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SENSORY OVERLOAD IN PUBLIC TRANSPORTATION

Towards Accessible Mobility

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ABSTRACT

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Accessible public transportation is important for equality. However, sensory overload causes barriers and challenges for people living with sensory overload. The triggers to cause sensory overload can be, for example, noise, lights, overcrowding, heat, and visual input. All these triggers are present in public transportation, making it a challenging environment for passengers experiencing sensory overload. In addition, the same triggers can cause discomfort for other people.

Sensory overload as an experience can cause stress, anxiety, panic, withdrawal, and impaired concentration. Symptoms cause a threat to well-being and health, and it has an impact on life quality. However, people use different coping strategies and digital tools to prevent sensory overload. In the future developing different solutions may help people manage symptoms and add quality for other users. Therefore, there is a need to define design drivers that can be used as a basis for design in both the built and digital environment. This thesis focuses on the phenomenon, and how it affects citizens' accessibility of different transportation services, and the development of design drivers for future development. The material is gathered from seven participants living with sensory overload through semi-structured interviews and travel-along methods in public transport.

Key words and terms: sensory overload, accessibility, public transportation, design drivers, design for all

Contents

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1 Introduction

Humankind is living in the middle of a climate crisis, which implies that we have to make changes in everyday life. People need to shift from present carbon-intensive mobility modes, which favor private driving, to using more sustainable ways of moving around, public transportation being one of the essential solutions. To make public transportation a more appealing and accessible mobility mode, consideration of many different aspects is needed. Including the special needs of people. However, the sensory overload phenomenon is often overlooked when designing for the masses.

Sensory overload can be explained as the overstimulation of senses by physical inputs that exceed the individual's usual level (Scheydt et al., 2017). Sensory overload causes a variety of negative and unwanted symptoms and is triggered through different senses. Public transportation is full of triggers, which causes an impact on individuals' life in different areas. If the negative consequences appear while using public transportation or if those prevent using, for example, busses, trains, and trams, it can be said that public transportation is not accessible for people experiencing sensory overload.

During this study, 7 people participated in thematic interviews and field studies, which aimed at revealing how people with sensory overload experience public transportation and how it impacts their daily life, and how to design to make improvements in accessibility. The insights from interviews suggest that the experience of sensory overload leads to avoidance of public transportation and limits the area of living and personal choices. The results also indicate that sensory triggers in public transport might lead to an increased negative effect on health and well-being. Accessibility is an important component of social sustainability which includes the built and digital environment, which the interviewees talked about in parallel and interconnected.

The theme selected beforehand through company and university collaboration was mobility and sustainability in the urban environment. The topic was narrowed down to travel chains and the experience of traveling from a sensory overload perspective. The topic was interesting as there was little research on it, especially from the perspective of public transport and accessibility. This perspective was selected from the student's own interest and fitted in with the work of the business partners since it includes both the digital and the built environment, which are also themes for businesses.

Sensory overload seems to be a common phenomenon globally experienced by many different groups. Sensory overload is linked to several diagnoses. However, it is known that sensory overload may also occur without a diagnosis, mental illness, or intellectual disability. Nevertheless, research has been conducted mainly from a diagnostic point of view.

Firstly, during the literature review so far, no literature was found that focuses on sensory overload without any diagnostic frame. Secondly, no academic references were

found that discuss sensory overload in public transportation as the main focus. Furthermore, this study focuses on self-determination on sensory overload since the phenomenon is experienced by different individuals without a common diagnosis. Thus, the target group of our study is people living with sensory overload, based on their subjective evaluation rather than a medical diagnosis.

In addition, the topic itself seems to be overlooked, especially in the mobility context. Public transportation can be at its best an inexpensive way to move around independently (Rezae et al., 2020). However, Legrain and others (2015) stated that stress caused by commuting or the idea of it being stressful may lead to people not choosing the more sustainable mode of transportation. Stress and other negative symptoms are common for sensory overload, possibly making it an unpleasant mode of transportation.

This thesis focuses on sensory overload in public transportation in Finland experienced by 7 participants in the study. The results present how sensory stimuli appear in public transportation and create design drivers for future design work for solutions to support traveling with sensory overload in public transportation. The topic and possible findings might benefit also other people outside of a focus group.

