traffic accidents reason from human error, more specifically being 90% of all accidents. Releasing the human from the driving situation is hence claimed to decrease accidents by 90% [HOH19]. Zooming in on more future-oriented scenarios, fully automated cars will likely be dominating the traffic picture. As a consequence, the driver will become more like a *rider*, enabling the opportunity to draw their attention away from the traffic. This will further lead to change in the way the car coupe is used.

Due to the driving responsibility, traditional cars only allow us engaging in a limited amount of multimedia not demanding full awareness from the user. The more future-oriented case for in-car multimedia is that it may be based on offering a higher degree of cognitive stimulation. Furthermore, this may lead to a phenomenon that with someone often appears in conjunction with not paying attention to the road while riding a car, namely motion sickness. Logically, studies have shown that user experience (UX) deteriorate as feelings of motion sickness increase [SR20]. This is an issue that will influence the user's ability to engage in Non-Driving Related Tasks [SS14]. It is clear to see the wide span of influencing factors related to QoE of in-vehicle multimedia, compared to a lab setting or a living room context. Not considering the potential overload from multimedia services may also lead to fatigue for the user, resulting in a downwards spiraling QoE riding an autonomous car. Because of this, ensuring infotainment and entertainment services of high quality having QoE in mind, would be beneficial also from a socioeconomic perspective, making good use of the sudden spare hours the inhabitants gain while traveling.

2.3 In-car multimedia systems

Types of in-car multimedia today vary in tact with the various car manufacturers. Some cellphone operators have teamed up with car brands, making room for in-car services like Apple Car Play and Android Auto. Apple Car Play [ACP] is compatible on selected brands and models, integrating iPhone with the car's own multimedia screen, knobs and controls. On selected car models it even enables start-up from your phone. Android Auto is Google's response to Apple Car Play, offering more or less the same functionality.

As mentioned, engaging in multimedia services in a car is not atypical today. As a method for trying to figure out activity patterns for the ones riding autonomous cars, Pfleging et al. [PRB16] conducted an observation study of train passengers, mapping what type of activities the test subjects performed at a train ride. Although a train is not an autonomous car, the steering situation does look similar in that the train does not demand the passengers to keep their hands on the wheel. Hence, it is not unthinkable that what passengers choose to do on public transport might look like what future engagement inside autonomous cars will look like. As a result, the study revealed that 19.3% of the performed activities consisted of using a smartphone in some way.

In order to evaluate the quality of multimedia used in cars, observing which activities are currently typical is a good start to understanding the user's needs. Still, taking into account *how* the activities/applications are affecting the driver's mood and overall experience, research also involving degrees of QoE needs to come forth in order to create services taking into account the holistic context. What might be problematic with the train passenger-approach is that their state of mind and perceived experience riding the train and doing their respective activities, is never mentioned. Only the *type* of activities are included, excluding context parameters that might heavily affect the experience as a whole.

2.3.1 ...in autonomous cars

Considering autonomous cars, several research groups have questioned the use of the car coupe when the driving responsibilities are taken away from the car holder. Having an autonomous car, drivers may engage in non-driving related tasks without increasing the risk of a fatal accident. There are endless possibilities for what the car coupe could be used for in an autonomous car, for instance upgrading the experience using augmented reality (AR) - being a combination of virtual reality (VR) and the real world - for both infotainment and entertainment, or gaming activities for killing time. Office spaces or mobile living rooms are proposed by Clemens et al. [SSR+20], taking into account Human-Computer Interaction (HCI) and raises questions towards methodology of investigating the use of in-car multimedia in autonomous cars. The

paper is proposing topics to talk about at the CHI conference (conference in the field of HCI) in 2020, but it was never brought up due to COVID-19.

Still, research including QoE in this brainstorming process are a shortage. Since the aforementioned was a CHI paper, not mentioning QoE was not a surprise however. This paper is just one of many papers not mentioning QoE in the context of autonomous driving. Interaction design and human-computer interaction are also important topics to consider in an autonomous car setting, and seemingly more popular routes to take when discussing the potential. Research has been considering usability and UX while seeing the car as an isolated system [BBP19], rather than viewing the driving experience in a wider perspective with possible influencing factors in a car ride, hence including QoE. Furthermore, for the in-car multimedia services to create an overall fulfilled and sufficiently good experience for the end users, the quality of the experience needs to be taken into account.

2.4 Quality of Experience

QoE is defined as *a users overall feeling of expectation fulfillment related to a service or an application* [WZ19]. More recently, it has been defined as *The degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state*[RE14]. This research area has developed from the term Quality of Service (QoS), being well-known in the networking community as a set of quantitative performance characteristics of a service [MR14]. QoE is said to tie the terms of user perception and experience together with measurable network parameters formally expressed as QoS [FHT10], and is a term rooted in the field of telecommunications. A so-called IQX hypothesis (and formula) is proposed as a dependency between Quality of Experience and Quality of Service, making it more feasible to use existing QoS measurements to directly get an understanding of the corresponding QoE impact. The hypothesis proposes that fluctuation of QoE is stronger where the experience is already very high, rather when the experience is already very low, e.g. seeing a hair in the soup at a Michelin restaurant decreases the QoE more than seeing the same thing at a poorly maintained pub [MR14]. Therefore, it can be assumed that QoE is dependent on the current QoE, given the same change of the QoS parameters. In the derivation of this formula, it is stated that QoE may be described as a function of n influencing factors, meaning factors having an influence on the resulting quality of the experience. Unlike the more measurement-oriented QoS, QoE addresses user's perception and their experiences towards the service in use instead of only looking at the quantitative usability of the service. Furthermore, to ensure QoE in an in-car multimedia context, one must find out the key influencing factors who make or break the overall QoE in the end.

2.4.1 Influencing factors in an in-car multimedia context

Considering influencing factors (IFs), these might be present and potentially highly varying in an in-car context. Driving conditions, weather, company in the car, cellular reception are all examples of factors which might majorly influence the overall QoE of an in-car multimedia source. Influencing factors can be seen as independent variables, while the QoE perceived by the user is a dependent variable, meaning that one might not be aware of the IFs, but one is usually aware of one's opinion of the overall experience [MR14, Ch. 4.1]. Furthermore, these IFs must be viewed in an interrelated fashion, being the fact that they combined might improve or deteriorate the user's perception of the quality. While sitting in a car, the product of several IFs will likely create a cocktail-effect where one added or removed IF may drag the experience up or down, but if they appeared isolated, the effects would not be as decisive.

User-related factors

User-related factors are also called human-related factors, being properties or characteristics of a human user [MR14, Ch. 4.2]. These characteristic might be related to socio-economic background, physical and mental health or emotional state of mind. The user-related factors might be hard to grasp, given the complexity and their subjective nature. Typical factors are age, gender and expertise, among others. The influence these factors have on the perceived QoE is said to be "poorly understood" because of the lack of empirical evidence [MR14, Ch. 4.2]. In the context of in-car multimedia, user-related factors might be present in that a user's acceptance of technology affects the overall experience, which in turn may rely on their age and experience with other forms of technology. A 30-year old user working in a big ICT corporation is thought to be more experienced with technology than a 60-year old user working in the construction industry without the use of advanced technology in the everyday-life. Also, driving skills (in non-autonomous cars) will naturally have an impact on how a driver perceives the overall experience, being more positive or negative depending on the amount of previous driving training.

System-related factors

Some IFs are directly related to the system in use, being system-influencing factors (SIFs). These are defined as characteristics that determine the technical quality of a service [MR14, Ch. 4.3]. These factors are further divided into content-, media-, network- and device-related IFs. Latency sensitive services like video streaming would in the future autonomous traffic be demanding smooth handovers and high quality even when the cars are passing by at 150 km/h. For the Internet connection and the cellular reception to be sufficient, 5G and beyond must be of high performance to enable and support the connected functions of an autonomous car.

Cellular reception - 5G and beyond An increasingly autonomous traffic calls for connecting the vehicles to each other, in addition to the infrastructure (road crossings, traffic lights) and pedestrians/cyclists roaming in the same area. Vehicle-to-everything (V2X) is an emerging field in telecommunications, aiming for connecting all vehicles to the cloud and also its surroundings [Lar21]. When rooting for all these connected vehicles in constant movement, there is an increasing need for low-latency networks and new Service Level Requirements (SLR) applied to applications connected by cellular V2X (C-V2X) technology. The 5GAA Automotive Association, bridging the telecommunication and automotive industries, presents in a white paper [Ass+20] a number of technical use cases demanding complex interactions between vehicles and other traffic infrastructure along with the SLAs derived.

Context-related factors

The contextual dependence of the quality of a car ride is perhaps the least highlighted topic in existing published research. Since QoE might be influenced by user expectations beforehand, the context and environment where measures are taken should be - if possible - their natural environment of normally consuming the particular service. The amount of factors potentially causing a fluctuating QoE is comprehensive and complex, not to mention situation-dependent. Context Influence Factors (CIFs) are per definition "*factors that embrace any situational property to describe the user's environment*" [MR14, Ch. 4.4]. The CIFs are further categorized differently depending on which research source one inspects. The CIFs may according to [JV10] be divided into physical, temporal, social, economic, task- and technical context characteristics. These characteristics may occur either separately or as a combination of the level of magnitude (micro or macro), behavior (static or dynamic) or occurrence patterns (rhythmic or random). In the following paragraphs, the several types of contexts will be further elaborated to get an understanding of what they involve.

Physical context A physical context-related factor while driving or riding a car is perhaps the most comprehensive context type. These relate to location, including movements and transitions. Whether the user is outdoor, indoor, in a social or professional space, noisy or peaceful, dimmed or bright environment and how the user their self are physically staying. Projecting this physical context into the traffic, good or bad driving conditions and weather for instance might heavily influence the physical context factor. Driving in slushy snow, slippery winter roads or pouring rain demands focused concentration and maneuvering from the driver, in current cars that is. Daylight versus the darkest nights, sitting comfortably versus sitting clinched to someone, or steaming hot temperatures versus comfortable temperature are all physical context factors able to fluctuate the overall QoE of a car ride [MR14, Ch. 4.4].

Temporal context The temporal context might sometimes relate to the physical context, in that temporal aspects may for example be time of day, week, month or year. A car ride in the summer season feels different than a ride during the coldest of winter time [MR14, Ch. 4.4]. Also, the mood of a car driver will likely be different on their way *to* work and on the way *home* from work.

Social context Social aspects is defined by inter-personal relations during the experience. Whether the experience is completed alone, with a friend, with a stranger or both, affects the social context of a situation. Many car drivers have passengers joining them for the ride, for example colleagues, children, family or friends [MR14, Ch. 4.4]. There is an obvious difference between riding with your best friend, or riding with both your best friend and his/hers three screaming children in the backseat.

Economic context This context is related to the economic situation of the unit in use, whether it is an application collecting a monthly subscription fee, a free application, or a very expensive one [MR14, Ch. 4.4]. The brand of the unit does also influence the economic context, for example having biased opinions the certain manufacturing company prior to testing their service in a supposed-to-be objective manner. Projecting this onto in-car multimedia, the economic context might be an overly prized service not working as the user had its right to expect, or enthusiastically using a well-performing service all free of charge. Maybe some time in the future the most normal thing will be to rent and autonomous car from a car pool when you need one, and not owning one. Then, some kind of subscription fee would probably be relevant, and perhaps with payed ads that you have to watch prior to starting the drive if you only subscribe to the cheapest subscription.

Task context The task context is a highly relevant context for in-car multimedia. What is supposed to be done, and with paying which grade of attention? The nature of the experience is what defines the task context. Multitasking, interruption and task type are situations whom may arise and affect QoE of a task context. Using a service in conjunction with having a conversation, working, or doing other distracting activities - hence multitasking - may affect user perceived quality and the overall satisfaction with the service as a consequence of less attention payed to the particular service. Also, doing activities like the above in conjunction with *driving*, must probably be the biggest (and most dangerous?) multitasking of them all.

Technical- and information context This context does balance on the edge between system- and context related influencing factors. It represents the relationship between the system in mind, and other systems interacting with it [MR14, Ch. 4.4]. This could for example be devices, applications, networks or other informational artifacts interacting with each other.

2.4.2 Traditional evaluation of QoE

Studies focusing on QoE have a tendency to reside inside a controlled laboratory, and with purpose, because of the nature of what is being evaluated. Whether it is video conferences or video streaming, this is feasible and accessible to researchers, offering the possibility to manipulate certain expected IFs while keeping others stable and being able to quantify the results. Quantifying the QoE is important to be able to improve it in the future, and to have a reference point to compare it with [FMRX16].

Standards for QoE evaluation

In order for QoE to be measured consistently ensuring common scales across research institutes and organizations, standardization of routines and evaluation methods is crucial. The International Telecommunication Union (ITU) is an organization focusing on strategic cooperation between stakeholders to ensure that the rapid changes in ICT (Information and Communication technology) affecting societies are discussed considering social, financial and political aspects [ITU]. In the following sections, I will introduce a few established QoE evaluation techniques for the various technologies relevant for the topic of this thesis.

Evaluating QoE of video streaming

Streaming video content in cars is a source of entertainment used by both drivers (while the car is still) and passengers. Video streaming is a latency-sensitive service, which can pose a major limitation and hence is prone to fluctuating QoE parameters. For instance, studies have shown that re-buffering is often the make or break factor for the users, where longer start-up delay is preferred as the alternative [MR14, Ch. 4]. HTTP Adaptive Streaming (HAS) has become the standard for streaming content over the Internet, because of the ability to match content quality to network performance [PHWT18]. QoE researchers have developed various video quality models to address various types of challenges related to video streaming [MR14, Ch. 19]. For instance, models for adaptive video streaming will estimate quality for a longer period in the video in question, where distortions might be spatial and temporal, as a measure to optimize the user's QoE [MR14, Ch. 19.3.3].

Evaluating QoE of speech communication

Communicating with others while driving or riding a car is widespread, either by using headphones or via the car's built-in speaker function using Bluetooth [PRB16]. Researchers have defined *speech quality dimensions* as measurable parameters describing the user's perception of speech communication, namely discontinuity, noisiness, coloration and loudness. To be able to measure the QoE of speech communication,

several method paradigms are used. These are *auditory* methods and *instrumental* methods.

Auditory methods Auditory methods rely on assessing test users' judgments on the quality of a speech communication [MR14, Ch. 12.3.1]. The two common types auditory methods are listening-only tests and conversation tests, whom both are standardized by ITU in their published P-Series of Recommendations. The ITU-R Recommendations contain methods for subjective assessment of sound quality [ITU-R]. The majority of the standardized methods operate by having the test subject assigning a single integer value, ranging for 1 to 5 where 5 is the best score (Likert scale), to the speech quality. These auditory tests are expensive in terms of costs and time, not to speak of the effort needed to be put in for recruitment purposes, which introduces us to instrumental methods as an alternative.

Instrumental methods These methods are the most common, given their accessibility and lower cost compared to the above auditory methods. Some of these methods compose a single integer value possibly representing the perceived quality, or a collection of several quality features. Researchers have raised concerns towards the fact that no tool covering all aspects of QoE in a single value does not exist yet [MR14, Ch. 12.3.2]. Also, current speech quality models do not cover noise from the environment in which the test subject is located [MR14, Ch. 12.4]. These facts could be projected on to the context of autonomous cars, emphasizing the fact that having only instrumental tools predicting the QoE of a context-dependent scenario such as automated driving, might be challenging.

Evaluating QoE of multimedia conferencing (telemeetings)

Considering the autonomous car context, turning the coupe into a mobile office is one of the scenarios researchers are foreseeing [SSR+20]. Conferencing and having online meetings are a big part of many employees' work life. As a consequence of the COVID-19 pandemic, the frequency of online meetings and conferences has been further increased, where Zoom, being one of the biggest online meeting platform in this period of time, reported an increase going from 10 million to 300 million when the COVID-19 pandemic hit [Zoom]. In the case of evaluation methodology, both subjective and instrumental methods are applicable today. The subjective tests mainly use metric scales, and the instrumental methods include quality prediction of video and audio. Möller et al. [MR14, Ch. 15] claim that traditional QoE evaluation methods used for two-party telecommunication should be the baseline also for testing video conferencing, but on the same time there is a lack of appropriate methods for this purpose. Technical conditions of a video conference setup are diverse, and hence bringing an extra layer of inaccuracy. To be able to create a more personalized and

surrounding experience in the autonomous car, a possibility researchers have been looking into is the evolving field of virtual reality (VR).

Evaluation the QoE of autonomous cars using VR

Gomes et al. [GFM20] have presented a QoE evaluation of riding autonomous cars by the use of VR. VR consists of multimedia in combination with instructed and rendered graphics, usually by the use of removable goggles and hence giving the user a sense of presence. By simulating traffic scenarios and typical road events using VR, user perceived experiences could be measured in a lab rather than using existing autonomous cars giving a debatable degree of perceived safety. Researchers [GFM20; WHPB17] have also discussed the trust, degree of acceptance and motion sickness of the user while sitting in an artificial autonomous car, but there is a lack of empirical studies aiming to test the simulation technologies and how they are adaptable for QoE evaluation. The presented evaluation methods so far has been mostly based on laboratory setups. However, there are also a set of more novel methodologies that include stepping out of the lab, and moving into the landscape of more real-life methodology which have gained popularity in recent years.

2.4.3 Evaluating QoE with the use of crowdsourcing

The method of crowdsourcing involves using a large pool of contributors to perform the same task and in some way report their task or task result back to the ones who gave them the task, and is known in the QoE field as an alternative to the traditional lab-based user experiments [MR14, Ch. 21]. It is a way to procure goods or services, finding and using workforce from the "crowd", being a large amount of people contributing with their workforce or empirical knowledge [SNL]. The method is popular in research communities, having the Internet as the main artery for collecting willing contributors from around the world. This will move the research away from the artificial labs, and into the population's home or another equally natural habitat, hence also ensuring diversity.

Hoßfeld et al. [HHR+14] summarize the best practices and recommendations for crowdsourcing-based research of multimedia services and applications, originally from the Qualinet Task Force on "Crowdsourcing". Several disciplines and domains were considered in the recommendations, amongst them being:

- Evaluation of 3D video
- QoE factors of cloud storage services
- QoE for HTTP streaming

To be able to give the recommendations, a set of mechanisms must be understood and explored from a crowdsourcing perspective, such as

- motivation and incentives,
- crowdsourcing frameworks and platforms,
- selection of these crowdsourcing platforms, and
- reliability of the methods.

Taking these perspectives into consideration, [HHR+14] summarizes the following key recommendations and best practices for crowdsourcing experiments:

1. Use common software without requiring admin installations
   - The software tools must be easy to use and set up
2. Simplify the questions
   - Because of the unsupervised nature of crowdsourcing
   - To limit the need for time consuming clarifications between the crowd and the experimenter
   - Use simple English or the user's native-language
3. Choose a proper duration for the experiment
   - The participants in crowdsourcing are less motivated and invested than in lab studies
   - Withdrawal can be done any time
   - Task length and reward ratio must be satisfying for the participants
4. Include training sessions
   - Both for the participant to practice, but also for the experimenter to get a hold on how well the participant understands the task
5. Integrate a feedback channel
   - For the test subject to report issues and ask questions
   - The channel must be permanently available
   - Define specific time slots where the subjects could expect to get a responses
6. Event logging

- To analyse user interactions
- Estimating reliability of users
- Logging user actions and test conditions

7. Include reliability checks in the test design
   - Estimating trustworthiness or reliability of a user
   - For example consistency checks, content questions or verifying the user's attention to the test
8. Include reliability checks during the test
   - Increases test reliability
   - Reduces administrative overhead after the test is terminated
9. Include reliability checks after the test
   - Based on the test outcome
   - Detection of outlier participants
10. The testing crowd consists of human beings
    - Treat them ethically and with empathy
11. Lessons learned from lab test - use them in Crowdsourcing too
    - QoE tests based on crowdsourcing are still psychometric experiences aimed to quantify user perceptions, so;
    - Keep the tests to a minimum duration
12. Use the appropriate scale for the problem
    - Users tend to avoid using both ends of the scales
    - Cultural and language differences between the score alternatives could make it difficult to compare results across borders
    - Absolute Category Ratings 5 scale is the most efficient and reliable (see Figure 2.1)
13. Look a gift horse in the mouth
    - Increasing payments will not always imply a better result, but rather increase the amount of unreliable users
    - Increased payments also often result in shorter experiments, which is not always desirable

14. Motivate the users
    - Aiming for the test subjects to be killing time or having fun is an alternative to only lure with monetary rewards
15. Crowdsourced lessons learned
    - Crowdsourcing hides pitfalls
    - Lack of feedback
    - Filter out the unreliable participants

Figure 2.1: Absolute Category Rating 5 scale from [HHR+14] via https://github.com/St1c/ratings

Projecting this methodology onto the in-car multimedia context would be beneficial for several reasons. First and foremost, for understanding the influencing factors of in-car multimedia services, since a lot of data would be collected on a reasonably short time. Secondly, crowdsourcing increases the possibility and feasibility of reaching out to people (drivers) from all over the world, and not just Norwegian people recruited from my own network. This would result in a higher degree of diversity, which in turn will gather more valuable information from several perspectives which might not be present in Norwegians. Norway has a well-established and functioning infrastructure, and generally very good cellular reception all over the country - which is not the case for the rest of the world. Including aspects and perspectives from countries where the infrastructure is not as expanded would serve as a good base for the ones developing services for *everyone*, not just the ones in the most industrial countries.

The crowdsourcing methodology consisting of a pool of test subjects in their natural habitat and their results, brings us to the next method which also is moved out from the lab and into the test subjects everyday life. For instance, Hossfeld et al. [HSH+11] has proposed a QoE assessment methodology for multimedia applications (YouTube in their case) based on crowdsourcing.

2.4.4 Evaluating QoE using a Living Lab Setting

To be able to evaluate QoE with more user-centric and context-aware methods, researchers have developed various frameworks. These frameworks are often made

out of some sort of diary studies involving test subjects, in conjunction with technical parameters logged by the same test subjects in the same contexts. QoE researchers have made use of frameworks such as *AWARE* to easily log *in-situ* mobile context information without also collecting novelty biased information, having the test subjects log the technical information immediately after using the service in question [VFG+14]. The types of information were in this research related to device, location, network and battery. AWARE is an open-source Android framework and mobile application making it easier for test subjects to report data for research purposes [AW].

Furthermore, another framework called *mQoL Lab*, developed by Alexandre De Masi, is a smartphone logging application (app) which triggers user surveys strategically [DW18] in order to get the user's QoE rating after using a specific set of apps. In comparison, the AWARE framework triggered user surveys at random times during the day, and not immediately after an app was used. De Moor [DKJ+10] has also proposed a framework for QoE evaluation in living lab settings. Yet, De Masi notes that this proposed framework can not to its full extent be used in today's mobile network infrastructure, when needing information from private mobile smartphones which is not publicly available. Using this methodology in an in-car context to evaluate in-car multimedia would open for the possibility to collect both subjective and objective measurements from the users, and hence seeing the correlation of these measurements and how they interact in different scenarios. This methodology has inspired one of the methods in the next chapter of this thesis, namely the diary studies.

The background information in this chapter is used as a base and inspiration for the further work of this thesis, and the next chapter will present the planned methodology and its reasoning.

Chapter 3
Methodology

The objectives and research questions presented in 1.1 call for several types of research methodologies, as well as integration of insights from several different fields of study. Fields including technological and psychological aspects will demand a compound approach, as the complexity of the context makes it challenging to use only one methodology from one research field. Often, the QoE term is used in conjunction with video streaming and hence focusing on performance-related parameters [Lar21]. In this thesis, QoE evaluation methods need to go further than only looking at system-related and performance-related parameters in order to gain needed insights from user perspectives. The different research fields call for a mixed methods design, to be able to obtain a holistic view and as many high-quality insights as possible. This is performed by combining and conducting various user studies along with including experts in the field.

This chapter will start by presenting the different research approaches that have been used, including the mixed methods approach. It will also share a note on ethics and privacy concerns, in conjunction with an explanation of the literature study. Following, the tools used to perform the different empirical studies and methodological operationalization are presented and explained for the research methods conducted.

3.1 Mixed methods

Combining qualitative and quantitative research approaches, the mixed methods paradigm is claimed to give deeper insights into complex situations and research issues [Lea17]. Since the context of this research is an important focus, the research would benefit from thoroughly including both qualitative and quantitative methods [Lar21].

3.2 Literature study

A literature review is a good opportunity to make oneself known of state-of-the-art research, also gaining in-depth knowledge of the different research fields contained in the research objectives. In addition, reviewing the literature is necessary to further narrow the scope of the thesis. Some literature was found already in the pre-project [Lar21], and adopted for use into this thesis.

Keywords combined in the search for relevant literature were amongst others: QoE, UX, autonomous cars, self-driving cars, car commuting, multimedia, 5G, 6G, smart vehicles, infotainment, fidelity and acceptance. Also, I consulted the "cited by" function in Google Scholar (forward snowballing) in addition to checking for interesting articles in some papers' reference list (backward snowballing). To better categorize and systematically access the literature, a simple table of papers was created with links to their respective online locations. This made it easier to gather all relevant papers and books, and eliminating some if they seemed excessive. Also, the issue of finding peer reviewed papers addressing the topics worked out relatively fine, excluding some more industry related white papers and research proposals. The studied articles were peer reviewed in recognized journals and/or published at peer-reviewed international conferences, organized by associations such as IEEE and ACM.

3.3 Survey

Creating a survey is a good mechanism to gather a reasonably large amount of data in a quick manner. Also, reaching out to many people is easy having access to social media and the ability to spread the word about the survey in different social groups etc. The motivation for using a questionnaire in this research is to gain understanding of what the users think of the different digital functions in their cars today. This will better the understanding of what is wanted, what is excess and what might not be made use of. Using a survey/questionnaire, the user-related influencing factors might reveal their presence. On the other hand, it is important to note that people might be biased, based on recent negative experiences or observations which could influence the respondent's state of mind during their responding phase. This could result in answers not reflecting their actual overall experience, but only their latest experience [Lea17].

The first research objective presented in Section 1.2 concerns influencing factors of in-car multimedia. Initiating a data gathering process based on feedback from users provides the opportunity to get insight into the user's experiences, hence being valuable for exploring the influencing factors. Their feelings towards and their relation to in-car multimedia, how it is used, why they use it, and what is challenging in this

context, are amongst the topics touched into in the survey. When that is said, it is important to note that collecting data from people's memory could result in being biased. The answers might be reflected from their latest experience, especially if this is a negative experience.

3.3.1 Survey design

The survey consists of questions regarding a wide range of situations within the context of driving cars, presented in Appendix B. It was designed taking into account best practices in questionnaire design [Mor94]. The use of digital services (if present), relationship to new technology, trust in automated functions (if applicable), experience with variations in cellular reception, experience with a few influencing factors, ferry rides, the duration and other characteristics of their usual car rides. Also, open questions concerning suggestions, thoughts and ideas are included to obtain more qualitative answers.