First, the study defines the field in which the research will be positioned using previous research. The Conceptualizing the Field chapter identifies the research gap and the research questions that this study seeks to answer. The Implementing the Study chapter describes the research design and the respondents, which will serve as a basis for the examination of the responses. Furthermore, the chapter explains what was done at what stage and how. Ethical issues related to the research are discussed in a separate chapter, which is relevant in the context of this study and sheds light on why certain solutions were chosen. The Findings section presents the results of the study, which are further elaborated in the Discussion chapter. The Discussion section defines the design drivers based on the results. The Conclusion draws together the main conclusions of this study.

2 Conceptualizing the Field

Sensory overload has not yet been widely studied and has been discussed mainly from the perspective of autism spectrum. Apart from a few sources, there is little research on public transport and sensory overload. The subject is strongly linked to accessibility and thus to sustainability from a social sustainability perspective. This chapter defines the main research frameworks.

2.1 Sensory Overload in Public Transportation

When an individual brain is not able to process input stimuli leading to overload, it may cause negative consequences: confusion, panic, frustration, perplexity, withdrawal, (Malhotra, 1984) impaired attention and concentration, perceptual disturbances, stress reactions, disturbed thought process, behavioral problems, including ineffective coping (Scheydt et al., 2017). Sensory overload may be caused by the difficulties of filtering irrelevant environmental stimuli and the symptoms may amplify if the person is feeling unwell or is in a new environment (Kong & Maha, 2019). Multiple senses are used actively when traveling by public transportation and sensory overload can be triggered for example by sound, lights, and smell (Nielsen, 2023).

Defining attribute	**Signs and symptoms**
Impaired concentration	Decreased attention and increased distraction, poor concentration, and introversion, appearing distant.
Interference in detection	Hallucinations and illusions, body image disturbances, altered perception of time and interference with the experience of time, sensory distortion.
Stress reactions	Increased heart rate, blood pressure and respiratory rate, restlessness, poor mental well-being, mental fatigue.
Disturbed thought process	Thought disorder, flying thoughts, reduced problem-solving ability, delusions.
Behavioral difficulties and poor coping	Mood swings ranging inside of aggression, fear and sadness, increased agitation, avoidance and withdrawal, saying they are unable to protect themselves or separate themselves.

Figure 1. Symptoms based on Scheydt and others (2017).

Sensory overload seems to be a common phenomenon globally experienced by many different groups. Sensory overload is linked to several diagnoses, such as schizophrenia, attention deficit hyperactivity disorders (ADHD), or autism (cf. Jones et al. 2003; Kircher & Gauggel 2008; Ludwig & Stark 1973; O'Neill & Jones 1997; Quednow 2008; as cited in Scheydt et al., 2017). Research has mainly, if not only, approached sensory overload through diagnosis. However, it is known that sensory overload may also occur without a diagnosis, mental illness, or intellectual disability (Behrens 2003; Behrens et al. 2012; Scheydt et al., 2016b; Süllwold & Huber, 1986; as cited in Scheydt et al., 2017). Why not study the phenomenon through common factors rather than through diagnosis, which does not even cover the whole population experiencing sensory overload?

The focus in the literature has been mostly on the autistic spectrum. This approach leaves out a variety of people experiencing sensory overload in a variety of spectrum. The experience varies between individuals, situations, and different points in time: for another individual, some stimuli can be manageable or even positive, while for another it is overload or strain (Behrens 2003; Behrens et al. 2012; as cited in Scheydt et al., 2017).

In urban environments, sources of sensory overload are present in the form of noise, overcrowding, causing stress among other symptoms. Firstly, noise is one of the major sources of sensory overload (Malhotra, 1984), and in public transportation, it can be caused by other customers, announcements, and how the vehicle itself sounds. Secondly, overcrowding can cause sensory issues for example through touch, noise, and smells.

Falkmer and others (2015) did research on adults on the autism spectrum in public transport, where sensory overload was one of the aspects. In the research, it was pointed out that other passengers can cause sensory overload through tactile input during peak hours. They found out, that individuals on the autism spectrum avoid peak hours in public transportation, and one of the reasons can be sensory overload. These triggers can lead to stress, which is linked to experiences in public transportation in general.

Legrain and others (2015) say that stress is seen as one of the most serious health threats when commuting and one of the concerns is how stress may affect public health and therefore serious health and life satisfaction implications caused by stressful commuting. Despite the wide range of effects that sensory overload causes, in many studies sensory overload is merely a side note in the study and not the main focus of the research. In addition, none of the studies did discuss coping strategies created by people to cope with sensory overload.