In the start of February 2022, Katrien De Moor held a seminar on the use of surveys and interviews in the master thesis. Here, it was said that using answer categories like *often*, *seldom*, *rarely*, instead of for example *occurrence the last 7 days*, might create biased and more subjective answers, relying more on the human memory rather than straight up facts [De 22]. Nevertheless, I have chosen to use these answer categories in my survey. This is simply because there might be people who do not drive a car too often, but still might have valuable experiences and feedback to report which are valuable for the research purposes of this thesis. With this in mind, I have not limited the target group to the ones who drive often, in case this would result in fewer answers. Furthermore, all questions are tried formulated as neutral as possible, to minimize the risk of "leading on" some of the respondents and hence influencing their answers. For quality assurance and making sure there are no ambiguities or confusing parts of the survey, a beta version was sent to a few chosen pre-test subjects prior to the release. After this, a few adjustments in grammar and explanations was done, and then the survey was rolled out fully.

3.3.2 Recruitment

The target group of this survey consist primarily of people who have obtained their driver's licence. Furthermore, respondents who drive a car to and from work are somewhat preferred, as they will likely be the most experienced and frequent drivers. Furthermore, the sampling strategy used was mainly social media and promotion in several online communities in which the chances were high for the target group to be highly represented. One of them is called *Hva skjer på Gossen?* (English: What is happening at Gossen?), being a local Facebook group for Gossen, an island community being dependent on ferries. The members in this group are especially

relevant for the questions concerning ferries. Also, the survey was accepted into *Tesla Owners Club Norway*, being a group of Tesla owners, which is highly relevant for the questions in the survey regarding automated driving and other automated in-car functionalities. The survey was also shared on my own Facebook wall, in old and current school-groups, and a few friends also kindly shared the post further on their own Facebook wall.

Having all this visibility in social media resulted in approx. 120 respondents in a day. After this, the number stabilized and increased by approx. 1 respondent a day. The survey was admitted to the Tesla-group one week after reaching 138 respondents, resulting in 183 respondents in total when closing the survey. The Tesla-group also contributed to spreading the respondents in terms of where they live. My own social network did naturally recruit respondents mainly from the region I am from and the region I study in, respectively *Møre og Romsdal* and *Trøndelag*. Since the amount of answers was already high just after a week, I chose not to start further follow-ups, reminding people to submit the survey. A large amount of respondents also answered the non-mandatory open questions, which might be a result of me beforehand specifying my gratitude towards the ones who kindly responded to these. The survey was highly concerning qualitative topics, since the goal was to collect influencing factors and the respondent's experiences in several scenarios on the road. Therefore, 183 submissions is an acceptable saturation.

This thesis did not receive allowance for recruitment purposes, and hence a large amount of the survey respondents were people known to me, to my friends or my family. Therefore, the age distribution visualizes the fact that a big part of the respondents are around my age.

3.3.3 Tools

In this subsection, the tools used creating, distributing and analyzing the survey are presented. Also, background information concerning the data analysis will be elaborated.

Nettskjema

The University of Oslo (UiO) provides a web-based survey program called Nettskjema [NS]. This tool is preferred when writing a master's thesis at NTNU, because NTNU has a data processing agreement with Nettskjema [NSN]. This makes it easier to get the survey approved for data gathering by NSD (which will be elaborated later), because Nettskjema is said to be more privacy preserving compared to some of the alternatives. This way, choosing Nettskjema for building the survey generates less hassle overall regarding the NSD application.

SPSS Statistics

For analyzing the survey results, the licensed software Statistical Package for Social Sciences (SPSS) was used. SPSS is a software including graphical interfaces for more easily performing statistical calculations and also has various tools for visualizing the results. The data collected in Nettskjema is downloadable in .sav-format, which is preferable for the SPSS software. After importing the .sav-file into SPSS, it is possible to give the variables more recognizable labels, and also create labels for the variable values, e.g values like *Agree*, *Disagree* as the answer alternatives. This way it is easier to recognize the actual answer alternatives when performing tests and also interpreting the test results with actual words rather than numbers.

To be able to run various tests on the data set, the type of variable must be defined in SPSS, in a column named *Measure*. The type of measure lays the foundation further for which tests may be performed on the variable. The variable types may be put to one of the following three types [Fie09, p. 9].

- *Nominal*, where the categories (answer alternatives) are equivalent, and hence can not be placed in an order, for instance male and female.
- *Ordinal*, in which categories can be ordered, but we do not know much about the specific differences between the categories, e.g "Every day", "Every other day", "Once a week" and so on .
- *Scale*, being integers which scales having a meaningful 0-points. For instance weight, age, height.

Prior to performing the tests, producing *frequency tables* is a helpful method to start with to gain an overview of what the respondents were answering, with percentages and the option to create various charts.

Tests in SPSS Tests in SPSS are used to provoke or explore contexts one might be interested in for the sake of a research project, e.g comparing different respondent groups against each other or seeing a connection between several questions and their respective answers. This is done by SPSS using different calculations on the existing data set, and producing a meaningful or a less meaningful answer.

To introduce the SPSS tests, we begin with explaining some statistical concepts and expressions. The goal of any test is to exclude the chance that the results are based on coincidences and not a significant difference. There are two hypothesises to start with prior to calculating a statistical coherence.

- The *null hypothesis* (H0) is based on the fact that there is no significant difference.
- The *alternative hypothesis* (H1) is the hypothesis to be tested, saying that there actually is a significant difference.

The significance level is usually 0.05. The result is significant if $p < \alpha$. P-value is the obtained result value to be matched against the significance level.

Also, there are two types of errors to possibly occur in a result.

- Type 1 error is where one believes that there is an effect on a sample, when in reality there is no effect. If the significance level is 0.05, there is a 5% chance for a wrongly assumption that there is an effect.
- Type 2 error is where one believes there is no effect, but in reality there is an effect. Type 2 error is the same as accepting the null hypothesis.

Having these concepts sorted out, the types of tests to be performed on the survey data set are the following.

Pearson's Chi-Square test This test is used for checking for dependencies between two categorical variables. The test will compare frequencies with expected values, and finding the probability that the data was only based on coincidences and hence were independent [Fie09, p. 688]. The result of a Pearson's Chi-Square test outputs a contingency table estimating the probability that there is no association between the variables which are involved in the test, this being named the *significance level*. If the p-value is below 0.05, then there is a significant dependency between the two variables. If there is no significance dependency between them, one reason might be that the sample sizes of the two values are too small (too few survey participants in this case) to be able to extract a meaningful dependency. The Chi-square test makes the following assumptions for calculating a result:

- The result is accepted if less than 20% of the expected frequencies in the contingency table are 5 or less, but frequencies above 5 is preferred.
- The test can only be performed where the options in the question are mutually exclusive, being that one respondent may only choose one alternative, and not several of them.

Kruskal-Wallis test The Kruskal-Wallis test is called a non-parametric test, and is used to compare several (more than two) independent (or unrelated) groups. A non-parametric test makes fewer assumptions about the type of data they can be used on [Fie09, p. 540] The test is meant to be performed on ordinal categories. The groups are significantly different if the p-value is less than 0.05, but what remains unknown is between which groups the difference lies. The test is based on ranked data, being that the data will give the lowest value rank 1, the second lowest value will get rank 2, and further on, where for example the option "Disagree" gets rank 1, and "Agree" gets rank 2. Hence, a calculation will be performed where a higher score will be equivalent to a sample where people agree more than disagree. The result of a Kruskal-Wallis test will only be accepted as significantly different if it is significant below 0.05 per number of tests, because doing several comparisons increases the probability of resulting in a *Type 1* error.

The null hypothesis is here that the distribution of all groups in question are equal, and hence the calculation will output the probability, or significance level, that it is true. Hence, if the significance levels is below 0.05, a difference between the groups exists, but *where* it lies is still unknown, in which the Mann-Whitney test can help clarifying.

Mann-Whitney test The Mann-Whitney test is a non-parametric test used to compare two independent groups of ordinal measure, for example binary gender [Fie09, p. 540]. Like Kruskal-Wallis, Mann-Whitney is also based on ranked data, with the concept explained above. For a p-value below 0.05, then the two independent groups are significantly different. To find out exactly where the difference lies, Mann-Whitney can be used in conjunction with Kruskal-Wallis to find the location.

For this thesis, differences based on gender was systematically analyzed using Mann-Whitney testing, since binary gender is split into two independent groups. Gender was combined with questions from all of the main categories in the survey, aiming to investigate whether there is a connection. Examples on questions that the gender variable is combined to in the Mann-Whitney test:

- Easily learning new technology
- Amount of driving
- Use of digital services
- Weather affection
- Use of autopilot
- Use of cruise control

- Types of roads driving more frequently
- Annoyances

In the survey, there was also an option for "Other" in the gender question. Since only 1 person used this option, this contribution was not included in the analysis for simplicity purposes. To exclude the "Other" option prior to importing the data in SPSS, the variable was manipulated in "Compute Variable" where an if-statement made sure to only use Male and Female in the following calculations.

Spearman's correlation coefficient - Rho Spearman's correlation coefficient (ρ or "Rho"), is a non-parametric statistic which requires ordinal data for both of the variables in the test [Fie09, p. 186]. This test works by first ranking the data, and further using Pearson's equation to the ranks [Fie09, p. 180]. For the questions formulated as statements with respective check-boxes on degree of agreement, these variables were tested towards each other and also towards the variable *Age*, using *Spearman's Rho* correlation for ordinal variables. This is located in SPSS under "Analyze" -> "Correlate" -> "Bivariate..". The correlations calculated will be categorized as low or high according to the scale below, given $p < .05$. [Gui50].

- $\rho < .20$: very low
- $.20 < \rho < .40$: low
- $.40 < \rho < .70$: moderate
- $.70 < \rho < .90$: high
- $> .90$: very high

The statistical tests which produced relevant and significant results will be presented in Chapter 4.

Preparing the data set for further analysis To make the data set ready for the tests presented above, some adjustments were made. The respondents had to type their birth year in one of the first questions, and to get an "Age" variable in SPSS, "Compute variable" was used by calculating the result of this year subtracting their birth year. These values can then be used in for example Spearman's Rho tests. To be able to use Chi-Square tests amongst others, age groups are simpler to use and output more meaningful results. Hence, three age groups were created going through "Transform" -> "Recode into Different Variables..", and the following two steps are shown in Figure 3.1 and 3.2. The age groups were chosen to be:

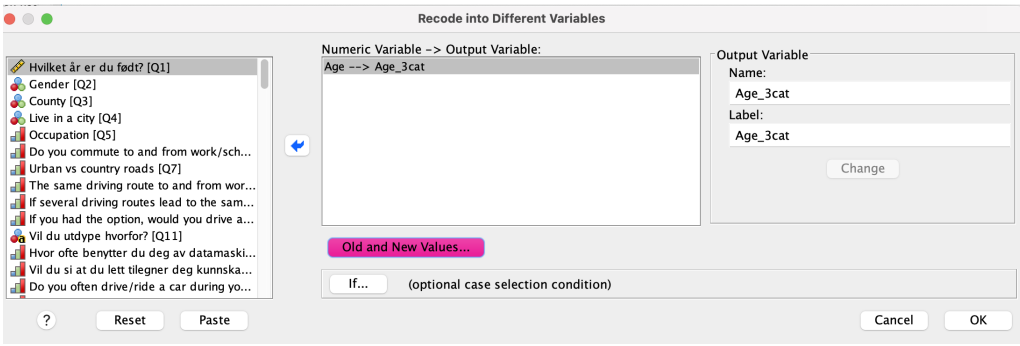

Figure 3.1: "Recode into Different Variables.."

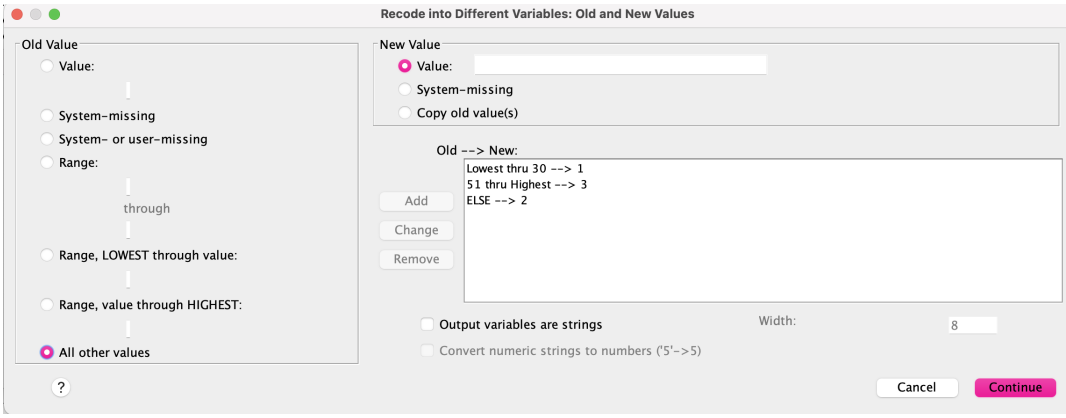

Figure 3.2: "Recode into Different Variables.." -> "Old and New Values"

- Group 1: Up to and including 30
- Group 2: The ones not in Group 1 and Group 3, being 31 through 50
- Group 3: 51 and over

To check whether the age groups are somewhat similar when it comes to frequency, this is checked through "Analyze" -> "Frequencies..", to justify the age selection of the groups. Since the three groups have very similar distributions, it is easier to justify the splitting conditions.

Now, the most important aspects of the survey data and the further processing has been presented. In the following section, the diary study will be elaborated.

3.4 Diary study

Using Section 2.4.4 as inspiration, conducting some sort of living lab study using diary studies in conjunction with measurable parameters would give more insight into how users experience using various in-car multimedia services. In addition, it addresses the potential bias introduced by a cross-sectional survey, namely that the experience is polled at one specific moment in time and heavily based on recall. The diary study consists of using the network speed service *Nettfart.no* prior to and after using some kind of in-car multimedia service, where the inspiration is taken from living labs discussed in Section 2.4.4. *Nettfart* is a service hosted by the *Norwegian Communication Authorities (NKOM)*, which is Norway's administrative authority within electronic communication [NKOM]. The service measures the performance of an Internet connection. These measurements provides the study with objective and quantitative information independent of the user's perception. Furthermore, the users are answering a few simple questions after the two measurements are done, to round off with a user-centric perspective on the overall experience. The questions to be asked look like this:

- Which service were you using? (YouTube, SoMe, Netflix..)
- On a scale from 1-5 (Likert scale) where 5 is the best, how was the overall experience?
- Do you want to elaborate further how the experience was?

These questions will be followed by the use of Nettfart once again (prior and after the multimedia use). The respondents were handed an information letter prior to the study, see Appendix F. The use of Nettfart would eliminate personal information and hence the need to apply for data gathering approval at NSD, in addition to eliminating biased subjective information. There exists more sophisticated applications intended for use in diary studies, for instance the AWARE framework mentioned in Section 2.4.4, but this would trigger a more comprehensive process with NSD, because the third-party application would collect information on the participants. Using this diary study, the thesis will gain more objective data on system-related influencing factors without triggering privacy issues, and also to which extent they affect the user's overall experience of the digital multimedia service.

3.4.1 Tools

Nettfart.no

For measuring download rates and hence seeing variations in these parameters as the days of the study go by, Nettfart is used in the diary study. The browser-version of

the service was recommended for the participants for the sake of more hassle-free data processing, but some of the participants still downloaded the Nettfart-application on their own initiative. The screenshots from the measurements looked like Figure 3.3.

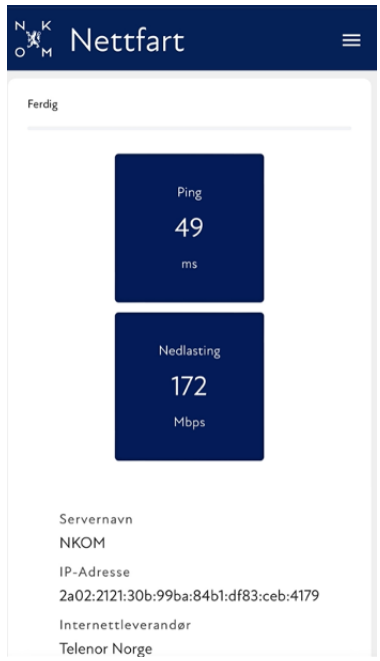

Figure 3.3: A typical Nettfart screenshot.

Nettskjema

For collecting the qualitative (and quantitative) experience-centric information, the survey-tool Nettskjema was used, the same as discussed in Section 3.3. Five surveys were made (one for each day), where the last survey (day 5) included a few more questions including driving habits, passengers and some annoyance statements with inspiration from the user survey in Section 3.3. The diary survey is shown in Appendix E.

SPSS

To be able to extract valuable information and insights from the resulting data set from Nettskjema, SPSS will be used to calculate and visualize findings. Also, measurements from Nettfart.no will be added to the data set to check for correlations between the participant's perceived network quality/experience and measurable network speeds.

Now, moving towards presenting the qualitative interview methodology.

3.5 Interviews

Interviewing both experts and users would gather data and perspectives for the benefit of both the first and second research objectives. Interviewing users will serve as an opportunity to better understand the influencing factors of in-car multimedia use, and interviewing experts will give a valuable insight into their speculations towards autonomous cars and future QoE evaluation methods.

3.5.1 Expert interviews

To be able to get insight into research perspectives and better my understanding in the topic, a few experts who have or have had experience researching QoE were contacted for an interview. These interviews were meant to be a casual conversation, rather than a formal interview. Some questions, topics and guidelines which I wanted to explore during the talk were sent to the interviewees prior to the meeting, and can be seen in Appendix D. The expert's perspectives and thoughts on my research topic is a method to amplify and support the literature review described in Section 3.2, and hence gaining several and diverse sources for answering the research objectives at last.

Because of privacy regulations, an application was sent to NSD in order to be able to cite the experts and present them with their full name in this thesis, if applicable. The interviewees must sign a consent form issued by NSD prior to the start of the interview to give their consent to the following conditions:

- To participate in the interview
- For information about them to be published in a way that they can be recognized

Recruitment

My supervisor, Katrien De Moor, has a great network involving researchers from around the world working in the field of QoE, 5G and others. She has kindly contacted them in order for me to more easily plan individual interviews with every one of them.

Tools

Zoom To carry out the interviews/conversations, Zoom is used as the meeting platform. All of the experts were located in other countries, but Zoom made it easy to meet up virtually and not having to travel. Also, Zoom's calendar/scheduled

meetings functionality made it easier to invite the experts to the meetings and letting them add them in their calendars.

3.5.2 User focus groups

Having user focus groups is a qualitative group based method. From first planning on individual interviews, this turned into user focus groups because of simplicity measures and also the ability to "go further" in discussions, where the thoughts and ideas of other participants might help against getting "stuck" in a mindset. Also, combining participants of different age groups and genders in the same focus groups creates a dynamic prone to interesting discussions and differences in attitudes and habits [Mor94]. The purpose of having user focus groups is to collect further insights and contributions going beyond the survey, also with the opportunity to ask follow-up questions where applicable. It is important to be aware of the fact that people tend to be biased, concerning their current state of mind and latest experiences in the field of the discussion topic [De 22].

Questions

The questions are focusing on the future of in-car multimedia and the users' thoughts towards influencing factors of in-car multimedia, also in autonomous cars especially. These consist of questions regarding habits using in-car digital services, annoyances, attitudes, distractions, acceptance towards autonomous cars and speculations towards more future-oriented traffic scenarios. The questions used in the focus groups are attached in Appendix C.

Recruitment

In the survey presented in Section 3.3, the last question was concerning partitioning in interviews. This way, the ones interested in being contacted for interviews could leave their e-mail address in the answer box.

Tools

Audio recording For transcribing purposes, the interviews were recorded using the recording application on my personal iPhone. These recordings were deleted once they were transcribed into documents using Microsoft Word.

3.6 Ethics and privacy concerns

Ensuring that the gathered data complied with the privacy requirements, an application process with NSD (Norwegian Centre for Research Data) was initiated to gain data gathering approval prior to obtaining respondents for the survey and interviews.

This application demanded to be informed of which personal information would be collected, and also the reasoning of why it was necessary to this research project. NSD found it questionable that the survey voluntarily collected e-mail addresses for the purpose of joining the petition (to win a gift card) and/or volunteering for a further interview, when the respondents could rather contact me if they were interested. My reasoning towards including the e-mail address field was that the threshold for people having to contact me themselves would be too high, and hence would reflect in less people volunteering for interviews. Other changes which had to be made according to NSD was the following:

- At the question about gender, instead of having both *Other* and *Deny to answer*, the two options should be combined.
- In the information letter intended for the respondents (see Appendix), it should be clear that the respondents agree to participation by clicking the link to the survey.
- In the same information letter as above, it should be stated that the University of Oslo obtains access to the collected data via Nettskjema.

The above mentioned methods are then conducted in order to collect valuable results. The results from the methods will be presented in the following chapter.

Chapter 4
Results

In this chapter, the results from the survey, user focus groups, expert interviews and diary study will be presented in their own respective sections.

4.1 Survey

This section will in a thematic manner present the demography of the survey respondents, the quantitative results from the radio button questions and the qualitative results from the open questions.

4.1.1 Survey respondents

The 183 survey respondents are diversely represented with regards to age, gender and domicile. Illustration of the age distribution is given in Figure 4.1. When it comes to the age groups, the frequency percentage of each group is indicated in parentheses in the list below:

- Group 1: Up to and including 30 (33.7%)
- Group 2: The ones not in Group 1 and Group 3, being 31 through 50 (37%)
- Group 3: 51 and over (29.3%)

Furthermore, the gender distribution of the respondents is shown in Figure 4.2, illustrating that;

- 53.3% identify as *Male*,
- 45.7% identify as *Female*, and
- 0.5% identify as *Other*,

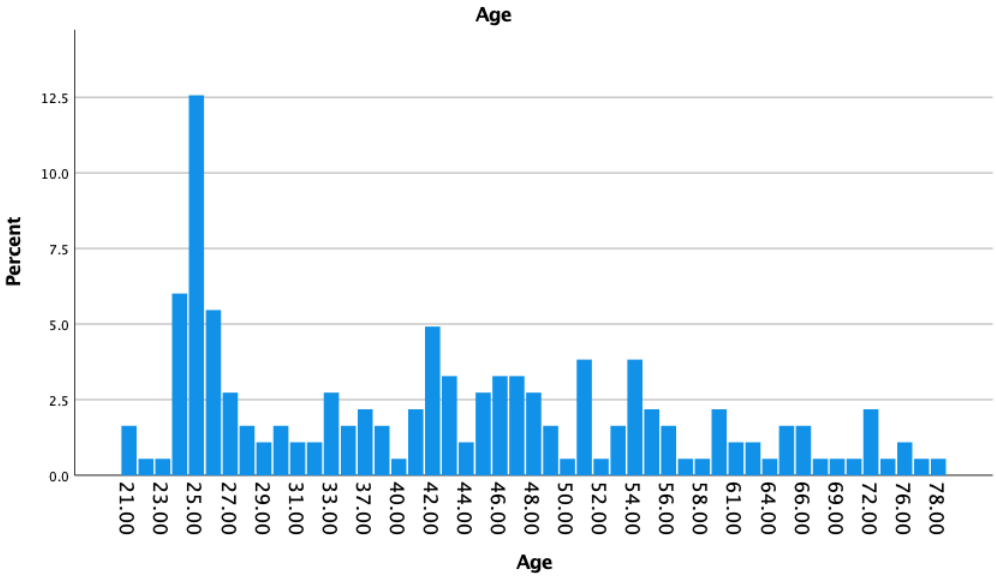

Figure 4.1: Age distribution.

which represents a relatively equal contribution from both binary genders.

When it comes to geographical location within Norway, all Norwegian counties except from *Finnmark* are represented, see Figure 4.4. *Møre og Romsdal* ensures for 53.8% of the respondents, followed by *Trøndelag* with 16.8%. Furthermore, the respondents' occupations are shown in Figure 4.3

To narrow the location down further, the respondents were asked whether or not they live in a city. The response is illustrated in Figure 4.5, showing a relatively even distribution.

4.1.2 Findings

As mentioned in Section 3, this survey was basically incorporated in the thesis to explore especially the first research objective regarding influencing factors for QoE of in-car multimedia today and in more future-oriented scenarios including autonomous cars. This subsection will present the most relevant survey results section-wise, by using both illustrations and specific percentages. Even though there are more significant correlations from the various statistical tests than are mentioned in this section, I will not mention all of them due to lack of relevance for the thesis.

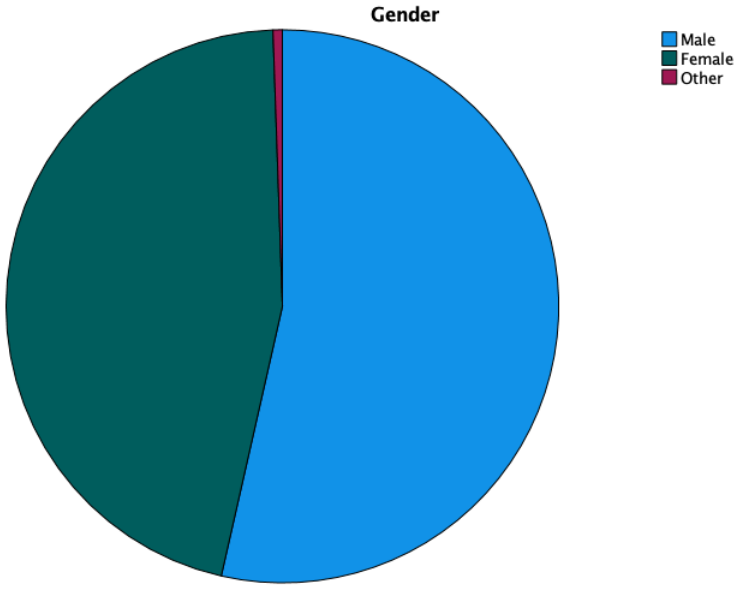

Figure 4.2: Gender distribution.

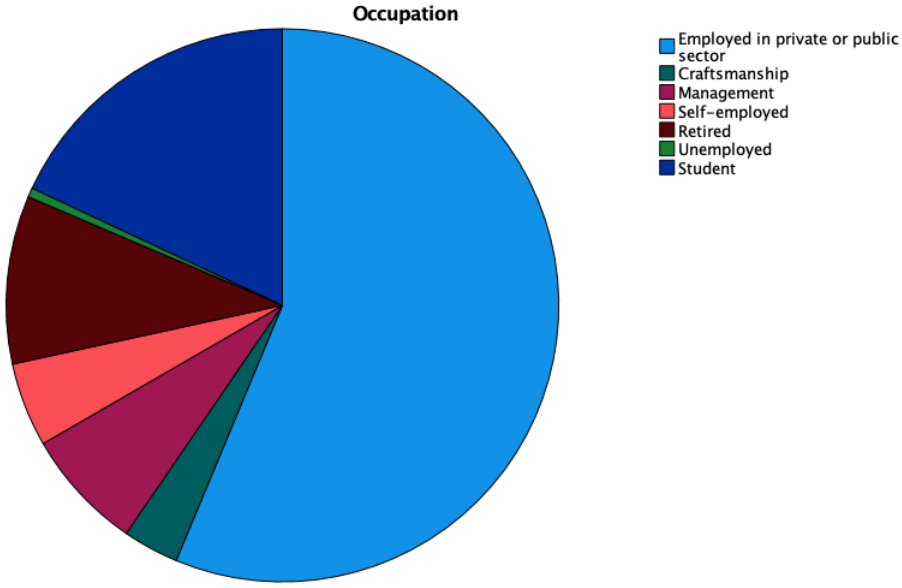

Figure 4.3: Occupation distribution.