2.2 Public Transportation and Mobility

On a global scale, one-third of the carbon emission comes from transportation (Anagnostopoulou et al., 2020), while in Finland transport accounts for the largest share of the carbon footprint (Akenji et al., 2021). Cities are key factors in climate change mitigation (Brozynski & Leibowicz, 2018), since more than half of the world's population lives in them and the number is growing due to urbanization trends and population growth (Rosenzweig et al., 2010). One of the strategies for the deep decarbonization of the cities is to support public transportation (Linton et al., 2021).

In 2021, 375 million trips were made by public transport in Finland. Around 60% of passengers used bus transport and a quarter used light rail. In Finland, the number of public transport passengers increased steadily before the COVID-19 pandemic, after which passenger numbers dropped. In 2021, the difference from 2019 was still 39%. (Traficom, 2021) The Statistics Finland table shows that public transport trip numbers were increasing in 2022 compared to 2021 as far as data are available (Statistics Finland, n.d.). Both Statistics Finland and Traficom monitor rail, tram, underground, bus, and ferry transport in public transport. In addition, air transport is also included in Statistics Finland's statistics.

Transportation modes and passengers	**2021**	**2022**
	Million trips	Million trips
Railway transport	55,0	76,1
Tramway transport	31,5	41,8
Metro	56,0	69,9
Bus and motor coach transport (Includes charter, not private)	222,7	-
Taxi traffic	44,6	-
Water transport (National and international)	9,6	17,1
Air transport (National and international)	5,4	15,6

Figure 2. Number of public transport trips in 2021and 2022 according to Statistics Finland (Statistics Finland, n.d.).

The use of public transport is closely related to the idea of mobility. In simplicity, mobility means being able to travel from one place to another (Merriam-Webster.com Dictionary, n.d.) A full and independent life requires travel to access basic services (Suen & Sen, 2004) and mobility means being able to travel when you want to, being informed about travel options, and having the ability and knowledge to use and pay for these travel services (Suen & Mitchell 2000, as sited in Suen & Sen, 2004). In addition, cognitive, psychosocial, physical, environmental, and economic factors influence mobility (Webber

et al., 2010). For example, sensory overload can be thought of as a cognitive factor affecting mobility. This in turn can be viewed through the concept of accessibility.

2.3 Public Transport Through Accessibility and Sustainability

Accessibility has many definitions depending on the situation (Persson et al., 2015) and can be defined for example: as "the quality of being able to be entered or used by everyone, including people who have a disability" (Accessibility, n.d.). The word access can refer not only to the interaction of the built environment and the removal of barriers but also to the opportunity to participate socially and politically in society. Williamson (2015) notes that the purpose is not to focus on or seek to correct or cure the disability of individuals but through institutional and material changes. (Williamson, 2015) Accessibility relates to many different situations, such as cognitive impairments, sensory impairments, and physical needs, just to mention a few. However, accessibility is still mainly discussed in terms of the obstacles that the physical world presents, for example when using a wheelchair.

Nielsen (2023) highlights in her research that psychosocial disabilities-related barriers to public transport are often non-physical. The research identified sensory overload as one of the barriers related to the mentioned group using public transportation. Furthermore, the study also raised the issue of sensory overload in station areas, where noise levels are often high. Sensory overload is not widely recognized as an accessibility issue, but it has implications that make it an accessibility issue.

Furthermore, accessibility in public transportation can be viewed through the idea of social exclusion. If the person's life is limited through lack of accessibility, it can lead to exclusion from society (Lucas, 2012). Accessibility can be defined in the context of public transport as, for example, the possibility to live a life of one's choice (Lätmann et al., 2016). Linked to this is the idea of social exclusion, defined by Levitas and others (2007) as:

> "Social exclusion is a complex and multi-dimensional process. It involves the lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole."

The European Accessibility Act includes public transportation as one of the most essential products and services. To improve accessibility, the directive aims to break down barriers created by divergent rules in the Member States. Furthermore, barrier-free accessibility in transport and mobility is recommended to be included in Part of Sustainable

Urban Mobility Plans by urban authorities. This also includes technological solutions in addition to other mobility aids. (European Parliament, Council of the European Union, 2019) In addition to this objective, it is important to identify aspects that contribute to accessibility in public transport, but which are not, at least not yet directly perceived as such. Sensory overload is one example of a phenomenon that has an impact on accessibility, although it is not reflected in the literature or discussions.