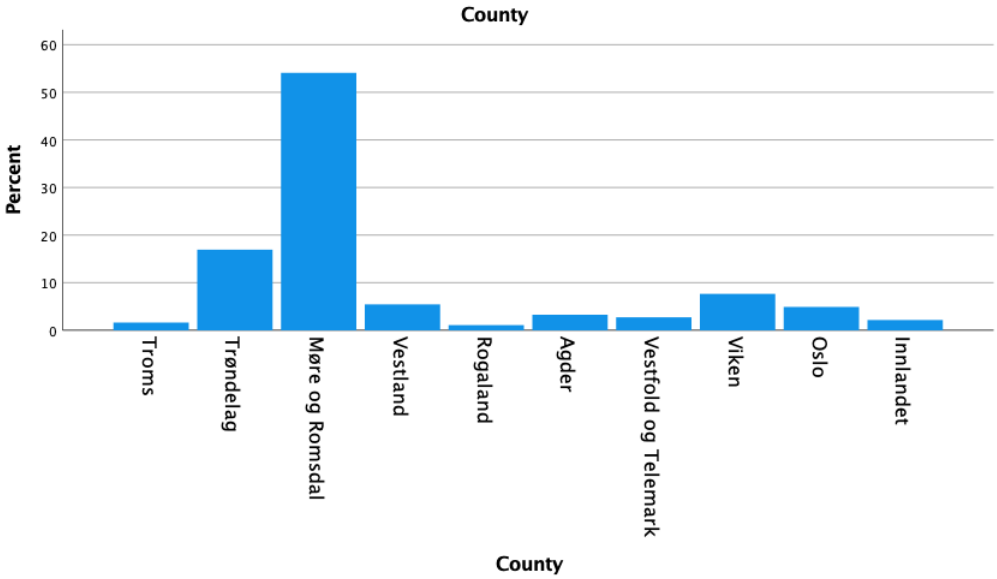

Figure 4.4: County distribution.

Open questions

In the survey, a total of 12 open questions were given to the respondents, where none were mandatory to respond to. In the open questions, the respondents were given a text box and asked to elaborate on situations, attitudes or an example of a scenario that often repeats itself in the cars. The answers were put into an Excel document and were systematically categorized in terms of what kind of common denominator the answers were involving, if any. The influencing factors discussed in Section 2.4.1 were the base of the grouping, respectively user-, system- and context-related influencing factors, and in some cases, their further subcategories. The open questions were all used as follow-up questions in a certain subcategory of the survey, and hence the answers are placed in their respective subcategory in this section. All the open answers are translated from Norwegian to English for the sake of this thesis.

Driving habits

To figure out the appropriateness of the respondents in terms of the survey questions, they were asked if they commute to and from work and hence drive a car approximately every day. The diagram displayed in Figure 4.6 shows the share that commutes to work, and also the duration of their trip one way. A total of 31% commute to work with a duration of 10-19 minutes one way, making up 20-38 minutes per day.

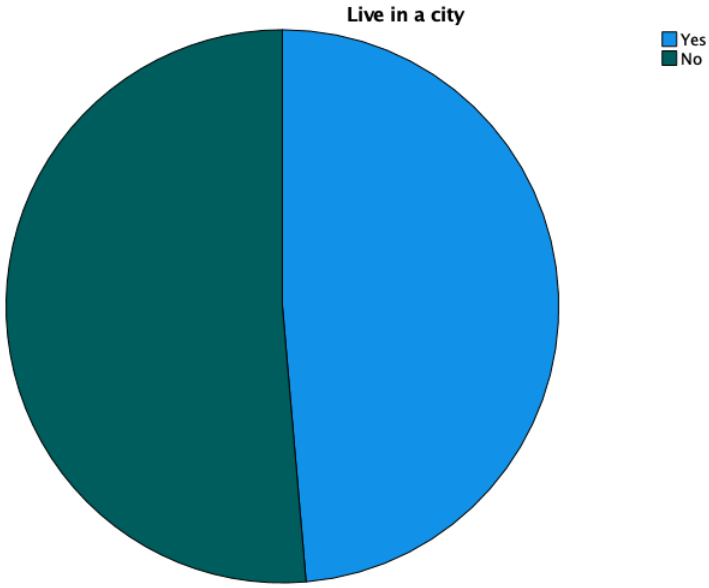

Figure 4.5: City versus district distribution.

Whether or not the respondents choose the same driving route to and from work, is presented in Figure 4.7, where

- 66.7% always choose the same route,
- 30.6% often choose the same route, and
- 2.7% choose a different route.

Regarding different driving routes to and from work, 62.8% answered that if they are given several route options, they will pick the fastest one, see Figure 4.8. Furthermore, 32.2% would pick the comfortable one, and 4.9% would pick the economic one.

If they would like to drive with a colleague or alone, is illustrated by Figure 4.9.

An open question is formulated as *Imagine yourself commuting to work, and you get to choose between driving alone or co-driving with a colleague. What do you choose?*. Some of the answers are presented in Table 4.1, and they are all categorized as context-related factors, and further sub-categorized into social-, economic- or

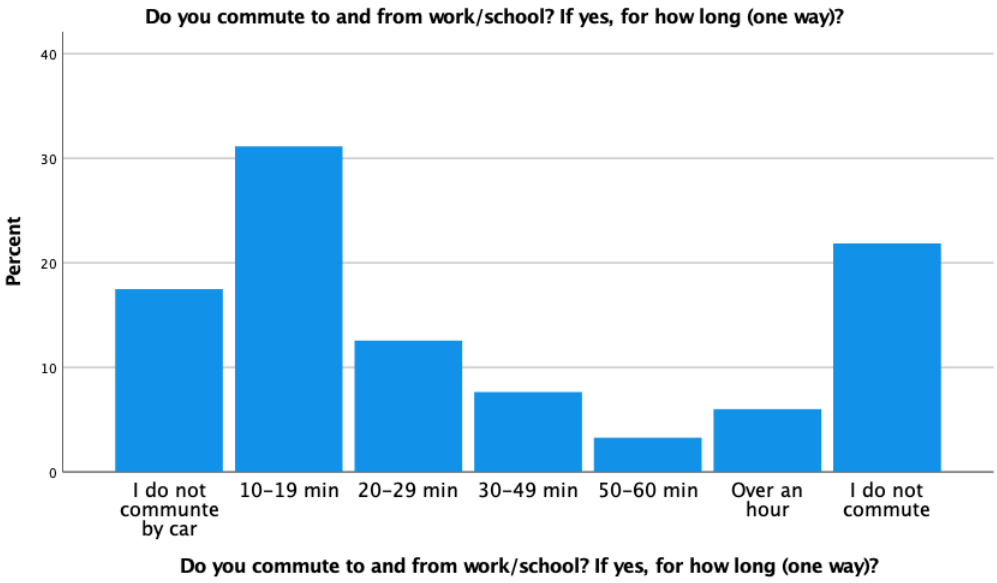

Figure 4.6: Commuting distribution.

temporal factors. Some of the answers are applicable to several subcategories, but are put into the most relevant column.

A question on whether the respondents drive mostly on urban or rural/country roads lead to the distribution shown in Figure 4.10, and has a coherence with whether or not they live in a city.

Attitudes towards technology

To get an understanding of who the respondents are in terms of experience with and relations to technology, a question on this was asked. The answer frequencies are shown in Figure 4.11. A Spearman's Rho correlation was used to check for dependencies between age and attitudes towards technology. A weak, but significant result shows that older people are slightly less comfortable with new technology ($p < .001$, $\rho = .290$).

Digital services

To map which in-car multimedia and generally digital services are most used amongst the respondents, a multiple choice question was presented which included the most basic digital activities to perform in a car (radio, music, podcast, video streaming,

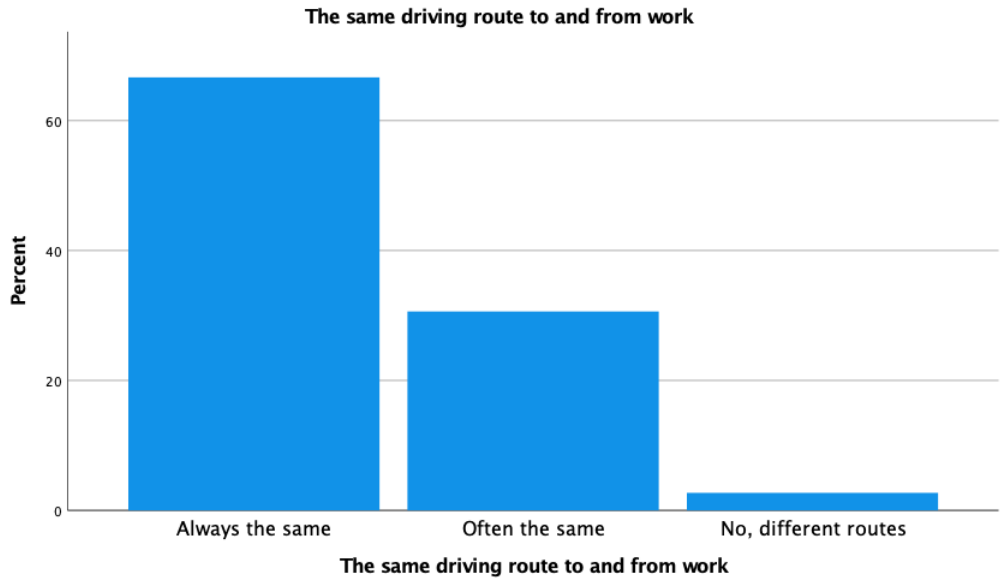

Figure 4.7: Driving route.

phone calls etc.). As a follow-up, a radio button question (only one answer) asked for which of these services the respondents use the most. The answer statistics are shown in Figure 4.12. Most respondents are most often listening to news on the radio (83.1%), followed by listening to music or podcasts (56.8%).

Not surprisingly, a Spearman's Rho correlation test shows that the respondents who listen to news on the radio also listen to music on the radio ($p < .001$, $\rho = .483$). Also, the respondents indicating to use social media in the car, also indicate that they tend to stream video ($p < .001$, $\rho = .524$).

To the open question *What do you mean affects your experience with using digital services in the car, either positively or negatively?*, the answers are categorized into the user-, system- and context-related influencing factors. In Table 4.2, selected answers are presented in one column, followed by their respective category in the subsequent column.

As a follow-up open question, the respondents were also asked to elaborate on a scenario that often repeats itself in the car considering the use of in-car digital services, either used by themselves or used by passengers. A common denominator in several of the answers are scenarios involving passengers scrolling on their smartphones with high volume, or children in the backseat arguing or sitting in silence with headphones

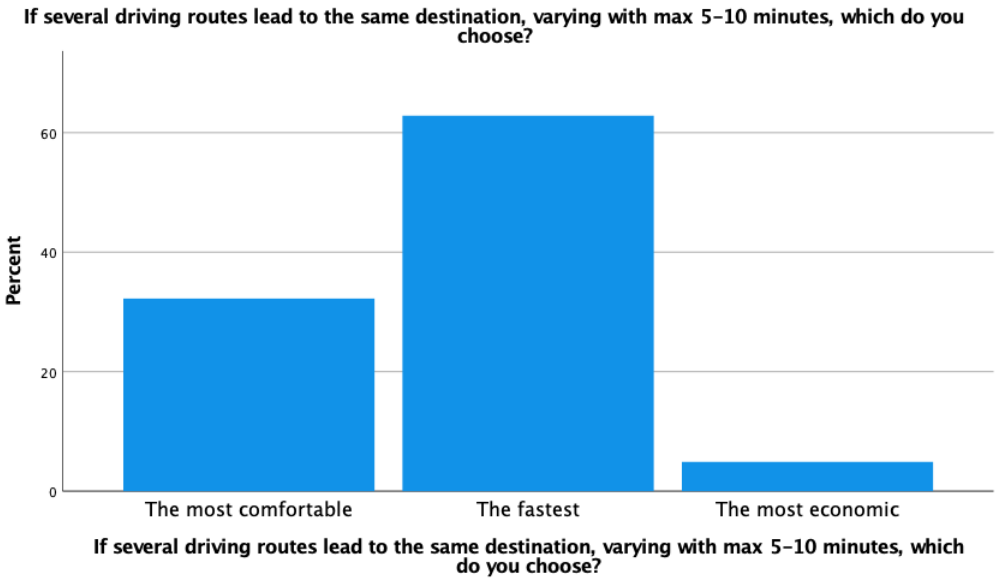

Figure 4.8: Driving route choice.

and tablets. These are both context-related factors, since the context of having passengers changes the experience in some degree. Also, ailments of system-related factors like "The music suddenly stops" are mentioned.

Annoyances

The survey further included seven statements with the headline "Annoyances", where the answer scale for each statement went from "Totally disagree" to "Totally agree". It was only possible to check one of the boxes associated to each statement. The statements are the following:

- **Statements**
  - I am more easily annoyed in the traffic than in the living room.
  - I am a better chauffeur when I drive alone
  - I am easily distracted in the traffic
  - I have experienced to be cut off in the middle of a phone call while sitting in the car
  - I always have just as good cellular reception in the car as in the living room

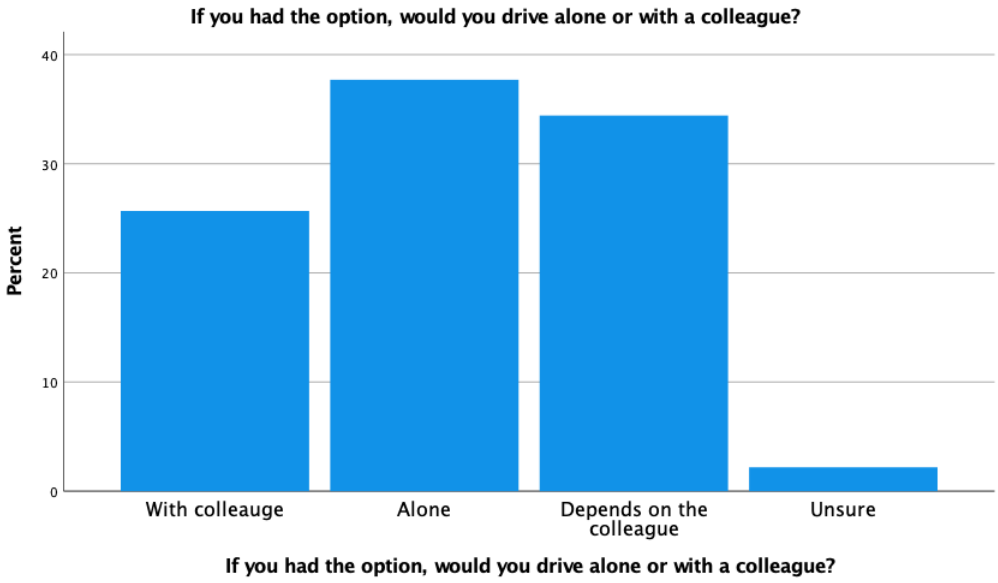

Figure 4.9: Driving alone or with colleague.

- I seldom experience problems with network services in the car
- Weather and driving conditions affect my use of digital services in the car

The answer statistics is presented in Figure 4.14, with the response share in percentages on the x-axis.

To check for dependencies in between the statements, *Spearman's Rho correlation* calculation is used. Firstly, I checked whether there are significant differences in attitude between respondents with different age. Here, it was found that the younger drivers indicate to more quickly become irritated when they are in traffic, compared to older respondents ($p < .001$, $\rho = -.292$). However, the correlation has a small number, hence it is weak.

Another significant attitude difference between different ages, was found in that younger drivers also tend to be more affected by the weather and driving conditions compared to the older respondents ($p < .001$, $\rho = -.260$), although this correlation is weak. A weak correlation is also found in that younger respondents indicate to be more easily distracted in traffic ($p < .001$, $\rho = -.242$). This may relate to the fact that younger respondents also indicate that they are more pleased with driving alone than driving with passengers ($p < .001$, $\rho = -.258$).

Social factor	Temporal factor	Economic factor
If I do not know the colleague well, I would rather listen to podcast/music, and not force a conversation	Alone. I want to be flexible in my everyday life	Yes, to save money
If it is a good friend, sure, but I also like to have me-time in the car in the morning listening to music or podcast	More flexible to drive alone, also more predictable when it comes to time	Yes, mostly economic
I like alone time in the morning	No, I need flexibility in the everyday life	If appropriate, I prefer driving with a colleague because of the economy and environment.
I do not want to talk with someone who is not fun to talk with	I work shifts, making start/end times unpredictable to others	Feels unnecessary to drive alone if one can fill the car up
Yes, if the colleague is fun. If not, I would rather drive alone	I do not want to be dependent of leaving at a specific time slot	Save money
I do not want to talk in the morning	Different work hours	Save time and money
Not every colleague is cool to chat with	I have children in the kindergarten that I need to drop opp, so it is easier to drive alone	Yes, so we can split the costs related to driving

Table 4.1: Subcategorized context-related answers to *Imagine yourself commuting to work, and you get to choose between driving alone or co-driving with a colleague. What do you choose?*

Also, it is found that older people are more likely to indicate that they have just as good cellular reception in the car as in the living room ($p < .001$, $\rho = .275$), with a slightly stronger correlation than the two correlations just above.

To go further with testing respondent's background information towards the survey questions, I am also checking for attitude differences between the binary genders. A Mann-Whitney test found that women (Median: 4.00) indicated to be

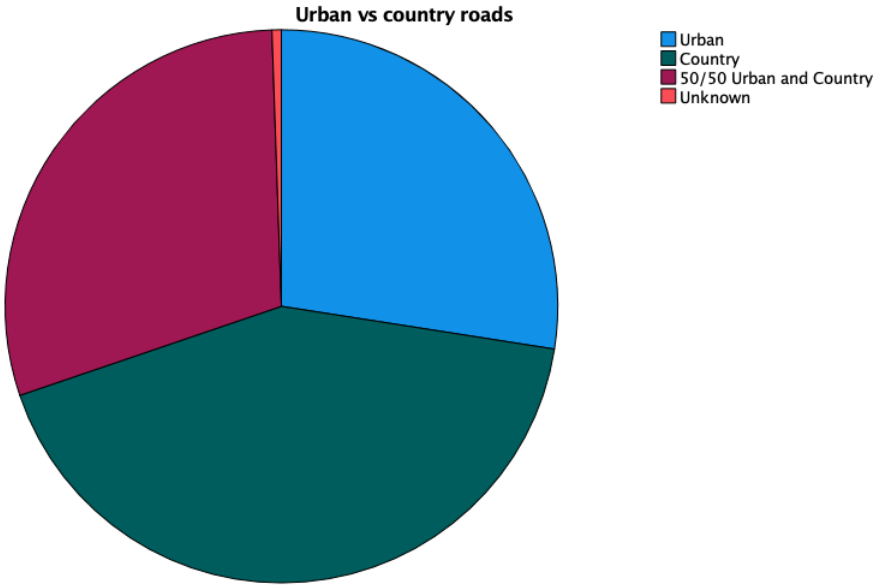

Figure 4.10: Urban versus country roads distribution.

more affected by the weather and driving conditions to a higher degree than man (Median: 3.00), U = 2907.5, p < .001. Also, women (Median: 3.00) indicated to have experienced network disruptions more often than men (Median: 4.00) and this difference is significant (U = 3366.5 , p < .028).

To reveal respondents who did not read the statements well enough prior to answering, two contradictory statements were intentionally included. These were *I always have just as good cellular reception in the car as in the living room* and *I seldom experience problems with network services in the car.* It turned out to be a significant correlation between responses in these two statements, where it is a moderate correlation (p < 001, $\rho = .528$). This result indicates consistency in the responses and rules out randomly checking the boxes.

In the survey section called *Driving habits*, the respondents answered questions regarding their commuting/driving situations. The amount of driving will naturally increase the respondents experiences with network disruptions, annoying situations, fluctuating weather and distractions due to a higher likelihood that these situations might occur. However, there were no notable significant differences in annoyances between the ones who drive often and the ones who do not drive just as often.

A Spearman's Rho test was used to find out if there are correlations between

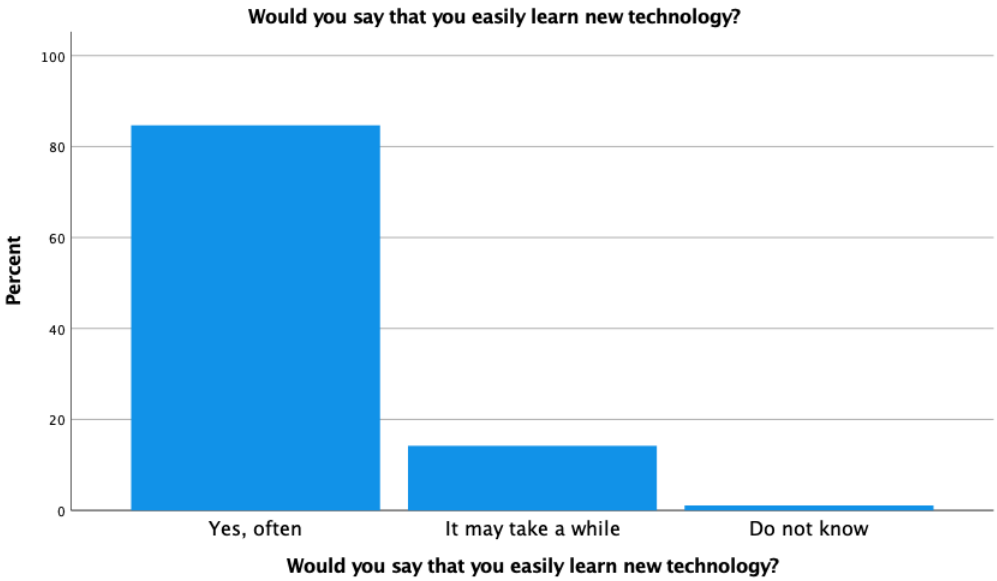

Figure 4.11: Relationship with technology.

stronger indications of annoyance and an increasing amount of passengers. However, no significant correlation was found here.

Ferries

A section concerning ferries is also included in the survey. The questions involved whether the respondents regularly ride a ferry, how they experience digital services and multimedia on board, what they spend time doing while they are on the ferry, amongst other questions. The reason for this section is that cellular reception can often fluctuate on ferry crossings, since they are in the middle of the ocean and far from the infrastructure at some point.

Out of all the respondents, 57.9% indicated that during a normal week, they never ride a ferry. 26.8% ride a ferry 1-2 times per week, 9.3% indicated 3-4 trips, and 5.5% indicated 5-6 trips. See Figure 4.15. The ones who indicated one or more trips per week, were also presented a question regarding how they feel about the general cellular reception on the ferry. The answer statistics is shown in Figure 4.16, where 45.5% of the respondents have indicated that "It happens" that the cellular reception is worse during the crossing.

Furthermore, the activities that the respondents tend to do during the ferry

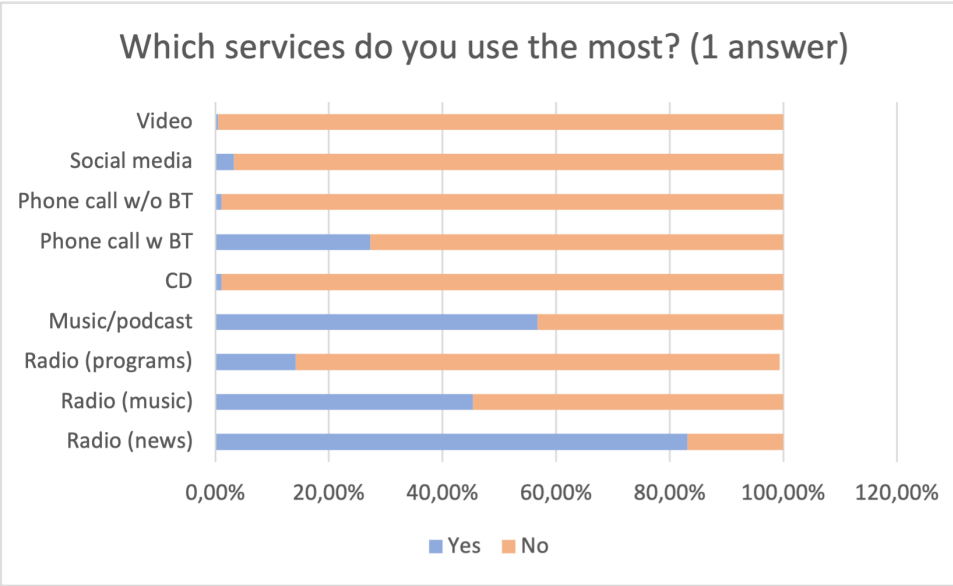

Figure 4.12: Most used in-car digital services.

crossing are presented in Figure 4.17. This question was also only asked to the ones who indicated that they use to take a ferry at least once during a normal week.

A Spearman's Rho test calculated a moderate correlation where the ones using social media during the crossing, also tend to use video streaming ($p < .001$, $\rho = .466$). Also, a moderate correlation is found in that the respondents who sit in the cafeteria also use the WC ($p < .001$, $\rho = .513$).

To check if there was a coherence between the ones riding ferries often, and the ones indicating that they experience network disruptions, a Chi-Square (crosstabs) test was run with no significant results. This is also the outcome when checking for coherence between the ones riding ferries and annoyance statements.

An open question included in the Ferry-section of the survey was formulated *If you have had negative experiences with using digital services during the ferry crossing, could you describe them?*. In Figure 4.18, the left part of the word cloud is where the answers regarding bad cellular reception are located. The right side contains more neutral or positive answers saying that the reception onboard the ferries is good or good enough. This word cloud is a collection of the most frequent answers. There were in total 20 open answers to this question concerning bad reception onboard the ferry, and seven open answers leaning more to the neutral/positive side reporting

Answer	**Influencing factor**
Traffic, weather, sound quality	System + Context
Negatively: When the Bluetooth does not want to work and my phone can not connect to the car	System
Sometimes the podcast I listen to will only work as background noise if the traffic becomes demanding	Context
The mood improves with good music in my ears	User + System
Time moves quicker when listening to podcasts or music	User + System
It is better to listen to music in the car rather than in the living room	Context
I am more focused when driving, rather than in my living room, because I am busy with other stuff when I am in my living room and do not have the same attention and focus to listen to a good podcast. So, it is a positive experience to listen to podcast in the car. I do not listen to podcasts at home, because I do not live alone	User
Peace and quiet	User
Stressful to be dependent on the phone to switch songs etc., it removes the focus away from the traffic which should be consuming all your attention	System
Negatively: When the Bluetooth does not want to work and my phone can not connect to the car	System

Table 4.2: Answers to *What do you mean affects your experience with using digital services in the car, either positively or negatively?* categorized into user-, system- or context-related influencing factors.

no disturbance during the ferry crossing. Two respondents reported disturbance or problems with Bluetooth connections, where the car stereo wants to connect to another passenger's phone or vice versa.