The focus in the literature has been mostly on the medicalized point of view, especially with the autistic spectrum. The medicalized view of disability refers to the view that disability is seen as a medical problem of individuals that needs to be cured, (Retief & Letšosa, 2018) and does not take into account the broader structures of society. The individual-centered approach is based on the premise that the individual must be rehabilitated to fit into society and that the environment is stable and neutral (Burchardt, 2004).

In contrast to the individual-centered view of disability, can be seen the social model of disability (Burchardt, 2004). According to The Social Model of Disability the dysfunctional structures of society make people disabled (Bolt, 2006). Furthermore, disabilities can be seen as a social construction, where the disability manifests itself when the surroundings create a barrier (Shakespeare, 2013). According to the social model, society acts as a disabler, which means that societal activities have a responsibility to make changes and solutions to remove or minimize barriers in the environment that prevent or limit access (Sullivan & Mauldin, 2020). Therefore, accessibility can be thought of as the concept that everyone should have equal opportunities to participate in society and, therefore, society should be constructed accordingly.

This can be thought of in terms of sensory overload. Sensory overload is not a disability as long as public transport triggers do not prevent or impede travel because of it. In addition, the word disability is not always a relevant word to use when considering accessibility, since our abilities change throughout our life (Persson et al., 2015).

2.3.1 Digital Accessibility

Currently, when traveling and observing other passengers, one cannot avoid noticing that most people's eyes are directed at the smart device in their hand and often with headphones in their ears, immersing themselves in their world. In 2019, 83% of Finns used a smartphone with internet access (Suomen virallinen tilasto, 2019). Julsrud and Denstadli's (2017) study discussed how internet-enabled devices have increased when traveling and how often they make travel time more pleasant and sometimes even improve attitudes towards public transport. However, the same study also points out that the increased use of smart devices has created new demands on public transport because people want to use smart devices during the trip and if it is not possible, the experience can be negative.

Accessibility is strongly linked to both the built and digital environment, even if they are not necessarily discussed in parallel. Digital accessibility can mean for example ability to use content with low vision, hearing loss, or cognitive limitation. This can be done with screen readers, captions in videos, and easily readable content. In a built environment accessibility can be for example ability to enter buildings with wheelchairs or the ability to use guidance with different abilities. In Public transportation both digital and built accessibility is present and therefore, the research on accessibility in public transportation should cover both aspects.

Furthermore, as mentioned earlier, the accessibility in public transportation includes the digital aspect in addition to the built environment. Mobile phone travels with a person as a personal entertainment center or workstation, as a navigation and route planning aid, and as a travel ticket (Bühler & Wallbruch, 2017). Digitality is also used to create one's own personal space during commuting, for example through sounds. Headphones are used to create a personal bubble, to listen to one's own choice of sound through smart devices to avoid hectic sounds created by the city (Patterson, 2020).

In Germany, the concept of 'total accessibility' has been used for public transport and the Bühler and Wallbruch (2017) study will try to define this concept in more detail. Although the concept is not well defined, they argue that it contains the idea of accessibility of both the digital and the built environment in the context of public transport, including built infrastructure and, for example, digital route guidance. It is not enough to simply improve the built environment in terms of accessibility; improvements must also extend to the provision of information on accessibility (Heck & Wallbruch, 2017). Thus, accessibility in public transport is a combination of the digital and built environment, therefore, they should be discussed together. However, this has not been done widely in previous literature.

While accessibility in the built and digital world is noted in the context of public transportation, sensory overload or sensory processing is not usually included when discussing on accessibility. Unfortunately, previous literature does not extensively consider sensory overload as an accessibility factor and how it affects to social exclusion. Furthermore, sensory overload in public transportation has been mostly discussed through autism, even though it is known not to be linked to many other diagnoses and does not require any diagnosis to manifest. Therefore, the previous solutions have been approached from autism specific point of view and therefore may not apply to the wide spectrum of sensory overload as an experience.

2.3.2 Sustainability and Accessibility

Furthermore, the idea of accessibility is closely linked to sustainability. Friman and others (2020) point out that to make public transport a viable alternative to private cars, attention must also be paid to accessibility. When speaking of sustainability, there are usually three to five domains in the discussion. The most commonly used framework is the Triple bottom line, which includes three domains: environmental, economic, and social (Little, 2014). James and Magee (2016) recognize the following domains of sustainability: ecology, economics, politics, and culture. Usually, there are at least three following: economic, environmental, and social aspects (Cavagnaro, 2017). Different sustainability aspects do not exist without one another, rather they are interdependent. Meaning, that lack in some will affect negative also to other dimensions (Fuchs & Obrist, 2010) and vice versa.