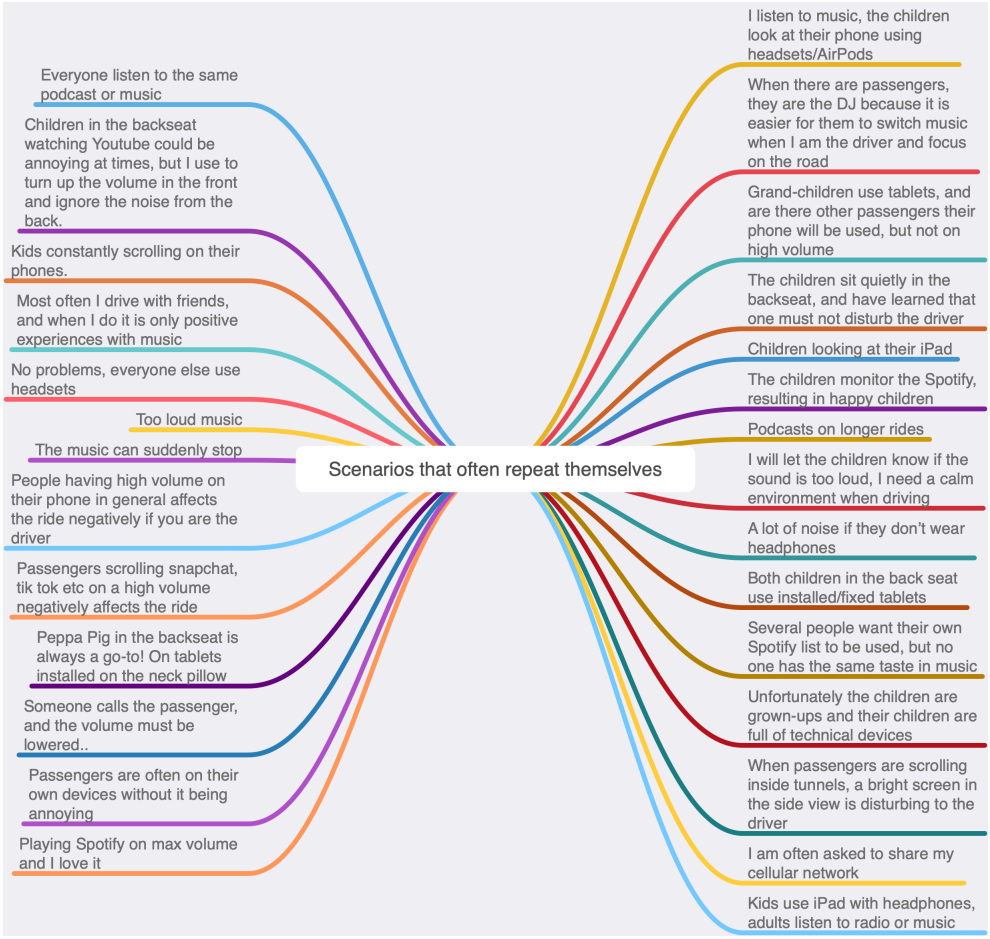

Figure 4.13: Scenarios that often repeat themselves amongst the respondents.

In-car touch screens

Moving on to in-car touch screens, which are a common feature in newer cars. The survey included questions concerning the use of these touch screens, and eventual annoyances associated with the use. In Figure 4.19, the chart presents that 63.4% of the respondents are having a touch screen in the car. Furthermore, the respondents answering "Yes" were asked what they normally use the touch screen for. The resulting distribution with percentages is shown in Figure 4.20, where 60.1% tend to use radio and/or music.

The respondents were also given 8 statements where the answer alternatives for

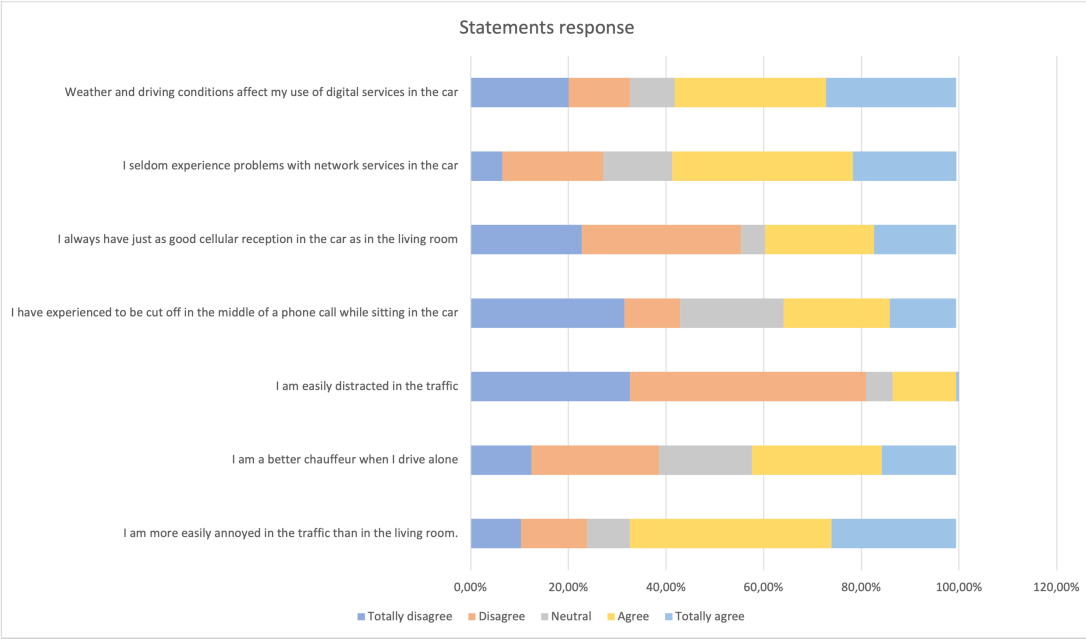

Figure 4.14: Annoyance-statements response distribution.

all of them went from "Totally agree" to "Totally disagree". The statements are listed below, and a chart presenting the results is shown in Figure 4.21.

- It is annoying that my hand moves during the drive, and not the screen
- The screen eases my drive
- The screen does not always react when I want it to
- I try to not use the screen during the drive, but I sometimes do it
- The screen disturbs my driving
- The screen makes it easy to set preferences for music, climate etc.
- The screen has a reasonable size
- I have not experienced something unpractical with the screen

Using a Pearson's Chi-Square (χ^2) test, various variables (see Table 4.3) were tested against the respondents share with touch screens. The results all came out insignificant.

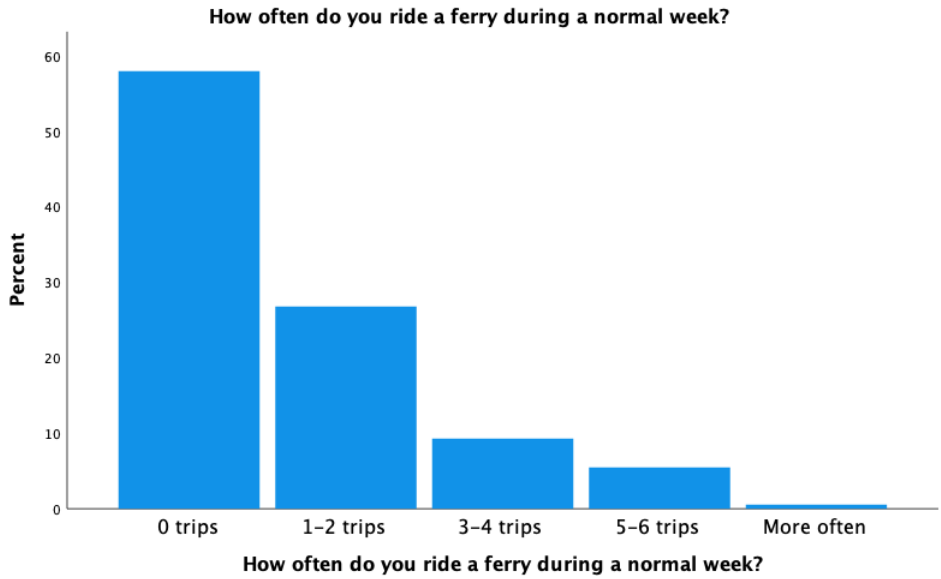

Figure 4.15: Ferry trips per week.

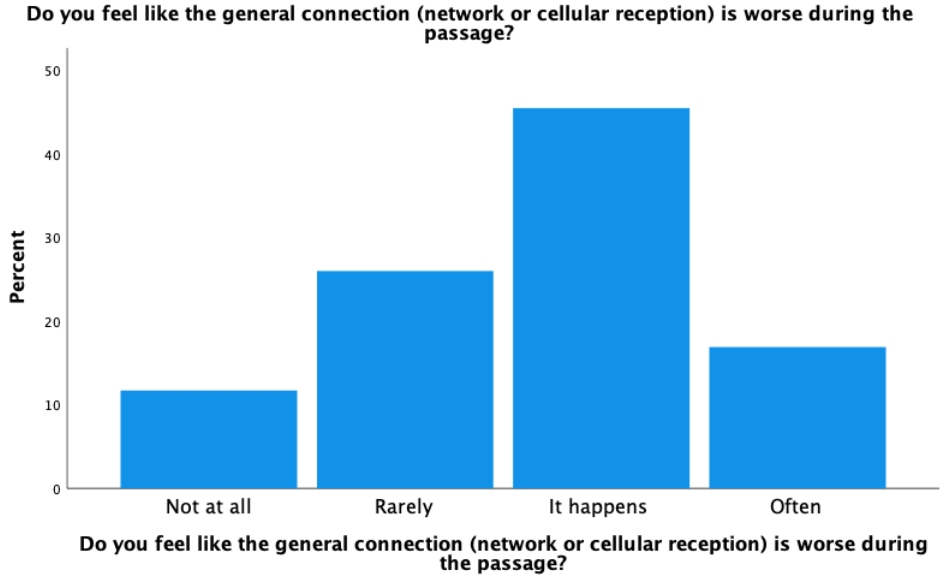

Figure 4.16: How the respondents feel about the cellular reception on the ferry.

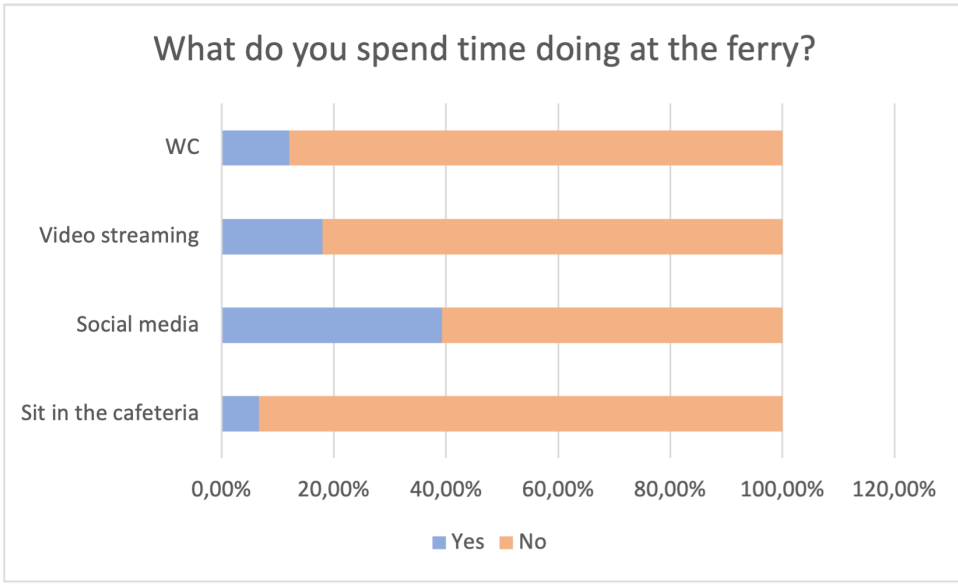

Figure 4.17: Activities on the ferry

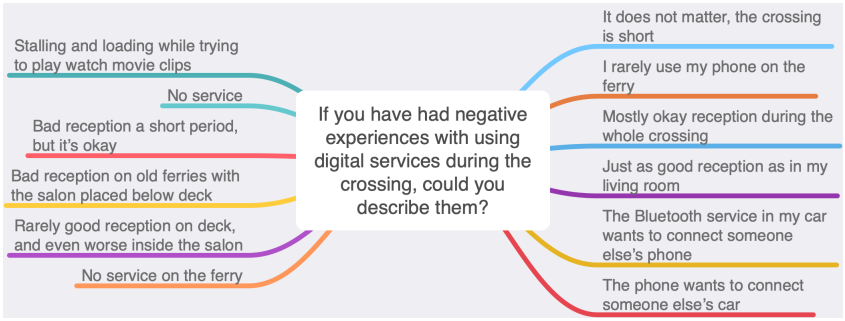

Figure 4.18: Answers to *If you have had negative experiences with using digital services during the ferry crossing, could you describe them?*

An open question formulated *Is there anything else you find annoying with integrated applications (on touch screen) in your car?* was also asked to the ones indicating that they have a touch screen in the car. 18 respondents answered something equal to "Nothing annoying", while the other 17 responses were the ones presented in Figure 4.22, or answers similar to these.

Also, an open question formulated *Are there any integrated services you miss in the car, which could have done your everyday easier or smoother?* received a few

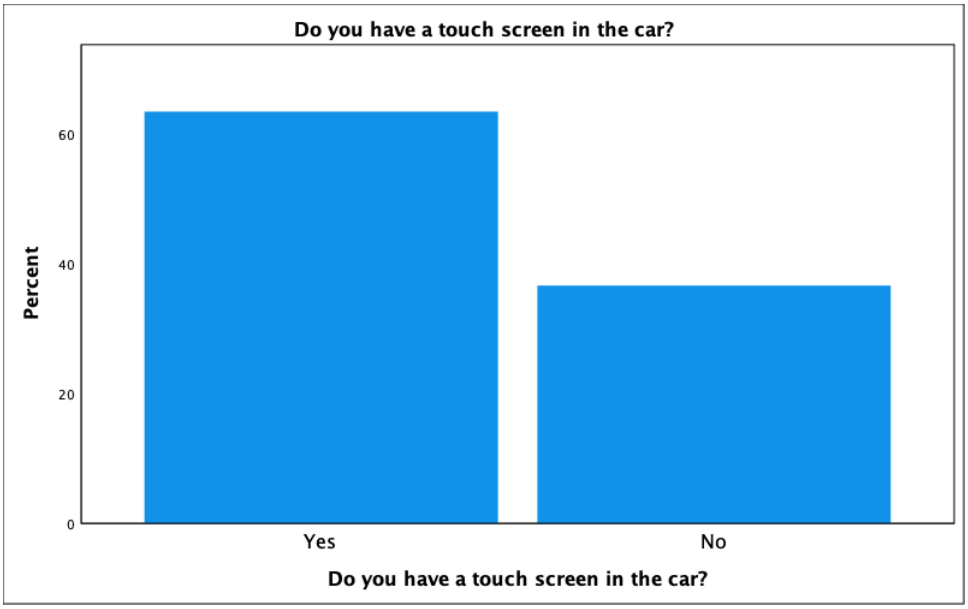

Figure 4.19: Share of respondents having touch screens in the car.

Variables tested	**Result**
Do you have a touch screen in your car? + I am more annoyed in the car than I am in the living room	Insignificant
Do you have a touch screen in your car? + Would you say that you easily learn new technology?	Insignificant
Do you have a touch screen in your car? + Do you often use cruise control?	Insignificant
Do you have a touch screen in your car? + Have you tried autopilot?	Insignificant
Do you have a touch screen in your car? + Age	Insignificant
Do you have a touch screen in your car? + Gender	Insignificant

Table 4.3: Variables tested with a χ^2 test.

answers, amongst:

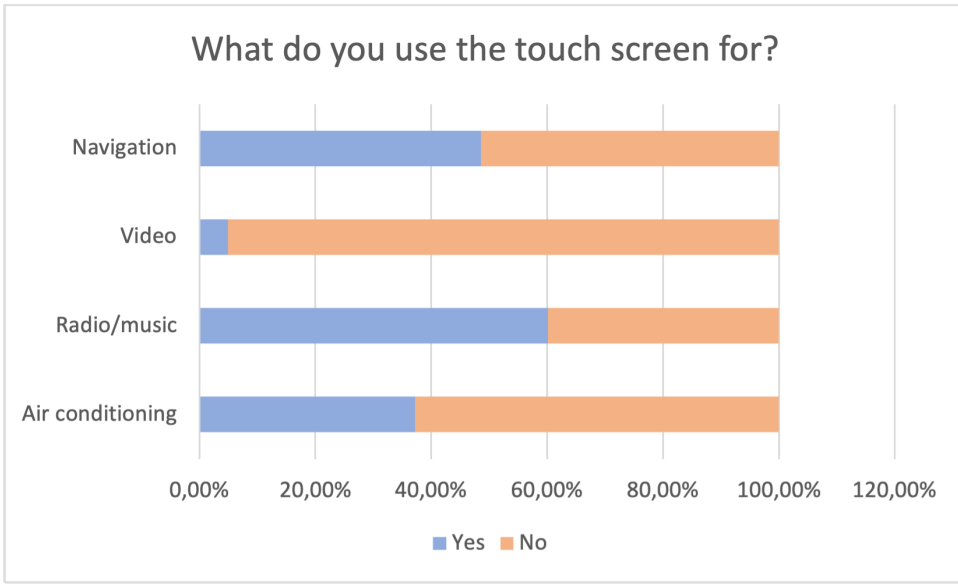

Figure 4.20: What respondents use their touch screen for.

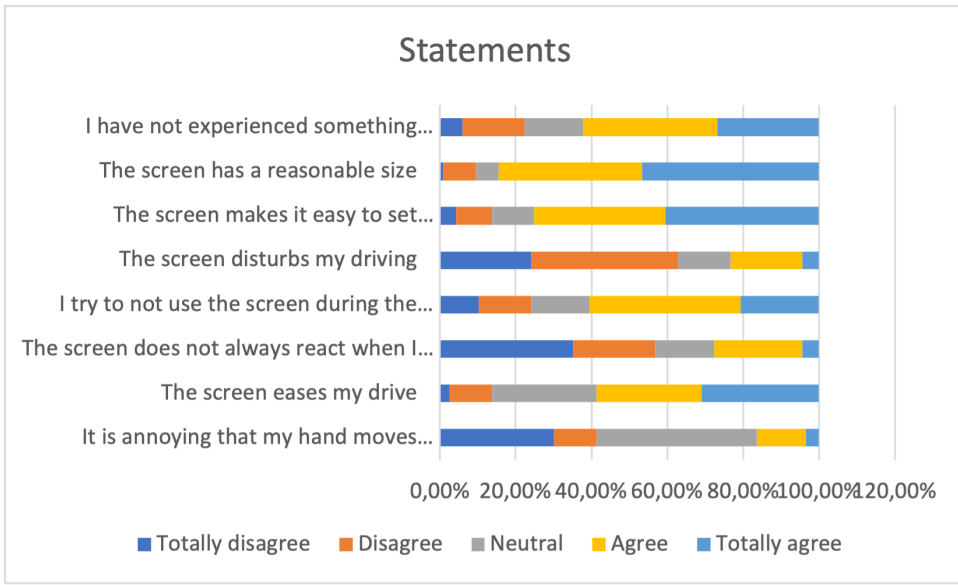

Figure 4.21: Statements regarding touch screen.

Figure 4.22: Annoyances related to in-car touch screens.

- Better route planning and guiding
- Massage in the seat
- Better buttons on the steering wheel
- Heating in the windshield wipers, for the snowy days
- Better voice recognition
- Video conferences
- Better speech assistant and possibility to customize buttons
- Queue alerts and de-tours in case of accidents
- Using Android Auto via Bluetooth, and not USB cable

Speech assistants

Cars with more advanced features like touch screens, often also have some kind of speech assistant either integrated or via Apple CarPlay, Android Auto or similar software. The survey contained a question on whether or not the respondents have access to - and if they use - speech assistants in their car, and the ones indicating that they have/use it were also asked in which situations they typically use it. The

answer distribution of the first mentioned question is shown in Figure 4.23. Out of all the respondents, 25.1% indicated that they do not have it in their car, 19.7% answered "It happens", and 6% answered that they often use it.

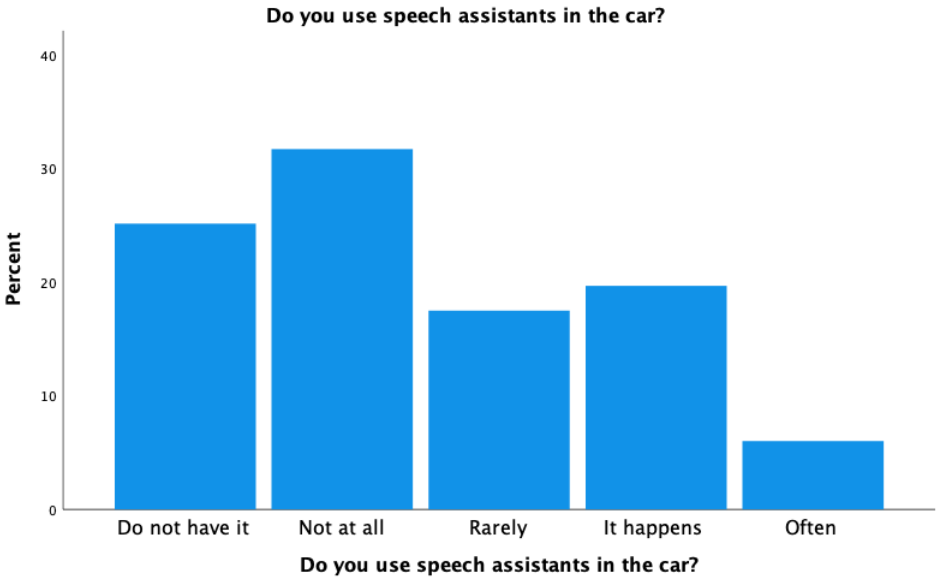

Figure 4.23: Speech assistant.

It is interesting to check the relationship between age and the use of speech assistants. A χ^2-test on the three age groups and the use of speech assistant, found that 38.9% of the respondents in G3 answered "It happens", while 44.4% of the respondents in G2 answered the same ($p < .018$, $\chi^2 = 18.535$). The result is significant.

The respondents who indicate that they use speech assistants were also presented an open question asking them to elaborate in which situations they use the speech assistant in the car. This question received 47 open answers, where the content of the answers included one or several of the following services.

- Calling someone: 46.8%
- Navigation commands: 21.3%
- Stereo/music adjustments: 21.3%
- Sending text messages: 21.3%

- Clock (countdown): 12.7%
- Air conditioning adjustments: 4.2%
- Change Bluetooth-source: 10.6%

Navigation

Integrated navigation systems is widespread in modern cars. The respondents were asked if they use some sort of navigation system in the car - either integrated in the car's software or by holding/looking at the smartphone screen. The answer distribution is shown in Figure 4.24. A Mann-Whitney test was run to check for dependencies between age groups, gender and the use of navigation, but the result came out insignificant.

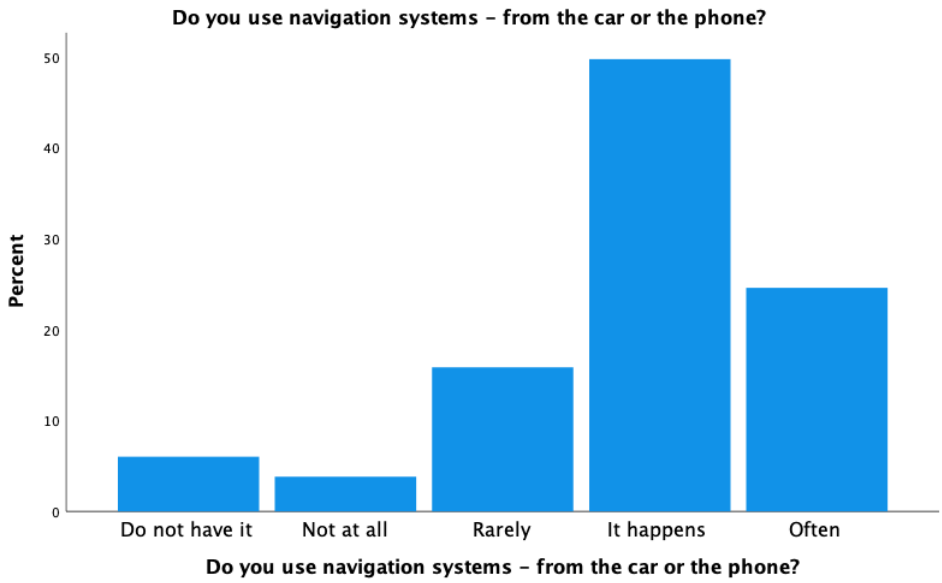

Figure 4.24: Navigation.

Cruise control

Newer cars are also often equipped with cruise control, and hence a question concerning this was also included in the survey. In Figure 4.25, the answer distribution is presented and shows that 46.2% of the respondents indicated that they often use cruise control.

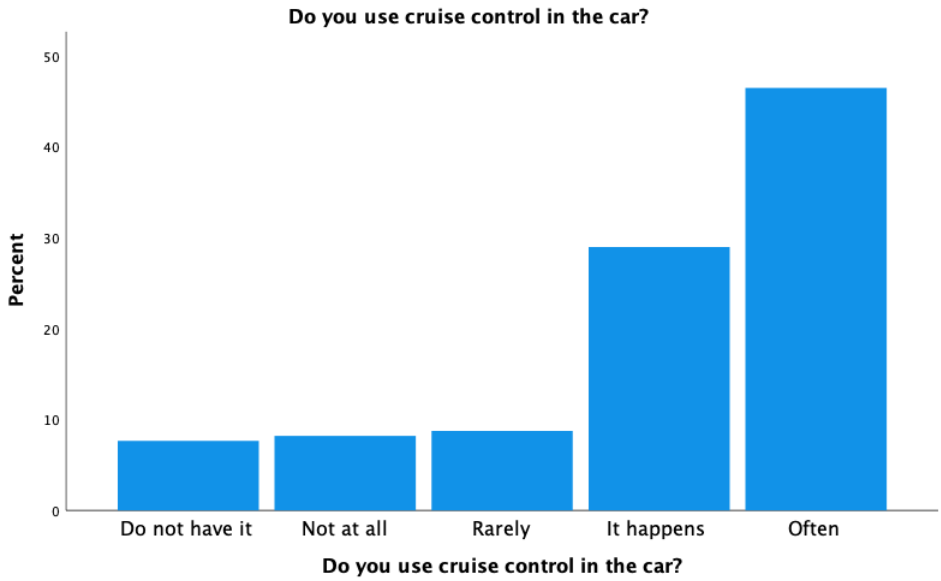

Figure 4.25: Cruise control.

A follow-up question regarding the use of active cruise control was also asked to the ones having cruise control in their cars. Out of the ones who has cruise control in their car, 42.2% indicated that they often use active cruise control, and 30.5% indicated that they do not have it. The answer distribution is seen in Figure 4.26.

Also here a Mann-Whitney test was used to find out if there were dependencies between age groups and the use of cruise control, but the results were insignificant and hence there was no obvious dependencies to find in the sample size of this survey.

Autopilot

Moving a step forward from active cruise control is the autopilot function that an increasing number of modern cars are equipped with. Out of all the respondents, 27.3% indicated that they have autopilot functionality in their car. Furthermore, 90% of the ones that answered "Yes", have used the functionality. These where then asked how they think this functionality works, and the answers with their respective response shares are given in Figure 4.27. Out of all the respondents who have and have tried autopilot, 37.8% think that autopilot works okay.

All respondents - regardless of whether or not they have autopilot functionality in their car - were asked what they could imagine themselves spend time doing if

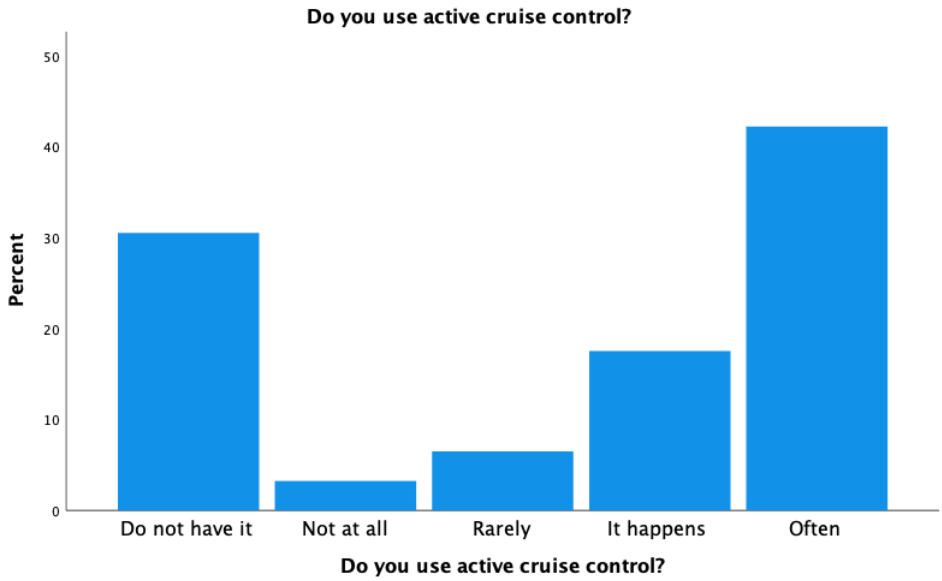

Figure 4.26: Active cruise control.

autopilot did not demand their hands on the wheel, hence being an autonomous car. The answer alternatives were the following:

- Social Media
- Music, podcast or audio books
- Work tasks
- TV or movie
- Sleeping
- Meditating
- Reading
- Observing the traffic outside the car

The answer frequency of each activity is presented in Figure 4.28. The highest "Yes"-percentage is seen in "Observing the outside traffic" with 19.7%.

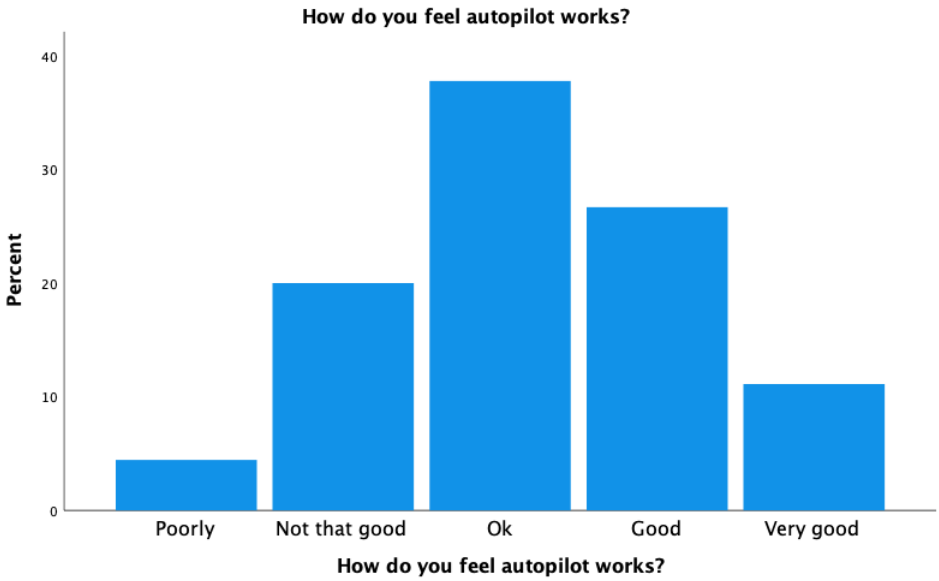

Figure 4.27: Autopilot functionality.

A Spearman's Rho test is used to check for dependencies and correlations between these activities and also the age of the respondents. The test revealed that there is a very low, but significant correlation between younger aged respondents and the increase in wanting to use social media while riding a car with autopilot ($p = .016$, $\rho = -.178$). Also, there are moderate correlations between the respondents who checked both boxes for the following answer alternatives:

- Listening to music/podcast + Watching TV/movie ($p < .001$, $\rho = .642$)
- Using social media + Working ($p < .001$, $\rho = .595$)
- Using social media + Watching TV/movie ($p < .001$, $\rho = .596$)
- Using social media + Sleeping ($p < .001$, $\rho = .541$)
- Watching TV/movie + Working ($p < .001$, $\rho = .561$)

The respondent group which had autopilot as a functionality in their cars, but have not tried it, were asked a question of what the particular reason for this is. The answer distribution is seen in Figure 4.29. The distributions of the questions show

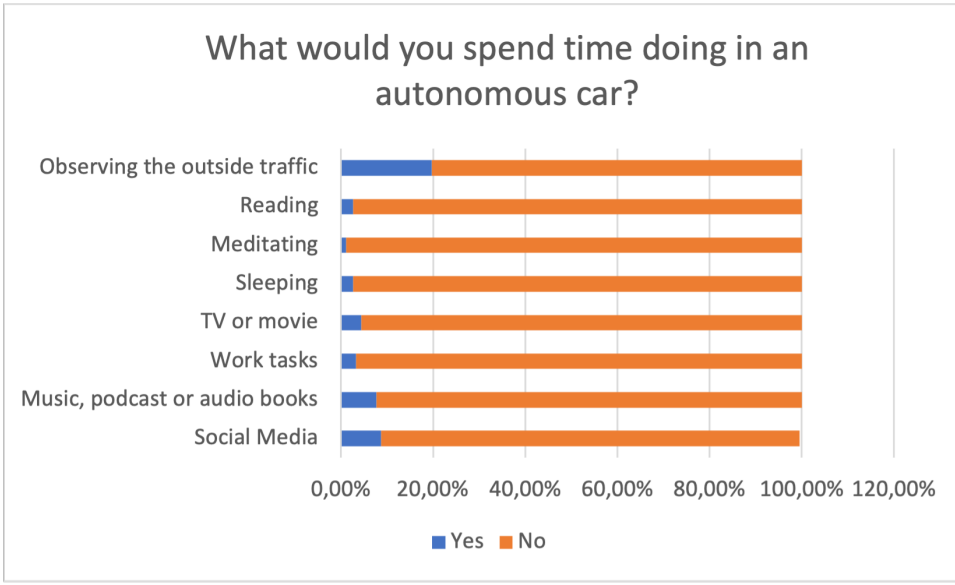

Figure 4.28: Activities during autopilot.

signs of a small respondent group, since several of the answer alternatives have a 100% "No"-answer share.

The respondents who answered "No" to the question on whether they have autopilot in their cars, were asked a follow-up question on whether they *would* use autopilot if they had the chance. The answer distribution is shown in Figure 4.30, where equally 39.1% answered "No" and "Unsure", while only the remaining 21.8% answered "Yes".

Highlights from the survey

- Almost 40% would prefer to drive alone instead of with a colleague, mostly due to flexibility
- Most drivers use the radio as in-car entertainment, followed by music and podcasts
- Younger drivers tend to be more irritated in traffic, more affected by weather changes and also are less excited about having passengers
- Ferry crossings are prone to cellular disruptions

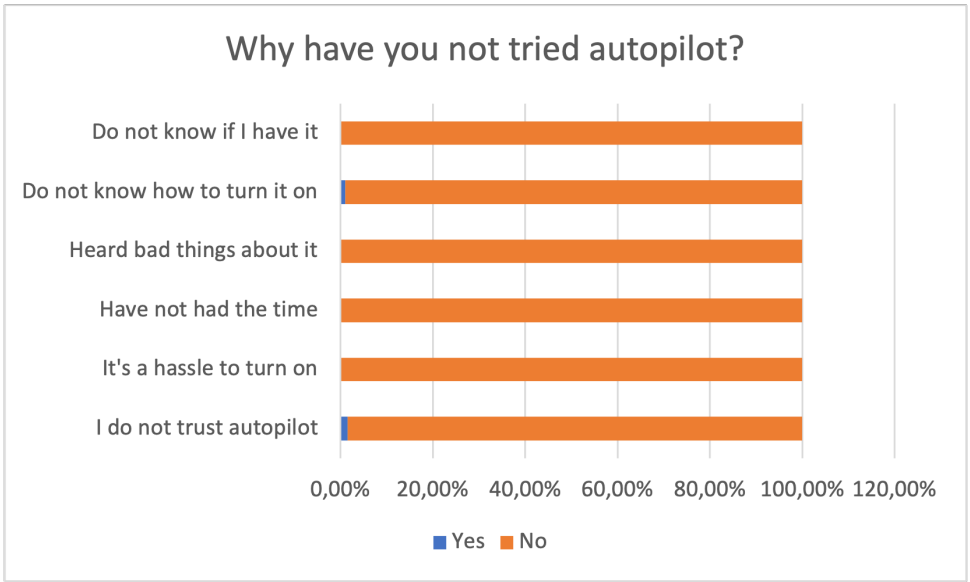

Figure 4.29: Reasons why respondents - who have autopilot in their cars - have not tried it.

- Drivers prefer buttons instead of touch screens for monitoring systems while driving
- All ages and genders are sceptical towards autonomous cars, resulting in that they would not try autopilot if they had it

Now, the most relevant results from the survey are presented, along with some statistical calculations made to explore correlations between answers and respondent groups. To continue, the results from diary study will now be presented.

4.2 Diary study

Prior to the start date of the study, the participants received a guide on how to create a Nettfart bookmark on their phone screen, and were encouraged to do so. This would make it easier to both easily access and to remember the Nettfart measurements. In addition, form of consent was also handed to all of the participants, collecting their consent before the study started. As concluding information, an information letter was handed to them prior to the study, to get a proper overview of their work tasks in the upcoming study. This information letter can be seen in Appendix F.

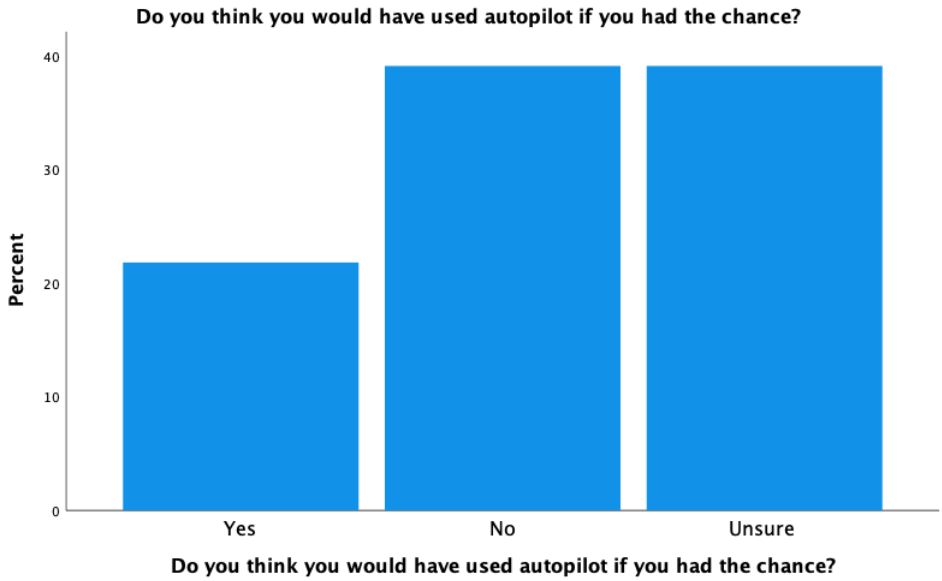

Figure 4.30: Whether the respondents - whom do not have autopilot in their cars - would use autopilot if they had the chance.

Every day of the study, a new questionnaire was sent to them named *Diary day 1 of 5*, counting upwards as the days went. This questionnaire was sent early in the morning, prior to the point where the participants started to commute. They were encouraged to answer this questionnaire as close as possible to the point where the quantitative network measurements were taken, to leave as little responsibility as possible on their own memory and rather have them collect their qualitative point of view when it was fresh. All participants were free to choose which time period of the day they would take measurements from, being to work, from work, going to the grocery shops etc.

The diary studies were brought out in two subsequent weeks, and lasted for five days starting Monday and ending Friday. One participant only handed in four out of the five samples of Nettfart measurements, the reason being that for one of the days no driving was performed. Another participant got infected by COVID-19 during the week, and only handed in two days of measurements. Throughout the study a few reminders were needed, both reminding them to send me measurement screenshots and to answer the following questionnaire if there were some missing. Their first names was the first question, making it easy to keep track of who's contribution was missing by the end of the afternoon.

4.2.1 Diary study participants

There were in total 10 participants in the diary studies, where seven (70%) were female and three (30%) were male, of age ranging from 23 to 52 with the distribution seen in Figure 4.31. They are all living in Norway, scattered around four counties as seen in Figure 4.32.

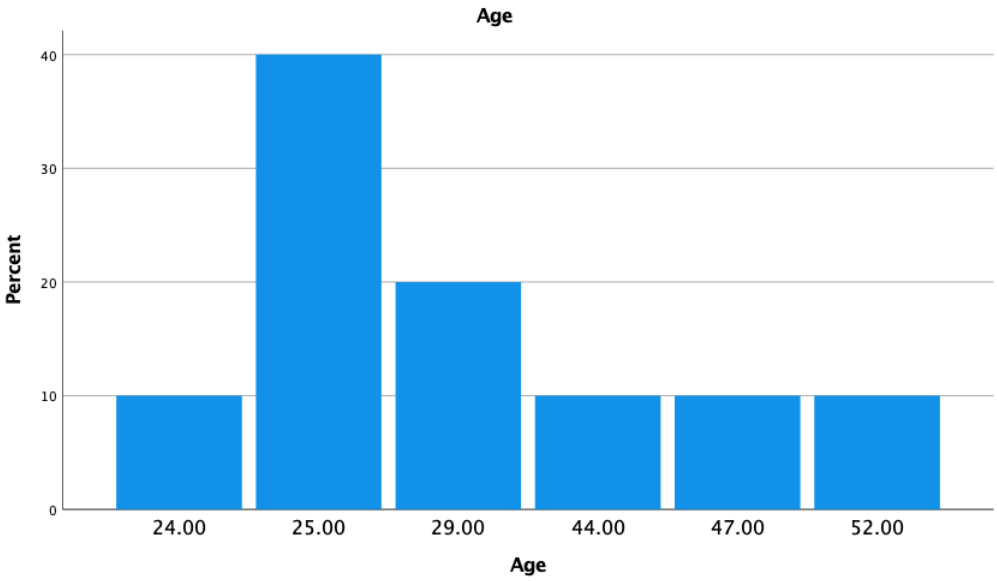

Figure 4.31: Age distribution of diary study participants.

The participants are all commuters to a certain degree, where some are commuters every day, while others work from home some days and commute the other days. The reason for not recruiting older participants is that the ones being relevant for the study (commuting) did never use their mobile phone for digital services for in-car use. It was challenging to find enough respondents whom not only commuted to work or used a car every day, but also performed streaming activities. Several potential candidates that were thought of had to be excluded due to their missing use of streaming-from-phone or built-in network connection (like Apple Car Play or Bluetooth connectivity) in the car.

4.2.2 Findings

The goal of these two iterations of diary studies was to find out to which extent system-related factors like poor or varying cellular reception or network connection does affect the user's perception of quality in the moment of using a digital service

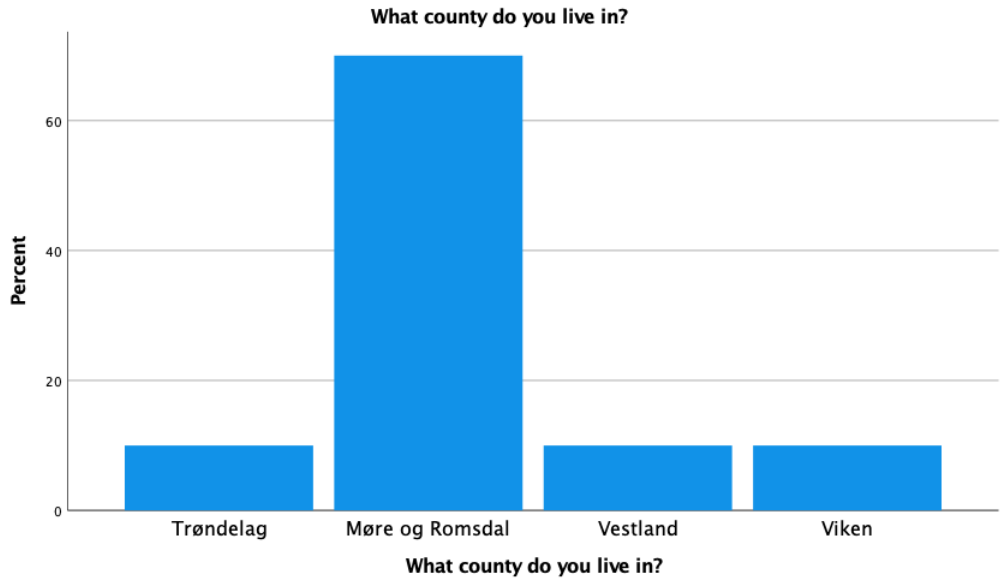

Figure 4.32: County distribution of diary study participants.

in-car. In order to obtain information from the in total five surveys from the diary study, SPSS was used also here. All the data from the surveys are put in the same data set and imported into SPSS.

To get a perspective on for how long the participants drive a car every day, they were asked this question in the last (day 5 of 5) diary survey. The response is seen in Figure 4.33, revealing that the greatest share drives for 21-40 minutes each day (40%), followed by a 30% share driving for 11-20 minutes each day. All respondents also answered that they were driving to or from from every time they completed the diary and took the Nettfart measurements.

Also, the amount of passengers the drivers had during the week could be an influencing factor to the overall perceived quality of the multimedia used. Therefore, a question requested to enter the amount of passengers they usually had during the week. The answer shares are seen in Figure 4.34, where 50% had one passengers once.

To categorize the open question regarding which service the respondents were using in between the Nettfart measurements, a new variable *MediaType* was created. This was a numeric variable, with the following categories.

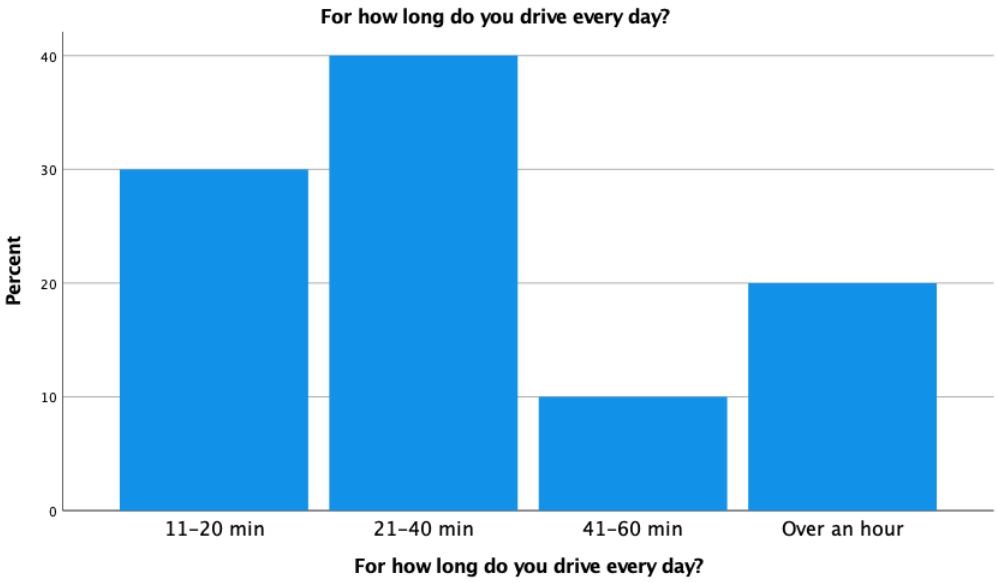

Figure 4.33: Distribution of the participants' time span in the car each day.

- 1: Music streaming (Spotify, podcast..)
- 2: Phone calls
- 3: Social media
- 4: Navigation

To fetch the frequencies of which services were used the most by the participants, SPSS's frequency tool is used. As seen in Figure 4.35, a dominating share is media type one, which is music/podcast streaming, accounting for 87.8% of the instances when looking at all five days as a whole. Phone calls (Type 2) accounts for 6.1%, and social media (Type 3) and navigation (Type 4) for respectively 4.1% and 2%.

Using a Likert scale, the participants were asked to rate their experience with their use of the service of choice. The answer distribution for all five days and for all ten participants (noted as P1 through P10) are seen in Figure 4.36. The scores are overall above the midpoint, with some outliers. There was seemingly little to no disturbance on a daily basis for the car commuters who part-took in the diary studies. This made an overall satisfactory perceived quality for the in total ten participants, being a mean score of 4.73 out of 5.

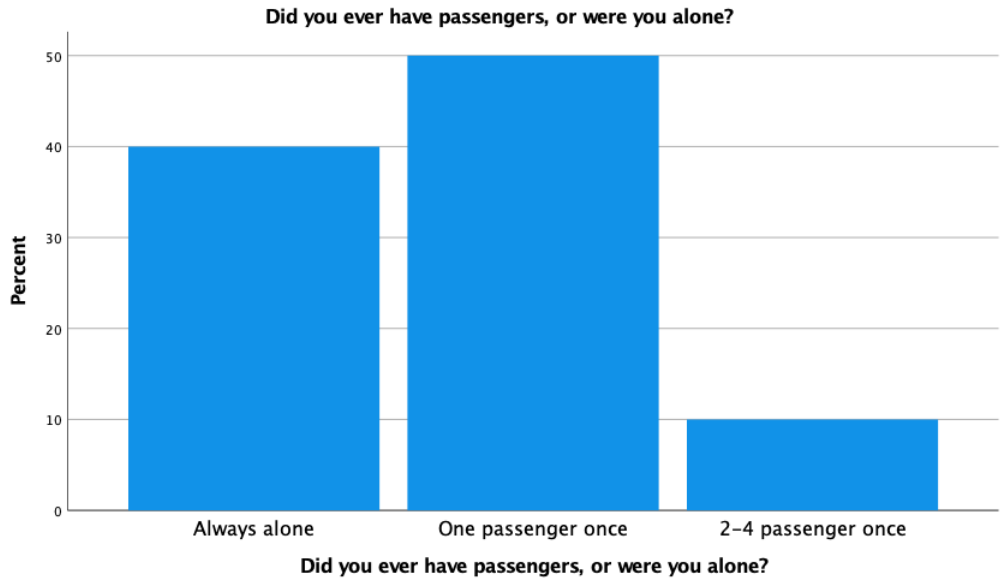

Figure 4.34: Distribution of how many/often the respondents had passengers in the car each day.

In a follow-up question after giving the experience a score from 1 to 5, the respondents were asked to write down the reason for the score in an open question. When the respondents gave a score below 5, the reasons stated were amongst others:

- Bad reception on the ferry
- Could not establish a Bluetooth connection between the phone and car. Resulted in a bad experience when having to use the phone speakers
- The podcast suddenly stopped playing and I had to pick up the phone while driving to monitor it
- It took some time to start the Spotify application

At the last day of the diary study (day five), the survey was a bit more extensive, also including five statements where the respondents were ranking their degree of agreement for each of the statements. The answer distribution is seen in Figure 4.37. Descriptive statistics can tell that the mean values of all statements is quite low, and also the standard deviation is high. This means that the respondents were

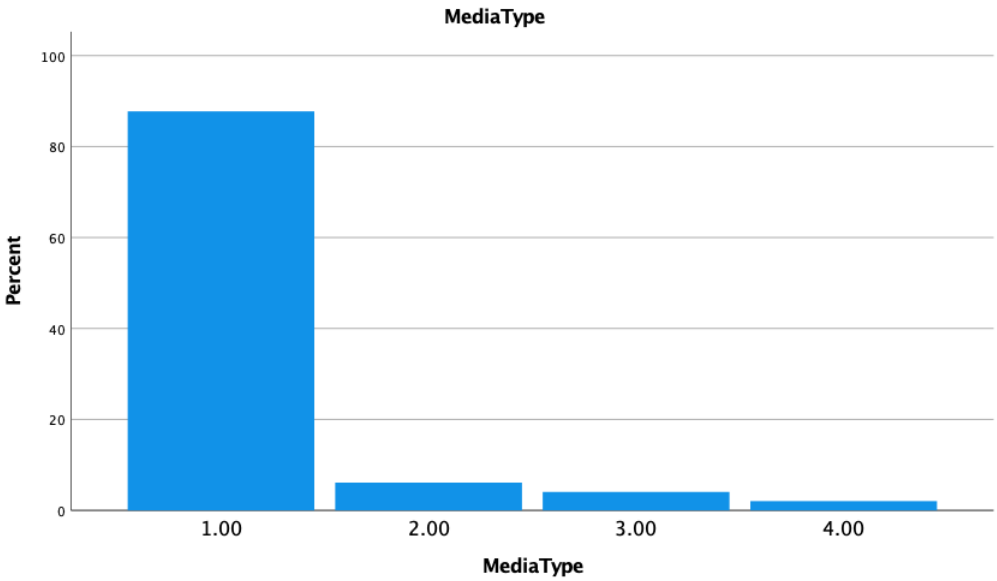

Figure 4.35: Media type distribution.

generally having a good experience, but there are also too few participants to be able to predict their answers, see Figure 4.38.

The Nettfart measurements were meant as a factor of certainty, being able to look at the oscillations in network speed and compare these with the user's perceived network connection and quality. The data from download measurements (measured in Mbps) for each day and each participant were put into the same data set in SPSS as the diary surveys. Since there were two measurements each day (prior and after the use of multimedia), the median of these two measurements was used in the data set to simplify the further calculations. After this variable - *DownloadMeasurements* - was made, a Spearman's Rho correlation test was performed on the measurement data and the perceived experience measurements (Likert scale 1-5). This was meant to check whether the perceived quality increased when the actual download speed increased, and if it decreased when the download speed decreased. This resulted in insignificant results, meaning that in this data set there were no correlations between the two variables.

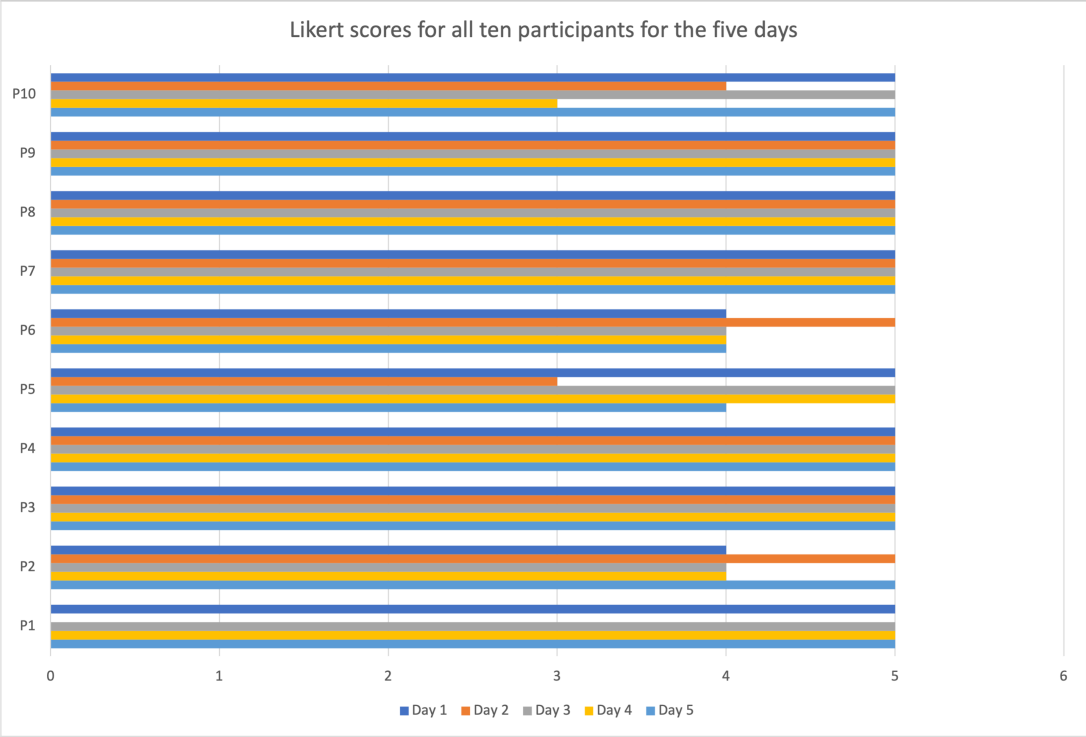

Figure 4.36: Experience-score distribution.

Highlights from the diary study

- Few had passengers during the study
- The dominating service was music/podcast streaming
- Bluetooth connection establishment is a source of annoyance
- No correlation found between subjective quality indication and objective network measurements

In the following section, results from the user focus groups will be presented.

4.3 User focus groups

The focus groups were recruited from my own network, which was because many of the volunteers from the survey respondents were people I already know. Also, focus groups with physical presence were prioritized, which in the end resulted in

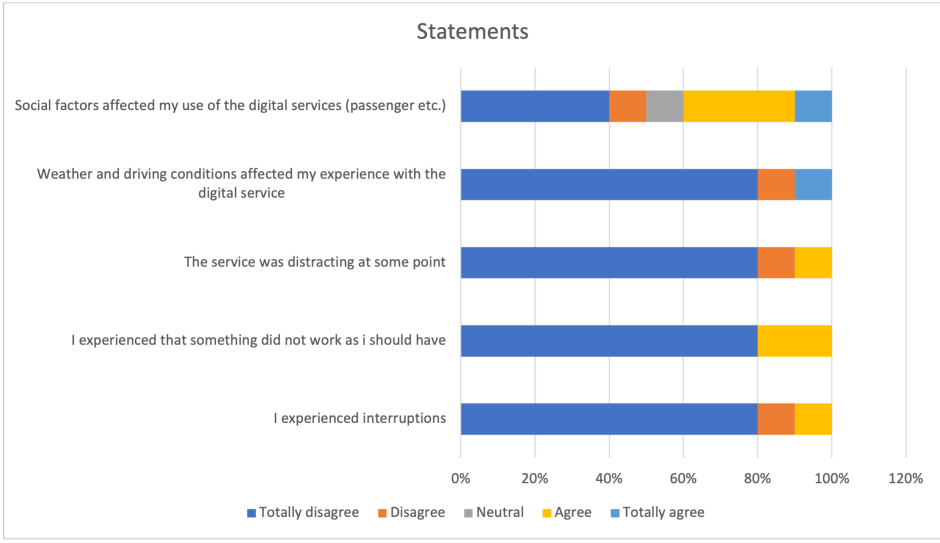

Figure 4.37: Statements distribution.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Statement_I experienced interruptions	10	1	4	1.40	.966
Statement_I experienced that something did not work as i should have	10	1	4	1.60	1.265
Statement_The service was distracting at some point	10	1	4	1.40	.966
Statement_Weather and driving conditions affected my experience with the digital service	10	1	5	1.50	1.269
Statement_Social factors affected my use of the digital services (passenger etc.)	10	1	5	2.60	1.578
Valid N (listwise)	10				

Figure 4.38: Descriptive statistics from Statements.

only physical interviews and none virtual interviews. In this section, the participants' demography and the key findings from all the user focus groups will be presented.

4.3.1 User focus group participants

A total of 12 individuals part-took in the focus groups. The distribution of gender is presented in the following list.

Out of the 12 participants,

- 50% were female, and
- 50% were male.

The represented age groups with their respective frequencies are given in Figure 4.39, showing that 50% of the participants are in their twenties.

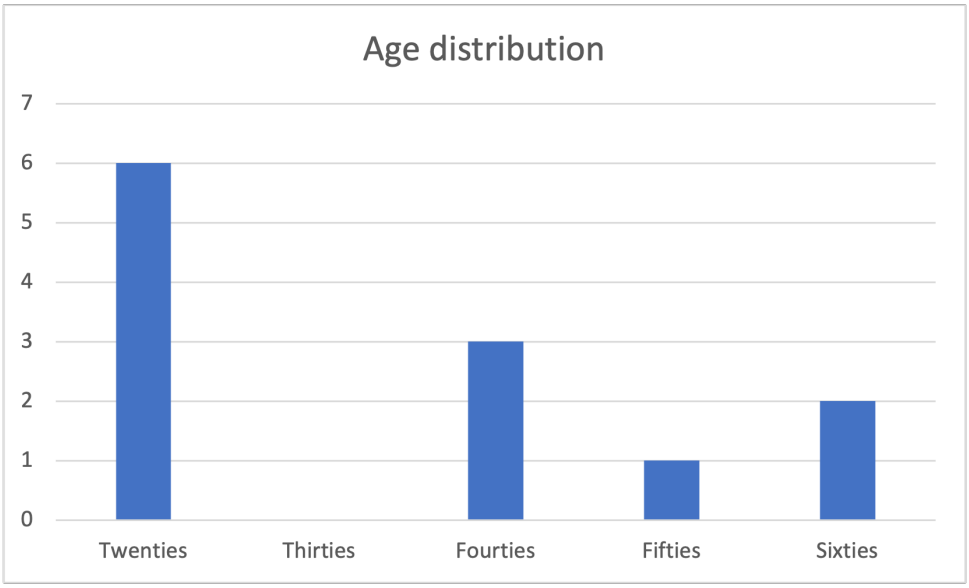

Figure 4.39: Age distribution of user focus group participants.

Location-wise, the county distribution is presented in Figure 4.40, resulting in 5 out of 11 counties represented.

In the survey (Section 4.1), a question asking for participants for an interview were mainly answered by people known to me and which were geographically close at some moment, either in Easter break or when visiting. Therefore, the decision of having only physical presence focus groups was made. This made it easier to create a natural environment in the homes of the participants, also including body

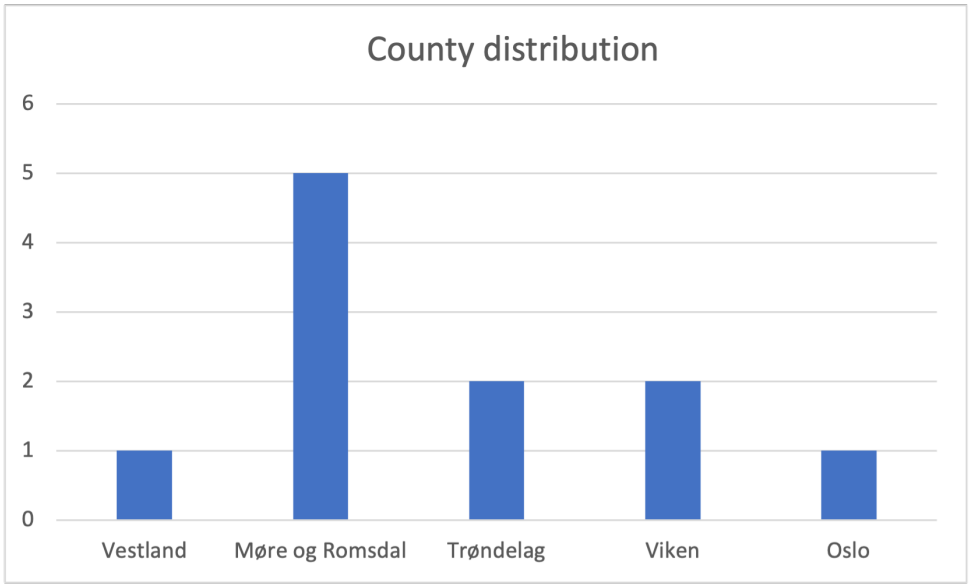

Figure 4.40: County distribution of user focus group participants.

language which goes missing into the great web if the focus groups would be digital. Furthermore, most participants were motivated and happy to help, resulting in few off-topic conversations lasting more than a few seconds.

4.3.2 Findings

As could be predicted, several of the participants did have trouble trying to imagine riding an autonomous car, saying that the scenario was hard to predict and almost felt Utopian. After being explained that they could start with imagining how riding a train all alone would feel like, they immediately had more contributions. The questions regarding their use of in-car multimedia today were more straight-forward in terms of complexity. Some highlighted results - being questions and answer shares from the user focus groups described in Section 3.5.2 - will in the following be presented in a thematic manner. For each topic presented, its respective IF-categorizing will also be stated if applicable and distinct.

Digital in-car multimedia services and applications

In Section 3.5.2, a description of the questions regarding topics and scope is given. Also, a reference to their location is given (Appendix C) where one can see how the questions were formulated.

- **Missing updated navigation services (system-related IF)** 5 out of 12 (41.7%) were missing an updated and integrated navigation system. A 48 year old male living in Viken and commuting to Oslo, driving mostly in rush hours, added that he would like a live updated traffic map where one can see where the queues are, and hence being able to choose a different route if applicable. He uses this feature from Google Maps, but has to use the smartphone for this.

- **Technical aspects being a source of irritation (system-related IF)** The participants were asked if there are any technical aspects in the car which they find annoying, and 33% responded that the car stereo-to-smartphone Bluetooth connection regularly fail to connect. The issue will sometimes lie in that the car wants to connect to another smartphone nearby (especially onboard the ferry), or the smartphone wants to connect another car or another previously saved device which is not nearby at the moment. Also, 25% added that onboard the ferry, the car stereo sound is very transparent to the surroundings - being that if you are in a phone call, you feel like everyone around you can hear what the conversation is about. As a consequence, these respondents tend to turn off the car stereo for the benefit of using the smartphone speaker instead. Several respondents also mentioned that when you have to move your gaze away from the traffic in order to monitor something that suddenly is not working properly (music stopping, podcast rewinding etc.), and the more focus is taken away from the traffic - the more does the risk of accidents increase. Furthermore, they added that it probably exists hand gestures or speech commands to monitor the car stereo and air conditioning, but there is an existing barrier to teaching new functionalities.

- **Concentration on the multimedia service in the car versus at home (context-related IF)** 60% of the participants indicated that their concentration is better in-car, see quote below. One participant living (and driving) in central Bergen disagrees, saying that the traffic takes the focus away from the multimedia and hence the concentration is better at home rather than in the car.

  > "More concentrated in the car. Seldom listen to podcast when I am at home, only in the car. At home, there are many more things one has/wants to do, but in the car you are kind of stuck in the moment and able to actually pay attention to what you are listening to."

- **Distractions and disruptions** All participants indicated to be distracted in some way by digital services in the car. Some of them added that the smartphone - especially if not on mute - is distracting when getting notifications and the screen lights up, for example laying in the passenger seat or in the center console. Also, if the phone rings, one has to do some kind of hand gesture -

either declining or answering. Speaking of phone calls and being cut off, most participants have experienced disruptions (67%), besides the ones living in the larger cities in Norway where all areas including tunnels have proper cellular coverage.

- **Influencing factors towards a better/worse experience of digital in-car services** The participants were asked to reflect on what would be the the make or break when talking about factors turning a good experience bad or a bad experience better. Here, the answers vary in terms of the system-, user- and context-related categorization. To make it easier to categorize the answers, Table 4.4 presents the categories and the respective answers.

Autonomous cars

Moving on to the section where the participants were asked to reflect around the use of autonomous car in the future. Some highlighted questions and answers are presented in the following.

- **Acceptance** The participants were asked to imagine themselves riding an autonomous car - and picture themselves what they would like to spend their time doing, alongside with how they would respond to suddenly ride a fully-autonomous car. 42% indicated that they would have big trouble with acceptance and letting go of the control, and that there would be a transitional phase where they would pay attention to the traffic all of the time. Another 42% agree about the fact that it would be a complete relief - *if* the car works as it should all the time.

- **Activities to kill time doing** Regarding activities inside the autonomous car, several participants mentioned several activities. 33% would sleep, 42% would scroll on social media and 16% would to work chores like answering e-mails. Also, 16% would read a book until they catch motion sickness. Some also mentioned that they would probably just look out the window if the landscape was nice.

- **Influencing factors towards a better/worse experience of digital in-car services in an *autonomous* car** In this case, 25% mentioned that the reception would be more important in an autonomous car scenario, because you would use the smartphone more and hence noticing smaller changes that would previously pass unnoticed. Another 33% think that the comfort would be more important - also here because you would pay more attention to it, when the traffic is no longer consuming all the focus. Also, a participant mentioned that it would be quite frightening if the weather was bad, because one would worry about the technical parts of the car not working or getting all the signals it

demands. Some said that there is no difference between the influencing factors in current cars and autonomous cars.

– **Important aspects to be aware of while developing in-car multimedia services for autonomous cars** The participants had several valuable contributions to this. One mentioned that it would be valuable for the mental health and well-being of future autonomous car-riders to develop services which do not necessarily involves *even* more time spent scrolling on social media or looking at TV-shows. We already spent a lot of time doing this, so incorporating other services like VR-meditation, VR-hiking etc. while sitting in the car would be beneficial. Simply using the technology for something helpful and uplifting for the passengers, not only saturating the car coupe with entertainment in the form of overly stimulating applications creating fatigue in the long run.

System-related IF	**User-related IF**	**Context-related IF**
Sound quality	If I have to focus better on the road, I turn down the volume	You are less focused about what happens *inside* the car if there are bad driving conditions
When Apple CarPlay etc. does not work, the experience will be worse	I like it when it is all quiet	Snowing weather or pouring rain
Reception, DAB radio sometimes cuts off	I am sensitive to loud noises, so if someone turns up the volume, the experience will decrease	If I am sleepy (driving to work), I do not concentrate on the multimedia at all
Quality on the dashboard. If the dashboard is high-tech and nice, the better do the digital services look - and the better you feel.		

Table 4.4: Influencing factors towards a better or worse driving experience.

To sum up, the personal preferences of each participant/driver has a big influence on their overall perceived quality. On some aspects many participants agree, but in other aspects there are greater contradictions. This is what is interesting with humans, because in the end there will always be personal preferences, previous experiences influencing the present, changes in experience or similar personal characteristics that will as a whole have a big influence in how an in-car multimedia service is experienced.

Highlights from the user focus groups

- Participants had a hard time visualizing the autonomous driving scenario
- Respondents miss navigation systems updated in real-time
- Respondents are more concentrated on the multimedia in the car rather than at home
- Smartphones, and too large touch screens, are a source for distractions
- Sleeping, scrolling and working during riding autonomous cars will be popular activities
- Seating comfort will be more important in autonomous cars
- Some people do not like being entertained all the time

Now, we are moving on to presenting the results from the expert interviews.

4.4 Expert interviews

The expert interviews were harder to implement than initially supposed. A total of four planned interviews were not carried out because of the busy schedules of the experts. Hence, a lot of time was spent on planning and waiting for the interviews, where several occasions resulted in the interviewees not showing up. Therefore, only two interviews were conducted in the end. The interviews (more like conversations) where solely performed to be a support to the already conducted literature survey.

4.4.1 Participants

In Table 4.5 the experts who part-took in the interviews are presented, along with their expertise and current occupation.

4.4.2 Insights gained from the interviews

The conversations were roughly noted, and the highlighted topics, claims and speculations are presented in this section.

QoE of in-car multimedia services

First off, QoE of in-car multimedia services might mean different things, depending on the specific service. Different multimedia gives different ways of experiencing it. It depends on the car, the type of multimedia, the screen, the interaction with the screen. Also, usability is a big factor in how the driver/passenger experiences the

Participants	Background	Occupation
Lina Karam	Has previously worked with QoE in the context of autonomous driving	Dean of Engineering at Lebanese American University (LAU)
Alexandre De Masi	Working with QoL (Quality of Life Lab) and has written several papers on the use of Living Lab methodology within the QoE field [DW18]	PhD candidate at the University of Geneva

Table 4.5: Interview participants.

in-car multimedia. The usability will also be dependent on the demography of the test subject, being older, younger, female or male - or in between. When it comes to QoE of in-car multimedia *while driving*, this is a compound and comprehensive field. It could be the QoE of video streaming, QoE of speech recognition, or the QoE of the driving itself - which is the case for this thesis. Therefore, the ability to restrict oneself to a more isolated field *inside the car* is necessary.

It is difficult to imagine the multimedia needs of the future, and what resources one might have in the future. Imagining the cars reporting all the interaction that the driver adds, where sensory data is sold to the car companies so that big data could make a decision. This could for example be a passenger trying to stream a video onboard the ferry, but the car does not understand because of bad cellular reception. Then, because of the bad quality in the video, the car could suggest listening to the radio instead. Also, using AR, where one combines VR with the real world, one could project/render various restaurant menus if the driver plans on having a lunch break soon. Creating a personalized experience for the passenger would be beneficial for the car manufacturers in the future. Wearing some type of wearable and hence reporting data to the manufacturers will make them able to process this big instant data and create personalized content for the user while sitting in the autonomous car.

In a transitional phase where autonomous cars are introduced to the public, trust issues of the driver in meeting with the autonomous car is also an important topic. When will the driver be comfortable with having the car doing all the steering itself - without ever having to interfere? These are also aspects covered in the survey presented in Section 3.3. Still, if an autonomous car works without glitches, and the user gets used to this, the user will enter a more comfortable phase regardless. The time it will take will vary a lot with the type of user, but in the end, the user will probably be able to (more or less) fully concentrate on in-car multimedia services

instead of nervously peeking out of the car all the time. Anyway, the time it will take for a user to fully trust the autonomous system must be taken into account while developing in-car multimedia service.

Methodology

To gain further insight into which methodologies the researchers preferred or find the most helpful, questions on this were asked. It was said that there is no well-designed and established protocol for the evaluation of QoE in autonomous cars - everyone seems to want to go their own way. Identifying the issues and limitations of today's used methods is a place to start rather than rushing into creating a whole new method. Which method to use depends on the type of application and the context, where different tools creates a whole different context and hence a different experience. Existing QoE evaluation methods might be applicable for the in-car multimedia purpose - but it would need to be adapted to meet the mobile and ever-changing context. A combination of existing methods could also be something to look into prior to trying to create a new one.

A methodology being mentioned was the *Ecological Momentary Assessment (EMA)*, which involves a sampling of the test subjects' behaviors and experiences in real-time, in their natural environments [SS94]. The devices used in the assessment are ranging from physical diaries to wearable physiological measurement sensors. The experts did not point out any other methods as better than others, but exaggerated the fact of adapting existing methods onto the mobile context, and combining the already existing ones.

The feasibility of testing the method itself is also a central issue. Using VR makes it easier to conduct research, especially when you do not have a manufacturer position and able to borrow automated cars - if the automated cars are secure enough for the driver to perform activities other than paying attention to the traffic. Still, making users show up to a lab environment and using VR to simulate traffic will always be somewhat realistic, emphasizing the *somewhat*.

As a result, it can be concluded that as this has not been a key topic in the QoE community yet, there is no standard or agreed upon approach yet. Rather, more efforts are needed to test out adjusted versions of existing methods and test protocols.

Highlights from the expert interviews

- AR holds great potential in regards to future-oriented in-car multimedia

- Important not to force high-tech functionality on users who do not appreciate it
- Using VR makes it easier to conduct future-oriented research on in-car multimedia use in autonomous cars
- Focus on adapting the existing methodology instead of inventing your own

Having these results in mind, their relevance to this thesis and their possible reasoning will be discussed in the following chapter.

Chapter 5
Discussion

The results from the methods chosen (Chapter 3) have now been presented in Chapter 4. Data has been collected from a (1) literature review in order to obtain background information, (2) a survey study mapping driving habits and needs, (3) user focus groups supporting the survey, (4) diary study combining accurate network measurements with user perceptions of quality and lastly (5) interviews with experts,. The goal of these methods and the related empirical studies is to answer the research questions and objectives presented in Section 1.2. To recap, these are essentially mapping influencing factors for today's and the future's in-car multimedia experience (RQ1), and to explore the limitations and adaption possibilities of existing QoE evaluation methods to be used in the future also (RQ2).

Diving further into the realm of existing research on QoE brings us the benefit of gaining knowledge about well-established QoE influencing factors and evaluation methods. The influencing factors, split into user-, system- and context-related factors are all factors which might be influencing to the user's overall experience when evaluating QoE. One of the research questions of this thesis concerns influencing factors for in-car multimedia QoE. Through combining background information, user survey, user focus groups and diary study, several perspectives have been established through the participants' contributions to the various methods.

5.1 Influencing factors in light of the user studies

In this section, some of the influencing factors found through the user studies will be highlighted and discussed. The findings will be categorized into user-, system- and context-related factors and separated into subsections.

5.1.1 User-related IFs

The results from the SPSS tests on the survey data set revealed some interesting significant (significantly interesting if you will) results regarding demographic infor-

mation like age and gender, being highly user-related. Younger people tend to become more annoyed overall while driving a car than older people, and also indicate to have experienced network disruptions to a higher degree than older people. Reasons for this might be many, and will hence be a user-related IF - where the QoE of in-car multimedia might decrease for the younger generation. One way to explain it is that younger people have to a certain extent grown up with more technology than the later generations. This makes them naturally more known to technology and hence might have higher demands to it and its usability - and therefore are more aware and get more easily annoyed when things do not work as intended. Also, the annoyance towards the general traffic might have something to do with less experience behind the steering wheel compared to the older ones having more experience. This can also be related to the fact that younger people tend to be more affected by the weather while driving, where the driving experience is an important factor to be able to handle it correctly and getting used to it. One participant in the user focus groups also mentioned motion sickness, being an aspect that could deteriorate when the driving conditions get worse (as stated in Section 2.2), and hence influencing the QoE. How these tendencies will look in an autonomous car context is hard to tell, since the weather will still be as shifting (perhaps even worse due to climate change), but the driver has no control over the monitoring of the car. Perhaps a gradual take-over of the car in bad weather could be a possibility?

Distractions are also an area where youngsters score the high points in the survey. The younger drivers tend to be more distracted by in-car multimedia than the older ones. Referring to the above, where younger people are more used to smartphones and social media, this might also be the case here, having social media "on the brain" more than the older. Maybe waiting for that special someone to answer your message on Facebook Messenger, looking for *that* name to appear in your Snapchat notifications - which could be distracting by gazing one extra time towards the smartphone laying in the passenger seat with the screen upwards, blinking with notifications. Distractions in an autonomous car would probably be turned over to be entertainment and time-killing sources, where the smartphone is no longer distracting, but the main source of attention. Still, if one is busy doing work chores, meditating, gaming or reading a book - distractions will take place no matter what.

Another aspect where younger people (from the survey) take the lead is when they are asked if they want to drive alone or with passengers. Youngsters want to drive alone, for the benefit of alone time. Pairing this with the distraction-tendencies, this might implicate that younger people tend to be more distracted by the *passengers* also. Or, it could mean that younger people tend to more often have passengers, or a bigger amount of passengers at a time - in turn creating more distractions. The tendencies of future passenger habits in autonomous cars could be various. Maybe having even more passengers while also being able to fully invest in the conversation,

instead of just listening partly because you have to pay attention to the road. Also, maybe having children in the car will be more of a blessing when the driving is left to the car itself, being able to join in on the fun and be more present in the moment with your children.

When it comes to speech assistants, neither older or younger people tend to use it more - but the ones in-between do, namely G2 (age 31 through 50). The results are a bit surprising, since one would think that the younger generation are open to new impulses and new ways to use technology. On the other hand, it is not very surprising that the older generation tend to not use it. One explanation of the youngsters not using speech assistants could be that they do not have "new enough" cars due to poor economy compared to G2 - since the survey also had an answer alternative for those who do not have speech assistants in their car. Younger people do not have as expensive and high-tech cars as "their parents", and hence drive around in cheaper cars made in the previous century - without speech assistants.

Now turning towards discussing answer differences which reason in gender, and whether the gender could be an influencing factor in specific in-car situations. It turns out that the women who answered the survey are more affected by weather changes while driving. This will in turn affect their use and quality perception of in-car multimedia services. Regarding concentration around the multimedia and awareness of disruptions, one would think that women do not pay as much attention to this if they are very concerned about the outside environment, but this is not the case. In fact, women also indicate to experience more network disruptions than men. The reasons could be many, for instance if women are more detail-aware of the quality of network connections, or simply spend more time on video streaming or other digital services demanding high network performance.

Moving towards another typical in-car service, namely navigation systems. No demographic background has shown to be an influencing factor in the general use and wishes for navigation systems, which in turn means that everyone - independent of gender and age - wants to use them. This is important insight for manufacturers and developers of these services, where the usability must be suitable for all age groups and genders.

The case for autonomous cars is that all, independent of age groups and gender, are sceptical towards them. Background literature in Section 2.1 highlighted that the trust and acceptance of different autonomy levels is highly dependent on user-related factors (age, gender and other personal characteristics), and this is further reinforced by the user studies of this thesis. Some mentioned that the scenario was hard to imagine. This is understandable, since it is a whole new aspect which will revolutionize the way we see traffic. Still, one would think that younger people

would tend to be more open-minded and curious, having in mind the amount of technology they consume and are known to. Yet, scepticism towards the unknown and uncontrollable is natural. When it comes to in-car activities in autonomous cars, a big share of respondents (19.7%) would still observe the outside traffic. This could be a result of not being known to the possibilities of activities to perform, a need for still feeling somehow in control, or just a genuine interest in nature and landscape. Also, younger people are more likely to want to spend time on social media in the car than older people are. This makes sense, since younger people are grown up with social media and hence might be more attached to it in many cases.

To summarize, future research on QoE of in-car multimedia should seek to take the following Human-related IFs into account:

- Age
- Gender
- Attitude towards technology

5.1.2 System-related IFs

In light of the background information, system-related IFs (SIFs) are characteristics to the systems that determine the technical quality of it. The user studies revealed several issues that the users and participants found annoying, malfunctioning or time consuming. This shows that system-related problems are a big influence towards the user's perception of quality of the system, hence being a system-related influencing factor. Often mentioned as something very important for the QoE of the in-car experience was sound quality. Having high-quality speaker setup increased the overall experience, while the demands are often not the same at home in the living room. Some reasoned this with saying that the car space is a closed space where you get the surround sound on a different level than at home, depending on the speakers you have, of course.

To connect to the integrated speakers in the car, most manufacturers use Bluetooth interconnection between the smartphone and the car stereo. This topic could also be categorized into the technical- and information context-related IFs, but for simplicity purposes it is now laid under system-related IFs. This connection is also prone for irritation, as indicated by the survey respondents and the user focus groups participants. Either the connection time is too long, alternating between wanting to connect your own phone and unknown devices, or the speakers are too loud while in a phone call and hence exposing the conversation to everyone outside the car. The last issue would naturally be manufacturer-dependent, where some cars are worse than others.

Other mentioned issues will also be very dependent of car manufacturers and the age of the car in question. Several respondents mentioned that they would want updated navigation maps, better sound quality, better appearance of the dash board and so on, being system-related IFs strongly dependent of the model of the car and the type. Luxury brands like Cadillac, Tesla and Mercedes Benz have in the recent years equipped their cars with extensive and feature-packed navigation systems, where for example Tesla have integrated Google Maps on a 17" screen [NAV]. For instance, the 2021 Cadillac Escalade offers head-up displayed navigation where the next route action is projected onto the window in front of the driver - as an integrated part of the traffic picture. Hence, it is a question of car type and model when a respondent wishes for better features, if the features already exist with other car brands.

The Tesla 17" screen was mentioned in the previous paragraph, but is a bigger touch screen an implication for a better experience? Both survey respondents and user focus groups participants have mentioned the unfavorable use of touch screens instead of buttons, for monitoring purposes while driving. Buttons are indicated to be a simpler way of interacting with the features while driving, instead of having to move the gaze in order to monitor a big touch screen, and focusing on it to hit the right screen area with your finger will move focus away from the driving. With that being said, most respondents are pleased with their in-car touch screens. Still, this satisfaction will strongly depend on the type of touch screen, its size and the functionality. Another functionality proposed by the survey respondents which is car-dependent is butt- and back massage in the seat. Massaging seats have existed for a while now, and is offered by Mercedes Benz and BMW amongst other manufacturers [MAS].

Now stepping out of the car and directing the focus onto cellular reception and 5G. To be able to have a series of Internet-connected devices but also moving at a pacing speed, might cause issues related to handover speed and infrastructure coverage. In the diary studies, commuters were asked to make use of some sort of in-car multimedia service and report their perceived quality along with measurements from Nettfart. This is an opportunity to check for coherence between perceived quality (reported using a 1-5 Likert scale) and measured quality. Nevertheless, no correlations were found between the measurements and the subjectively perceived quality. Why is it that with poor cellular reception, the users are still content and happy with the multimedia service? Maybe because they are still paying most attention to the road, and hence not noticing small variations in the cellular reception or network connection. In addition, the number of observations is low. Still, when autonomous cars start to infiltrate the garages, one will have more time to pay attention to the overall network speed and its quality parameters like availability, latency, performance.

What is also worth noting when talking about non-noticed service disruptions in the diary study, is that many participants used Spotify, and hence maybe played already downloaded playlists. Still, one could use Spotify for other things like podcasts, which are not as often downloaded for everyday use. Also worth noting about the diary study is that the sample size was small (N = 10), which could be a reason for no correlation between measurements and subjective opinions.

When it comes to learning new technical features in high-tech cars, the user studies has shown to be a barrier for both young and older people. Both user focus group participants and the survey has revealed answers from people saying that learning new things might be problematic, even for the younger generation. A user focus group participant commented that "i know that my car offers some kind of hand gesture to monitor the screen instead of touching it, but I have not had the time or bear to figure it out". This was a 27 year old man with a high understanding of technology. Also, a 64 year old man mentioned approximately the same. This means that some features can actually become *too* high-tech, creating a barrier between the feature and the user in terms of how much effort is demanded to put into learning it and further underlining the importance of user-centered design processes and overall usability. These are aspects worth noting for the further developing of functionalities to integrate in autonomous cars.

To summarize, future research on QoE of in-car multimedia should seek to take the following System-related IFs into account:

- Sound quality of speakers
- Bluetooth connection establishment time
- Buttons instead of touch screens for in-motion monitoring
- Trade-off between functionality and the demanded effort to learn the functionality

Now, moving over to the context-related factors, where in this case some high-tech features might be perfect in one place but totally excessive in another.

5.1.3 Context-related IFs

Context-related IFs are probably the most extensive and relevant type of IF in this thesis. The context of an in-car experience is mobile, highly uncontrollable (today, at least), and prone to many sudden situations and hence fluctuations in QoE. There are in total six categories of context-related factors, and this subsection will address

some of the ones applicable to the in-car scenario. First off, the physical context gets a go.

Physical in-car context

The physical context is essentially the location. In the car, in your living room, at your in-law's house. Indoor, outdoor, or in transition. The physical context of driving a car is always mobile and in continuous transition, except from the still moments of parking lots, ferries and queues. When it comes to in-car multimedia services, the physical context will be an influencing factor of how the multimedia or service is consumed, and to which degree of attention. Streaming a movie on a tablet in the backseat is not the same if the road is bumpy enough for you to lose focus, or if sunbeams dazzle the screen so that minimal of the video content is visible. A user focus group participant claimed that one can not not pay the same amount of attention to the conversation in a podcast if there is a blizzard or a rainstorm outside hammering on the windshield. The bad weather and the outside environment will consume all available attention that the user has, resulting in less awareness to the services and hence possibly decreased QoE. Whether you are located in a big city center, or a rural area where the houses are far from each other may influence the network connection, and might be visible through latency or stalling events in the services in question. For instance, several user survey respondents and user focus group participants mentioned that the connection onboard ferries is bad, which is a physical context-related IF. The collection of different contexts one is located in during a car-ride is endless, and ever-changing. To filter out some most important influencing factors for these contexts is comprehensive, where the possibility of incorrectly ruling out some of them is present. The business of traffic and exact location will be even more important for the autonomous cars, but it might be less important for the ones riding it.

Temporal in-car context

Several contributors answered that in an autonomous car, they would do work chores *to* work, but not on the way home. This might implicate that activities done to and from work are different, because the end station and its purpose is just as different and dependent of time of day. Also, a temporal context could be related to seasons, and hence snowy weather - being a disturbing factor mentioned by several participants. Hence, snowy weather and bad driving conditions in general might be both a physical and temporal context. Another context which could be dependent of the time of day, is the social one.

Social in-car context

The social context comes in to play when there are other people inside the car with you. If they are either known to you, are strangers or even acquaintances is also a factor to consider. From the user studies, interesting insights from experiences with children in the backseat were frequent contributions. Children playing with their tablets, adolescents scrolling on TikTok with the volume up high, whining children in the backseat fighting each other. Also, grown up passengers were reported to speak loudly on the phone, scrolling with the sound on, amongst other things. All these scenarios are disturbing to the driver to various extents, and will have a say in the overall QoE. Hence, social context IFs are an important topic. Having passengers which are known to oneself was also a preference frequently reported in the user studies, and driving with good friends would probably increase the QoE of in-car multimedia services, perhaps when playing your and your best friend's favorite playlist. Furthermore, respondents would rather drive alone if the alternative was to drive together with a slightly annoying colleague. Still, no correlations was found between the annoyance statements in the survey and the increasing amount of passengers on the daily, and no one mentioned other road users as an annoyance either. Passengers will also be relevant for the autonomous car context, where the context will be a whole different one dependent of how many and which passengers are on board. Maybe passengers are annoying to a certain degree, but not to the extent that it affects the experience noticeably? Or, perhaps people do not very often have passengers with them in the car, but when they do, *they do*.

Task in-car context

What is even the purpose of in-car multimedia services, and what do the users wish to achieve with their use of the services? Navigation applications for infotainment purposes, podcasts for entertainment, or phone calls for professional purposes are all contexts belonging to the *task* category. For instance multitasking - which means doing multiple tasks at once - might increase stress levels and affect the user's perceived level of QoE. Several incoming alerts and notifications can be an example of this, and may be disturbing. User group participants mentioned that having the phone screen visible while driving and seeing incoming notifications is disturbing and takes focus away from the driver. Driving a car is often a form of multitasking, since you are continuously driving a car and in addition often do other actions also, as for example answering incoming calls, putting on your sunglasses, or turning up or down the stereo volume. The action of driving the car will always interfere with the use of the multimedia service, as long as the driving responsibility still lies on the human. For today's drivers and traffic, maybe it has to be said that the biggest influencing factor of in-car multimedia services is the driving itself? But, what will happen when the autonomous cars takes over this responsibility? The users will

be able to perform each task in isolation, not needing to worry about the traffic constantly. Several participants have indicated that they focus better in the car, but others disagree saying that the traffic takes too much attention. When the car in the future does the driving itself, the users may be agreeing more about this. Although, the car will still be a confined space isolated from the outside world, and hence creating a fruitful environment for alone time, meditation, and *mono-tasking*. After all, one participant actually enlightened the fact that there should be more focus on mental-healthy activities rather than just exaggerating the amount of screen time and over-stimulating entertainment that just makes the travel more exhausting than relaxing.

To summarize, future research on QoE of in-car multimedia should seek to take the following Context-related IFs into account:

- Physical location of the vehicle including weather changes, driving conditions and whether the location is rural/urban
- Temporal factors like time of day and season
- Amount of and type of passengers (children, colleagues, relatives etc.)
- Mono-tasking rather than multi-tasking (for future scenarios at least)

Furthermore, one could bring many suggestions to the table, but how are all these services supposed to be QoE evaluated in the ever-changing context of driving?

5.2 QoE evaluation methods in light of user studies, expert interviews and existing research

The evaluation methods are as earlier mentioned often conducted in laboratories for feasibility purposes, while researchers have in the later years stepped outside and made use of crowdsourcing and living labs. The research question concerning evaluation methods in Section 1.2 has resulted in gained insight into limitations and demands, with most help from the expert interviews and the background information, but also from user contributions.

From the survey, one of the test results showed that younger people tend to have higher demands to the digital services, and are also more easily annoyed in traffic. For evaluation measures, this might imply that researchers should primarily use young people for quality evaluation, as they may have a tendency to be more "picky". However, when it comes to the user-centered design and evaluation of in-car entertainment services, a diversity of user segments should be included, e.g., also

older people should be included in later iterations for usability evaluation. After all, it is shown via the user studies that people have a hard time learning new technological features, and especially the older generations. Some dread it and find it challenging, and for that reason, the service usability should be carefully evaluated in terms of older people's user needs and barriers. Of course, there are exceptions of older people loving new technology and adapting to it quickly. In addition the population is aging, with Europe as the oldest continent, where it is predicted that 34% of the population will be aged 60 years and over in 2050 [Qua16]. Therefore, the older generations are essential to include and listen to in the research. Also even including them as co-researchers might be beneficial in for example an interviewing process where also older people are interviewees, to gain trust and in turn collecting richer and more valuable data [Tou20].

Moving forward into different evaluation methods, VR is a rising field with increasing relevance to QoE evaluation. The experts also highlighted VR testing and QoE evaluation of autonomous cars as an alternative to in-field testing, since the field does not exist in its entirety yet. This is also an alternative that was presented in the background literature (Section 2.4.2) Using VR makes it easier to conduct research, especially when you do not have a manufacturer position able to borrow automated cars - where the automated cars are secure enough. Using VR in a laboratory would be a low-budget alternative if the other option is creating a traffic consisting of only autonomous cars today. In the future, these things would of course be easier, because then the autonomous cars will probably dominate the roads anyway and be easily accessible. Hence, being able to create an experience close to the reality with VR, will enable the possibility of a big amount of user testing with respect to diversity, without it being too time-consuming and too much hassle demanding resources like a traffic consisting of only autonomous cars. Still, the users will know that they are in a laboratory and wearing VR goggles or lenses. The VR projection and design must be as realistic as possible, with pedestrians, other cars, weather changes, sudden car accidents, technical problems appearing and so on. Adapting the VR technology to be used for QoE evaluation of in-car multimedia services, and maybe combining this with some in-field research like living labs with existing autonomous cars could be a starting idea. Existing methods must be adapted to the in-car context, and also perhaps combined, to find a suitable match for this scenario.

This could raise the question: Why would we even need a QoE evaluation method of the in-car multimedia services of autonomous cars *before* they are even created for the general population? Can we not just let the manufacturers do their job and create some infotainment and entertainment services and go from there when the autonomous cars are more widespread? The risk that comes along with just creating and developing things without any proper reflection on diverse user needs is that the first systems pushed to the market might become the standard. If users get used

to them, and the marketing is done right, systems that are not very suitable and beneficial for the users might become a preference and it could be hard to influence the manufacturers into thinking the opposite. For example, when the QWERTY standard of keyboards arose, there were competing keyboard types like Dvorak which were more ergonomic to the human hands and which created more natural and efficient finger movements - but they were too late to the party. QWERTY became the standard keyboard layout despite the fact that it was not the "best" keyboard. Hence, early bird often gets the worm also when talking about innovation.

Finding and using methodologies to evaluate QoE of ever-changing contexts would demand a compound approach, but without it being too comprehensive and hence resulting in it not being used. One combination would for instance be the crowdsourcing method with a living lab approach as presented in Section 2.4.4. That could be a variation of a diary study, where the crowdsourcing ensures proper and extensive participation, and the living labs ensures for objective and subjective data. Also, some sort of EMA method as proposed by the experts could have ensured components like trust, acceptance and real-time behavior, since this method is leaning more towards sampling measurements from the physiological side. Still, this would be for the *current* car context. But what about the future car context?

Despite the fact that QoE evaluation of in-car multimedia services using VR would have the test subjects know that the context is somewhat artificial, it might be the best solution when it comes to the autonomous driving scenario. Combining VR labs with in-field methods like train passenger observation (as presented in Section 2.3) could have made the results be situated at a level of high-fidelity, but it is challenging to claim something like that without having it tested beforehand. Having a manufacturer lining up with autonomous cars to test, will include the context-factor to a greater degree. Still, today's traffic will solely consist of normal cars with normal drivers, even if a manufacturer and researchers are testing automated cars (unless a whole road area or field is being closed for testing).

To summarize, future research on QoE of in-car multimedia should seek to take the following into account when choosing QoE evaluation methods:

- Ensure diversity in the research, especially with regards to the participant's age and gender
- Develop realistic VR projections to simulate autonomous driving, but in conjunction with in-field research like living labs or train passenger observation
- For the current traffic scenario, a compound evaluation approach consisting of crowdsourcing recruitment for an EMA and living lab combination would be beneficial to include as many aspects as possible

– Testing the methods themselves before jumping to a conclusion on what is the better method

5.3 Limitations

Several of the methods in this thesis have some sort of limitations. A recurring trend is that sample sizes are small. The survey collected 183 responses, which in my opinion is good when the recruitment process only consisted of my own network and the social media groups I am a part of. Still, having an even larger sample size here would have resulted in even more robust findings and statistical test results with a higher power. The same goes for the diary study. The data sets from the diary study were also imported into SPSS, but the sample size was very low here ($N = 10$). This resulted in few significant correlations and protruding tendencies, which might have given different outcomes if the sample size was more towards the size of the survey sample size. Also, extending the diary study to last for a longer time period and based on random day sampling over an extended period would help with collecting even more data.

Also, user focus groups and expert interviews had small samples. These interviews were only qualitative, and hence these results did not have the same obvious opportunities to seeing correlations. Still, similarities were clear in the answers from the user focus groups also, despite the fact that samples were small. The expert interviews were more all over the place, even if only two experts showed up. In hindsight, experts interviews should have been started earlier, to get the possibility to follow up re-scheduling for a longer time. Re-scheduling was a clear tendency in the expert interviews, and consumed a lot of time.

The recruitment of participants is also a limitation of this thesis, where a lot of the participants in all the studies were people known to me in some way. Having participants already known to me and also to each other, likely created a more laid-back and open climate cultivating creativity and free thinking in the more future-oriented questions in the user focus groups. With that being said, people who know each other will more likely derail and start talking off-topic. Combining strangers would likely create more forced, but also more factual and on-topic conversations. The fact that I am myself also known to the ones part-taking in the focus groups, probably lead to even more laid-back discussions, which could be both a blessing and a curse. It might lead to more off-topic discussions and chit-chat, but also creating a safer and more comfortable environment where everyone says what is on their mind. With that being said, people known to me could probably be more likely to tend to "please" me with their answers, focusing on what I want to hear rather than what they want to answer.

Having these limitations and main implications in mind, the thesis will be concluded in the following chapter.

Chapter 6
Conclusion

In this thesis, the focus has been to explore and identify influencing factors related to in-car multimedia services in today's car and trying to project this onto the autonomous car scenario. It is challenging to predict such factors from a non-existing traffic perspective, not knowing the resources we might have access to in the future, nor the user needs and preferences. What we now have insight into are influencing factors of in-car multimedia services *today*, and also speculations towards what these might be in the future. Age, gender and the user's relationship with technology are the most prominent user-related factors found from the user studies of this thesis, and might possibly be projected onto the future scenario as well where differences in users will create different experiences. Trust and acceptance varies with the person in question, and will hence be a user-related factor in autonomous cars as well, when loss of control will be a central issue in that context.

The user's feeling of control will in the future be in the hands of the car manufacturers. They will get the chance to create a personalized experience for the users, where their personal preferences should be able to unfold. All digital services in the car must have its purpose and its place, taking into account that attention of the brain is limited. Maybe, isolating the car fully for the benefit of seeing the coupe as a closed space where in-car multimedia services can unfold. Still, it is unnecessary and counterproductive to force technological functions on someone that does not appreciate it. For example older people who prefer the more analogue activities like reading and looking out the window, rather than having AR projecting gaming and video streaming alternatives in front of their faces as soon as they enter the car. The technological functionalities must feel simple and feasible to learn for riders in all ages, so that user's do not end up with not having the energy to learn it and hence downgrading the experience.

From the user studies, it has been highlighted that *time* is a precious good for many. System-related factors like establishing an integration connection from car to smartphone, has to work properly and quickly in order to not annoy the passenger.

In the future, if system components take too long to turn on due to latency in the network or similar, this will influence the user's experience. Not to mention the technicalities of the autonomous car itself, where trust is a big issue. Everything must work perfectly, with no glitches, for the riders to feel safe. Also, good sound quality, ergonomic monitoring buttons and a well-designed dashboard is important for the users. Sounds are important for many of us for situation awareness, and hence the quality of it must be a priority. When autonomous cars arrive, these things will be even more important due to the increased attention dedicated to everything else than the driving. This also includes spending time with passengers.

Interestingly, the number of passengers a driver has has no correlation to the driver's annoyance levels. Still, many drivers prefer to drive alone, and have numerous examples of undesirable scenarios with passenger and hence being the most prominent context-related factor. It is however unsure how this may change or not in a more future-oriented scenario. Also, weather changes represent a big factor when contexts change. The autonomous cars must have incorporated techniques to make precautions when the weather is bad, like slowing down the speed, checking for slippery roads etc. What is the most important context-related factor for the QoE of in-car multimedia is probably the driving itself. The driving takes all the focus away from the multimedia service (naturally), and hence has a big influence on the way we experience what is being said in the podcast for instance. Current traffic brings along a whole lot of distractions, since it is all man-made. The future will hopefully bring cars that do this job for us, and hence we are able to fully focus on the multimedia service.

In other words, QoE of in-car multimedia is influenced by several factors depending on the situation, the weather, the passengers and the technical functionalities. Projecting this onto the autonomous car context, a lot of the influencing factors will look similar, except from the most influencing factors of all - namely the driving. How are we supposed to carefully evaluate the QoE of in-car multimedia in the *future* scenarios? What is worth testing is merging several already established QoE evaluation methods and adapting them to the mobile context. Combining crowdsourcing recruitment with diary studies (Living Labs), VR and EMA for example, could be a compound approach taking into account the vigorous and ever-changing context, the trust and acceptance, all in the user's own cars to get an understanding of what autonomous driving consists of. Then, combining this with VR experiments having the user's experience autonomous driving on their bodies. The various measurements and insights one would get from this combination would be valuable data for developers and car manufacturers.

6.1 Further work

A natural next step for this research would be to systematically test out adapted or novel methodological approaches to conduct QoE studies. Testing the method combinations, predicting the cost and benefit, and learning the limitations of each of the combinations. The results will hopefully reveal the value of the data that is being outputted, seeing patterns in user behavior and needs, and finding influencing factors dominating the in-car multimedia experience. Further, using this insight to develop and create good and beneficial in-car multimedia services for the users, while having QoE, usability and user's trust and acceptance in mind.

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Appendix A

Data collection approval - NSD

NSD NORSK SENTER FOR FORSKNINGSDATA

Vurdering

Referansenummer

807831

Prosjekttittel

QoE of Multimedia use in Traditional and Autonomous Cars

Behandlingsansvarlig institusjon

Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for informasjonssikkerhet og kommunikasjonsteknologi

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Katrien De Moor, katrien.demoor@ntnu.no, tlf: 73594329

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Tuva Larsen, tuva.larsen@ntnu.no, tlf: 41798967

Prosjektperiode

10.01.2022 - 14.06.2022

Vurdering (1)

28.01.2022 - Vurdert

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med meldeskjemaet med vedlegg, meldingsdialogen og vurderingen her. Behandlingen kan starte.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 14.06.2022.
Vi legger til grunn at dere i spørreskjema slår sammen svaralternativene "annet" og "vil ikke svare" (kjønn).

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

Appendix B
Survey

Bruk av digitale tjenester i bil

Bakgrunn
Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke utfordringer knyttet til bruk av digitale tjenester i biler, både i automatiserte og ikke-automatiserte biler. Her blir det gitt informasjon om mål for prosjektet og hva deltakelse vil innebære for deg.

Spørsmålene handler om tidsbruk i bil, bruk av tjenester i bil samt bruk av (og personlig forhold til) automatiserte funksjoner i bil.

Formål
Dette er et forskningsprosjekt knyttet til en masteroppgave ved NTNU i Trondheim, og vil fokusere på svar fra de med bilførersertifikat og som kjører bil i hverdagen, enten til/fra jobb eller på fritiden. Formålet med prosjektet er å undersøke Quality of Experience (QoE) relatert til bruk av multimedia i biler i dag, og i mer fremtidsorienterte scenarier, i.e. i konteksten av selvkjørende biler.

Hensikten med prosjektet er å:

- Kartlegge påvirkende faktorer til QoE i in-car multimedia tjenester den dag i dag
- Kartlegge hvordan eksisterende QoE-valideringsmetoder kan brukes for å evaluere QoE i in-car multimedia i både dagens biler og i mer selvkjørende biler
- Finne ut hvilke utfordringer relatert til QoE i in-car multimedia som vil følge med utrullingen av autonome biler

Hvem er ansvarlig for forskningsprosjektet?
Dette er et forskningsprosjekt av masterstudenten Tuva Larsen, med veileder Katrien De Moor fra Institutt for informasjonssikkerhet og kommunikasjonsteknologi ved NTNU.

Hvorfor får du spørsmål om å delta?
Det blir utført en spørreundersøkelse rettet til alle som kjører bil i hverdagen, og målet er å samle så mange svar som mulig.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du fyller ut et spørreskjema. Det vil ta deg ca. 10 minutter. Spørreskjemaet inneholder spørsmål om dine erfaringer med bruk av digitale tjenester i bil, samt holdninger til automatiserte funksjoner i bil. Dine svar fra spørreskjemaet blir registrert elektronisk.
Det er ønskelig å utfylle og diskutere svarene fra undersøkelsen ved å utføre intervju av frivillige deltakere senere. Om du kunne tenke deg å bli invitert til et slikt intervju kan du fylle ut e-postadressen din. Det blir også gjort en premietrekning blant de som ønsker å være med, og ved å delta fyller du inn e-postadressen din på slutten av undersøkelsen. Disse e-postadressene blir slettet etter trekningen, og vil ikke være koblet til dine svar på undersøkelsen.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil dermed bli
slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta, eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Opplysningene om deg vil kun brukes til formålene spesifisert i dette skrivet. Opplysningene behandles konfidensielt og i samsvar med personvernregelverket, og det er bare studenten og veilederen som får se de samlede opplysningene.

Hva skjer med opplysningene dine når forskningsprosjektet avsluttes?
Opplysningene anonymiseres når prosjektet avsluttes, som etter planen er senest 14.06.2021.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
• innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
• å få rettet personopplysninger om deg,
• å få slettet personopplysninger om deg, og
• å sende klage til Datatilsynet om behandlingen av dine personopplysninger.
Den eneste direkte personopplysningen vi kommer til å spørre om er e-postadressen din i forbindelse med premietrekning og/eller intervjudeltakelse, og som er frivillig å oppgi.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke. På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

NTNU v/ Tuva Larsen, tuva.larsen@ntnu.no.

NTNU v/ veileder Katrien De Moor, katrien.demoor@ntnu.no.

Vårt personvernombud: Thomas Helgesen, thomas.helgesen@ntnu.no
Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Undersøkelsen er meldt inn og godkjent av NSD (Norsk senter for forskningsdata), med referansenummer 807831. Hvis du har noen spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

E-post: personverntjenester@nsd.no

Telefon: 55 58 21 17

Ved å fylle ut spørreskjemaet kan vi behandle opplysninger om deg basert på ditt samtykke.

Tusen takk på forhånd!

Generelt

Hvilket år er du født? Skriv inn 4 tall, f.eks. 1994.

Hvilket kjønn identifiserer du deg som?

Mann

Kvinne

Annet

Hvilket fylke bor du i?

Troms

Finnmark

Nordland

Trøndelag

Møre og Romsdal

Vestland

Rogaland

Agder

Vestfold og Telemark

Viken

Oslo

Innlandet

Bor du i en by?

Ja

Nei

Hva er din nåværende sysselsetting?

Ansatt i offentlig eller privat sektor

Håndtverker

Ledelse/management

Selvstendig næringsdrivende/frilanser

Pensjonert

Arbeidsledig/jobbsøkende

Student

Kjørevaner

Pendler du til og fra jobb/skole med bil? Hvis ja, hvor lang tid tar det en vei?

Pendler ikke med bil

10 - 19 minutter

20 - 29 minutter

30 - 49 minutter

50 - 60 minutter

Over en time

Pendler ikke

Kjører du oftest på urbane veier, eller på mer landlige veier?

Med urbane veier menes for eksempel veier som har rundkjøringer, lyskryss, tunneller og 2-feltsveier. Med landlige veier menes veier som i stor grad kun består av strake veier, 3-arms kryss, og områder med høyreregel.

Urbane

Landlige

Ganske likt fordelt mellom urbane og landlige

Vet ikke

Velger du samme kjørerute til og fra jobb?

Dette elementet vises kun dersom alternativet «10 - 19 minutter eller 20 - 29 minutter eller 30 - 49 minutter eller 50 - 60 minutter eller Over en time» er valgt i spørsmålet «Pendler du til og fra jobb/skole med bil? Hvis ja, hvor lang tid tar det en vei?»

Ja

Som oftest

Nei

Dersom flere kjøreruter fører til samme destinasjon, og de ikke varierer med mer enn 5-10 minutter, hvilken kjørerute velger du?

Den mest behagelige

Den raskeste

Den mest økonomiske (drivstoffbruk, slitasje på bil)

Tenk deg at du pendler til jobb, og kan velge mellom å kjøre alene eller sammen med en kollega. Hva velger du?

Med kollega

Alene

Kommer an på kollegaen

Vet ikke

Vil du utdype hvorfor?

Ditt forhold til teknologi

Hvor ofte benytter du deg av datamaskin, smarttelefon, nettbrett eller lignende teknologiske gjenstander?

1-2 ganger i uken

3-4 ganger i uken

Daglig

Flere ganger daglig

Vil du si at du lett tilegner deg kunnskap om ny teknologi?

Ja, som oftest

Det kan ta litt tid

Vet ikke

Nei, det er ofte vanskelig

Kjøring på fritiden

Kjører du (eller sitter på) mye i bil på fritiden i løpet av en uke?

Aldri

1-2 ganger i uken

3-4 ganger i uken

Daglig

Flere ganger daglig

Hvor lenge varer disse kjøreturene normalt?

Dette elementet vises kun dersom alternativet «1-2 ganger i uken eller 3-4 ganger i uken eller Daglig eller Flere ganger daglig» er valgt i spørsmålet «Kjører du (eller sitter på) mye i bil på fritiden i løpet av en uke?»

Under 10 minutter

Over 10 minutter

Hvor mange pleier å sitte på i bilen under hele eller deler av reisen? (Utenom deg selv)

Dette elementet vises kun dersom alternativet «1-2 ganger i uken eller 3-4 ganger i uken eller Daglig eller Flere ganger daglig» er valgt i spørsmålet «Kjører du (eller sitter på) mye i bil på fritiden i løpet av en uke?»

- Ingen
- 1 person
- 2-3 personer
- 4 personer
- Flere
- Det kommer an på

Bruk av digitale tjenester i bilen

Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du kan krysse av flere.

Her kan du krysse av flere.

- Radio (musikk)
- Radio (nyheter)
- Radio (radioprogram - P3morgen, Nitimen eller lignende)
- CD-spiller
- Musikk/podkast/lydbok
- Telefonsamtaler over Bluetooth-anlegg
- Telefonsamtaler kun via telefonen
- Sosiale medier
- Video på nettbrett eller telefon
- Ingen

Hvilke av tjenestene benytter du deg desidert oftest av?

Dette elementet vises kun dersom alternativet «Radio (musikk) eller Radio (nyheter) eller Radio (radioprogram - P3morgen, Nitimen eller lignende) eller CD-spiller eller Musikk/podkast/lydbok eller Telefonsamtaler over Bluetooth-anlegg eller Telefonsamtaler kun via telefonen eller Sosiale medier eller Video på nettbrett eller telefon» er valgt i spørsmålet «Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du kan krysse av flere.»

Her kan du krysse av inntil 2 alternativer.

- Radio (musikk)
- Radio (nyheter)
- Radio (radioprogram - P3morgen, Nitimen eller lignende)
- CD-spiller
- Musikk/podkast/lydbok
- Telefonsamtaler over Bluetooth-anlegg
- Telefonsamtaler kun via telefonen
- Sosiale medier
- Video på nettbrett eller telefon

Hva mener du påvirker din opplevelse med å bruke disse tjenestene i bilen, enten positivt eller negativt? Sammenlign med hvordan det er for eksempel hjemme i stua.

Dette elementet vises kun dersom alternativet «Radio (musikk) eller Radio (nyheter) eller Radio (radioprogram - P3morgen, Nitimen eller lignende) eller CD-spiller eller Musikk/podkast/lydbok eller Telefonsamtaler over Bluetooth-anlegg eller Telefonsamtaler kun via telefonen eller Sosiale medier eller Video på nettbrett eller telefon» er valgt i spørsmålet «Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du

kan krysse av flere.»

Er det andre i bilen som bruker noen av tjenestene nevnt over? For eksempel barn eller venner.

Dette elementet vises kun dersom alternativet «Radio (musikk) eller Radio (nyheter) eller Radio (radioprogram - P3morgen, Nitimen eller lignende) eller CD-spiller eller Musikk/podkast/lydbok eller Telefonsamtaler over Bluetooth-anlegg eller Telefonsamtaler kun via telefonen eller Sosiale medier eller Video på nettbrett eller telefon» er valgt i spørsmålet «Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du kan krysse av flere.»

- Ja
- Nei
- Noen ganger

Vil du fortelle om en konkret situasjon som gjerne gjentar seg? Hva var positivt eller negativt?

Dette elementet vises kun dersom alternativet «Radio (musikk) eller Radio (nyheter) eller Radio (radioprogram - P3morgen, Nitimen eller lignende) eller CD-spiller eller Musikk/podkast/lydbok eller Telefonsamtaler over Bluetooth-anlegg eller Telefonsamtaler kun via telefonen eller Sosiale medier eller Video på nettbrett eller telefon» er valgt i spørsmålet «Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du kan krysse av flere.»

Dette kan for eksempel være at barna i baksetet bruker nettbrett under kjøreturen, eller at personen i passasjersetet scroller på TikTok med lyden på full guffe.

På lengre bilturer, endrer bruken av tjenestene seg? På hvilken måte?

Dette elementet vises kun dersom alternativet «Radio (musikk) eller Radio (nyheter) eller Radio (radioprogram - P3morgen, Nitimen eller lignende) eller CD-spiller eller Musikk/podkast/lydbok eller Telefonsamtaler over Bluetooth-anlegg eller Telefonsamtaler kun via telefonen eller Sosiale medier eller Video på nettbrett eller telefon» er valgt i spørsmålet «Benytter du deg av disse tjenestene når du kjører/sitter på i bil? Du kan krysse av flere.»

Dette kan for eksempel være at personen i passasjersetet sover mye i stedet for å scrolle på sosiale medier, eller at man har pauser fra musikkanlegget til fordel for å dra i gang en quiz el.

Irritasjonsmomenter!

Kryss av for i hvilken grad du er enig i utsagnene.

Jeg blir lettere irritert i trafikken enn i stua hjemme

- Helt uenig
- Delvis uenig
- Vet ikke
- Delvis enig
- Helt enig

Jeg kjører bedre når jeg er alene i bilen

- Helt uenig
- Delvis uenig
- Vet ikke
- Delvis enig
- Helt enig

Jeg blir lett distrahert i trafikken

- Helt uenig
- Delvis uenig
- Vet ikke
- Delvis enig

Helt enig

Jeg har opplevd å bli avbrutt midt i en telefonsamtale når jeg sitter i bilen

Helt uenig
Delvis uenig
Vet ikke
Delvis enig
Helt enig

Jeg har alltid like god dekning i bilen som jeg har hjemme

Helt uenig
Delvis uenig
Vet ikke
Delvis enig
Helt enig

Jeg opplever sjeldent problemer med internettjenester i bilen

Helt uenig
Delvis uenig
Vet ikke
Delvis enig
Helt enig

Vær og kjøreforhold påvirker min bruk av digitale tjenester i bilen

Helt uenig
Delvis uenig
Vet ikke
Delvis enig
Helt enig

Bruk av ferger

Hvor ofte tar du ferge i løpet av en normal uke? 1 tur regnes her som tur/retur.

Alle elsker ferger!

0 turer
1-2 turer
3-4 turer
5-6 turer
Oftere

Hva bruker du tiden din på under fergeoverfarten?

Dette elementet vises kun dersom alternativet «1-2 turer eller 3-4 turer eller 5-6 turer eller Oftere» er valgt i spørsmålet «Hvor ofte tar du ferge i løpet av en normal uke? 1 tur regnes her som tur/retur.»

Her kan du krysse av flere.

Sitter i cafeen og ser utover havet
Sosiale medier

Videotjenester på mobil/nettbrett/styreflate i bilen

Går på do

Opplever du at den generelle dekningen (både dekning for å ringe/sende SMS + 4G/5G - dekning) er dårligere under fergeoverfarten?

Dette elementet vises kun dersom alternativet «1-2 turer eller 3-4 turer eller 5-6 turer eller Oftere» er valgt i spørsmålet «Hvor ofte tar du ferge i løpet av en normal uke? 1 tur regnes her som tur/retur.»

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

Dersom du har hatt noen negative opplevelser ved bruk av digitale eller videobaserte tjenester under fergeoverfarten, kan du beskrive hendelsene?

Dette elementet vises kun dersom alternativet «1-2 turer eller 3-4 turer eller 5-6 turer eller Oftere» er valgt i spørsmålet «Hvor ofte tar du ferge i løpet av en normal uke? 1 tur regnes her som tur/retur.»

For eksempel angående dekning, forstyrrelser eller gode opplevelser!

Bruk av berøringsskjerm/touch-skjerm i bilen

Mange biler er utstyrt med berøringsskjermer hvor man bruker fingertuppene for å navigere seg frem på skjermen.

Har du berøringsskjerm («touch» - skjerm) i bilen?

Ja

Nei

Hva pleier du å bruke denne skjermen til?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Her kan du krysse av flere.

Justere klimaanlegg

Radio/musikk

Video

Kart

Kryss av for i hvilken grad du er enig/uenig i følgende utsagn.

Det er irriterrende at hånden min beveger seg under kjøringen, men ikke selve styreflaten

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Styreflaten forenkler kjøreturen min

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Styreflaten reagerer ikke alltid når jeg vil at den skal reagere

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Jeg prøver å ikke bruke styreflaten når jeg kjører, men gjør det av og til likevel

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Styreflaten forstyrrer kjøringen min

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Styreflaten gjør det lettere å velge ulike instillinger for klimaanlegg, musikk mm.

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Styreflaten har en praktisk størrelse

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Jeg har ikke opplevd noe upraktisk med styreflaten i bilen

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Helt uenig

Delvis uenig

Vet ikke

Delvis enig

Helt enig

Har du videospill/YouTube/Netflix på styreflaten i bilen din, og hvis ja, benytter du deg av disse funksjonene?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

I hvilke situasjoner og hvordan benytter du deg av disse funksjonene?

Dette elementet vises kun dersom alternativet «Sjeldent eller Det hender eller Ofte» er valgt i spørsmålet «Har du videospill/YouTube/Netflix på styreflaten i bilen din, og hvis ja, benytter du deg av disse funksjonene?»

Er det noe annet du synes er vanskelig/irriterende med innebygde applikasjoner i bilen (på berøringsskjerm) som du kommer på nå?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Er det noen innebygde tjenester du savner i bilen, som kunne gjort hverdagen og kjøreturen litt enklere eller mer behagelig?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Er det noen tjenester du liker spesielt godt?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du berøringsskjerm («touch» - skjerm) i bilen?»

Taleassistenter

Taleassistenter øker i popularitet, og har som mål å gjøre oppgaver enklere for brukeren ved at man roper på de, og dermed gir dem en oppgave de skal utføre. Eksempel på disse er Apple (Hei Siri!), Amazon (Hei Alexa!) og Google (Hei Google!) sine tjenester. Eksempel på oppgaver de kan utføre er for eksempel "still alarm til klokken 8 i morgen" og "ring Mamma".

Benytter du deg av taleassistent i bilen?

Har det ikke

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

I hvilke situasjoner benytter du deg av taleassistent?

Dette elementet vises kun dersom alternativet «Sjeldent eller Det hender eller Ofte» er valgt i spørsmålet «Benytter du deg av taleassistent i bilen?»

Kartfunksjoner

Benytter du deg av kartfunksjoner (enten innebygd i bilen eller fra telefonen) når du kjører bil?

Har det ikke

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

Bruk av Cruise Control i bilen

Cruise control er en funksjon som gjør at man slipper å tråkke på gasspedalen/bremsen for å justere farten, men heller bruker en annen styring (knapper/hendel) for å gjøre dette.

Benytter du deg av cruise control i bilen?

Har det ikke

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

Benytter du deg av aktiv cruise control?

Dette elementet vises kun dersom alternativet «Sjeldent eller Det hender eller Ofte» er valgt i spørsmålet «Benytter du deg av cruise control i bilen?»

Dette er en form for cruise control der bilen foran bestemmer farten.

Har det ikke

Ikke i det hele tatt

Sjeldent

Det hender

Ofte

Hvorfor benytter du deg ikke av det?

Dette elementet vises kun dersom alternativet «Ikke i det hele tatt» er valgt i spørsmålet «Benytter du deg av cruise control i bilen?»

Jeg vil ha kontrollen selv

Jeg synes det er tungvint å bruke

Det gjør det vanskeligere å følge med på trafikken

Annet

Autopilot!

En bils evne til å styre seg selv uten din hjelp er et hett forskningstema.

Har bilen din autopilot-funksjon?

Ja

Nei

Har du benyttet deg av autopilot-funksjonen?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har bilen din autopilot-funksjon?»

Ja

Nei

Hvordan synes du autopilot fungerer?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

Veldig dårlig

- Ikke så bra
- Helt greit
- Bra
- Kjempebra

Gjør autopilot deg mer avslappet under kjøreturen?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

- Ikke i det hele tatt
- Sjeldent
- Det hender
- Ofte

Liker du best å kjøre med eller uten autopilot?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

- Med
- Uten
- Både og, det avhenger av kontekst

Dersom autopilot ikke hadde krevd at du må ha hendene på rattet, hva tror du at du ville brukt tiden på i bilen?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

Her kan du krysse av flere.

- Sosiale medier
- Musikk/podkast/lydbok
- Arbeidsoppgaver
- TV/film
- Sove
- Meditere
- Lese bok/aviser
- Følge med på trafikken rundt

Vil du utdype hva du ville brukt tiden på, og hvorfor?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

Hvorfor har du ikke prøvd autopilot enda?

Dette elementet vises kun dersom alternativet «Nei» er valgt i spørsmålet «Har du benyttet deg av autopilot-funksjonen?»

- Jeg stoler ikke på autopilot
- Jeg synes det er tungvint å skru på
- Jeg har ikke rukket å prøve det enda
- Jeg har hørt mye dårlig om det
- Jeg vet ikke hvordan jeg skrur det på
- Jeg vet ikke om jeg egentlig har det

Tror du at du hadde benyttet deg av autopilot-funksjon dersom du hadde tilgang til det?

Dette elementet vises kun dersom alternativet «Nei» er valgt i spørsmålet «Har bilen din autopilot-funksjon?»

- Ja

Nei

Vet ikke

Kan du utdype grunnen til svaret ditt?

Dette elementet vises kun dersom alternativet «Ja eller Nei eller Vet ikke» er valgt i spørsmålet «Tror du at du hadde benyttet deg av autopilot-funksjon dersom du hadde tilgang til det?»

Tid for premie!

Dersom du vil være med i trekningen av et gavekort til en verdi av 500 kr, kan du skrive inn e-postadressen din under. Dine svar i undersøkelsen vil ikke bli knyttet til denne kontaktinformasjonen, og e-postadressen vil bli slettet etter trekningen er gjort.

Skriv inn e-postadressen din her dersom du ønsker å være med i trekningen.

Kan det friste med et intervju?

Det hadde vært til stor hjelp dersom du vil møte opp til et (digitalt eller fysisk) intervju for videre spørsmål.

Intervjuet vil bestå av videre spørsmål rundt det samme temaet, altså digitale tjenester i bil, både i ikke-selvkjørende og selvkjørende biler. Det spiller ingen rolle om du har automatiserte funksjoner i bilen din eller ikke, da jeg ønsker respondenter fra flere kategorier. Send meg gjerne også en e-post dersom du ikke vil stille til intervju, men likevel har innspill!

De som stiller til intervju er med i trekningen av enda et gavekort på 500kr. Varigheten på intervjuet er fleksibel og kommer an på tiden du har til rådighet og hvilken informasjon jeg trenger.

Skriv inn e-postadressen din her dersom du ønsker å bli kontaktet for intervju.

Appendix C

User focus group questions

User focus group – questions

1. Thinking of the digital services you have in your car today, do you feel like something is missing?
2. Are digital services in the car important to you, or does it make no difference to the ride?
3. Do you find yourself distracted to digital services in the car, concerning paying attention to the road?
4. Have you experienced network disruptions in the car?
5. How is your concentration around the multimedia in the car vs at home? Do you pay the exact same amount of attention to the multimedia in both locations?
6. Are there any technical aspects in the car who may sometimes be a source for irritation?
7. Do you have higher, lower or the same preferences for sound quality and generally functional technology in the car vs at home?
8. When you are several people in the car, what is best - having isolated entertainment zones or one common?
9. What are the biggest influencing factors towards a better or worse experience of digital in-car services?

Appendix D
Expert interview questions

Expert interview – questions

- Please present your background in academia, worklife etc.

- What are your associations to in-car multimedia, and QoE in this context?

- What do you think will happen to in-car entertainment services in the future context of autonomous cars? What will be the biggest changes and challenges?

- Which (influencing) factors might be the most important to consider, in this context?
    - How can this look like more specific, thinking of methods and evaluation practice?
    - How may one evaluate these QoE factors in a context which not yet exists in common everyday life? To be able to conclude with results presenting useful insights, also ensuring high ecological validity and fidelity.

- How do you think one might best evaluate QoE for in-car multimedia in autonomous cars?
    - Which QoE evaluation methods would you prefer, and which do you think are the most important ones in the context of autonomous cars?

- How do you foresee the development and switch towards autonomous driving would look like, considering in-car multimedia use?

- What do you think will be the main challenges and changes in the context of autonomous driving and 5G?
- How will the future traffic network become in terms of 5G?
- Specific evaluation of QoE and 5G

- What do you think will be the main challenges and changes in the context of autonomous driving and 5G?

- Which opportunities do you see in using VR as part of QoE evaluation of in-car multimedia in autonomous cars?

Appendix E
Diary study questions

Dagbok 1 av 5

På tide å skrive dagbok!

Hva heter du (fornavn)?

Nå skal du benytte deg av en valgfri tjeneste i bilen. Dette må gjøres via mobilen din, gjerne tilkoblet bilen med Bluetooth, men dette er ikke et krav.
Ta en måling på **Nettfart.no** (trykk på *Start testen*) før bruk av tjenesten, og en måling umiddelbart etter. Ta skjermbilder av begge målingene, og send disse til meg i rekkefølgen **1. før - 2. etter**.

Hvilken tjeneste benyttet du deg av?

Dette kan være video streaming, streaming av musikk, podcast, CD-spiller, scrolling på sosiale medier, taleanrop.. Forklar så detaljert du vil.

På en skala fra 1 til 5, hvordan var den helhetlige opplevelsen du satt igjen med etter å ha brukt tjenesten?

1 er verst, og 5 er best.

Vil du utdype mer om hvorfor du svarte det tallet du svarte?

Tusen takk for ditt bidrag, og ha en fin dag! Jeg setter pris på deg!

Appendix F

Diary study information letter to participants

Dagbokstudien går ut på at du bruker Nettfart.no og tar en test før og etter (ved avreise og ved ankomst) bruk av en tjeneste i bil, for eksempel Spotify.

Hver dag i **5 dager (man-fre)** skal du..

1. Før du starter å kjøre bil, ta en Nettfart.no-måling (trykk *Start testen*) på mobilen din og ta skjermbilde av resultatet s
2. Start en digital tjeneste. Spotify, lytte på podkast, radio fra telefonen, hva som helst. Det er ikke viktig at du skrur på tjenesten *etter* Nettfart-målingen, det viktigste er bare at du måler farten ved avreisestedet.
3. Kjør bil og kos deg
4. Ved ankomst, ta en ny Nettfart-måling og ta skjermbilde av resultatet
5. Send de to skjermbildene til meg
6. Svar på dagens spørreundersøkelse

Annen informasjon:

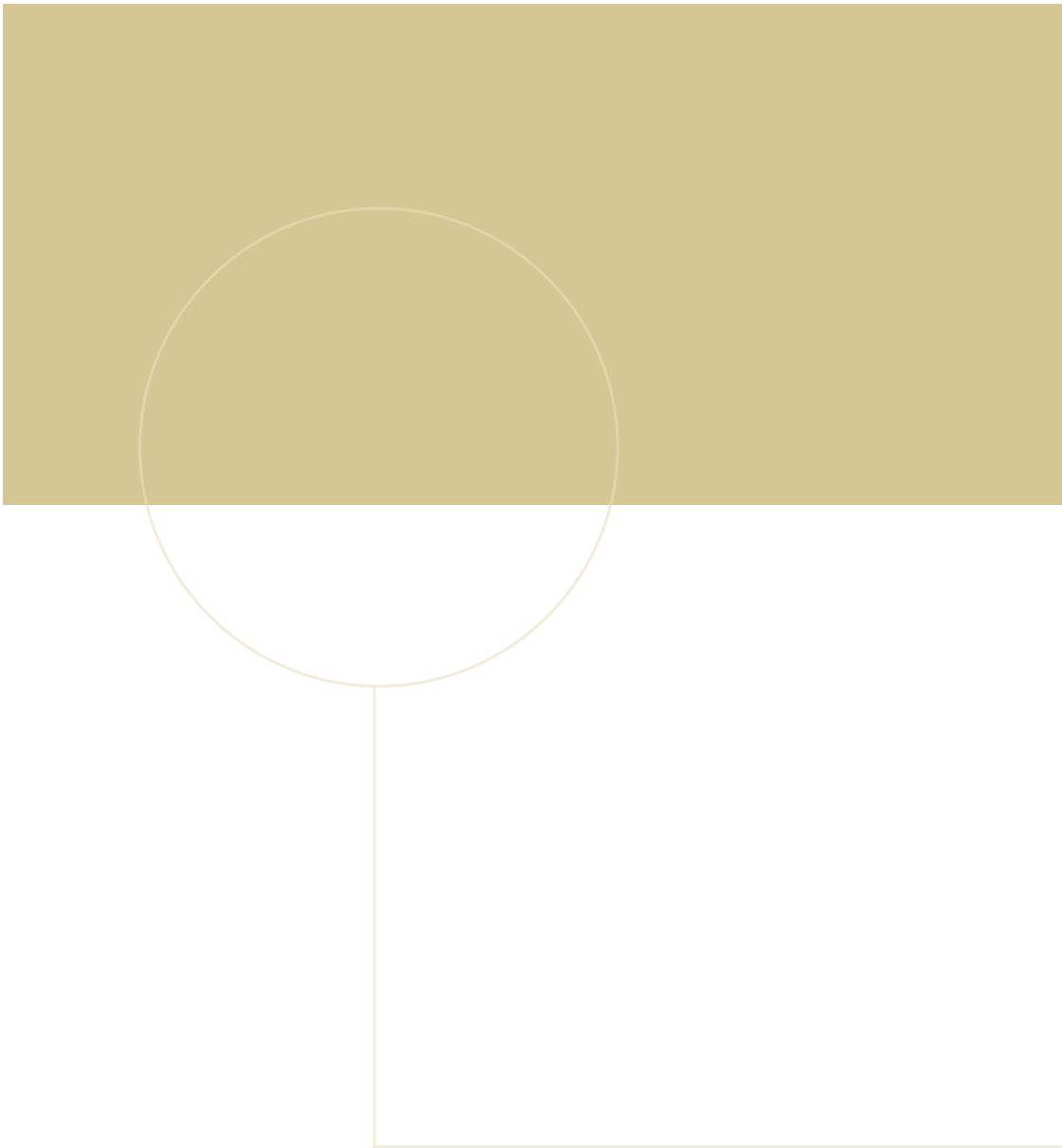
- Jeg sender deg et samtykkeskjema, med informasjon om dine personlige opplysninger
- Du får tilsendt en ny spørreundersøkelse (en lenke) hver dag som skal svares på
- De 4 første spørreundersøkelsene er veldig korte, den siste har noen flere spørsmål
- Mange velger å måle til jobb, for da er man tidlig ferdig for dagen og slipper å tenke mer på det (man trenger altså ikke måle tur/retur, kun en vei)
- Dersom du ikke er på jobb en dag, kan du heller ta målinger til butikken eller treningssenteret for eksempel
- Dersom du heller velger kollektiv transport en dag, kan du ta målinger på samme måte
- Jeg sender påminnelser på ettermiddagen dersom jeg ser at du ikke har besvart dagens spørreskjema eller sendt skjermbilder til meg den dagen
- Send skjermbildene fortløpende til meg, på hvilken som helst måte, sånn at du slipper å lagre og holde styr på disse selv
- Som takk får du et gavekort på valgfritt sted til en verdi av 100kr

Som forberedende før Dagbokstudien (som starter på mandag) kan det være lurt å legge til Nettfart.no på Hjem-skjermen💁🏼‍♀️

1. Bruk Safari-nettleser (om du har iPhone)
2. Søk opp nettfart.no
3. Aksepter cookies
3. Klikk på Dele-tegnet nede i midten
4. Klikk på “Legg til på Hjem-skjerm”

Nå har du et Nettfart-ikon på Hjem-skjermen, og da blir det enda enklere å huske på/ta Nettfart-målinger i Dagbokstudien!👨🏽‍🎓📊📝

Ved spørsmål, spør meg!



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