All of the above-mentioned aspects of sustainability are present in the topic at hand. However, especially social sustainability is the focus through accessibility and inclusivity. For example, considering how accessibility affects on environmental aspect. the shift towards more sustainable modes of transport in dense cities to take place, it requires accessible public transport to be a viable alternative to car travel (Friman et al., 2020).

However, as argued above, sensory overload can cause an accessibility issue when using public transportation. Hence, there needs to be more research done on how sensory overload affects the use of public transport to create a viable alternative to the private car. This perspective can also bring new insight into the travel comfort of other passengers and is therefore also a fruitful way to explore travel as an experience.

2.4 Previous Solutions for Sensory Overload

Sensory overload and related solutions have previously been studied mostly from the perspective of autism. Solutions have been sought in both the built and digital environments. One design work directly related to the topic was found in the previous literature. Rezae and others (2020) made a demo study for an autism-specific application OrienTrip to help navigate through the challenges in physical and mental aspects of public transportation. Sensory overload was one of the themes and part of the designed features. The features were, for example, route planning, real-time information on crowdedness, location tracking, strategies on how to manage anxiety, and sensory overload in public transportation. One of the features was designed specially to help with sensory overload, but some other functions are also beneficial for the mentioned purpose. For example, real-time information on crowdedness helps to choose less packed shifts, crowdedness being one of the possible triggers. In addition, anxiety management function can be also beneficial for

people experiencing sensory overload, since anxiety can be the result of sensory processing difficulties (Haas et al., 2020). Furthermore, route planning can be beneficial since people feel more stress during longer commutes (Legrain, 2015).

As mentioned, noise is one of the biggest triggers for sensory overload and noise is one of the biggest health issues as well. People living with sensory overload may use headphones to control unpleasant sounds (Neave-DiToro et al., 2021). Headphones are also used to indicate that a person does not want to be interrupted in addition to shutting down the noise (Haas et al., 2020). Noise-canceling headphones can also help to create personal space in a crowded vehicle, in addition to the reduction of noise (Hagood, 2011).

Other options could be decreasing crowding by adding extra carriages or adding areas or seats that are sensory-friendly (Falkmer et al., 2015). Furthermore, dimming the lights, quieter areas, or providing sensory tools can be helpful (Kong & Maha, 2019).

2.5 Sustainable Design Process and Design Drivers

To address the issue at hand, for solutions, design drivers need to be formed from a sensory overload perspective. Here is extremely important to take into consideration sustainability aspects and sustainable design in a physical and digital world.

Participation is an important aspect of sustainable design. When people participate, they are part of creating the reality around them, which they partake in every day. Society, which is cooperative, participatory, and sustainable, guarantees a good life for all. This also applies to information society by including people and thus, improving life for all and the future as well. Different sustainability aspects do not exist without one another, rather they are interdependent. Meaning, that lack in some will affect negatively also to other dimensions. (Fuchs & Obrist, 2010) This should be noted in the design process.

When designing accessible ICT products, the benefits usually extend to other stakeholders as well. Universal design, inclusive design, accessible design, design for all, and accessible design are all different design approaches that try to make ICT products more accessible. The different approaches are coming together making it harder to separate them from each other. However, they all understand different needs and aim to include them in the design process and the product and services. (Persson et al., 2015).

Design for all is most applied to other concepts, and it aims to design for as many people as possible. However, emphasizes that no one solution would fit all. Now people live longer and their need change throughout their lives, which bring variety to their needs. Trying to include these needs into the design process and the product is one of the key factors in design for all approaches. The aim is to enable equal opportunities to participate in society for all people by accessible design. This happens through the design process, where the end-users are part of the process every step of the way. (Persson et al., 2015) As the experience of sensory overload varies between individuals, it is important to involve those who experience sensory overload in the design process.

Participation and collaboration are part of the Scandinavian design culture. Cooperative design is an approach that acknowledges that bringing different users with different special requirements brings new insights to the process making it more fruitful. This can help to increase accessibility. The process is fully cooperative between users and the designer, engaging them fully in the conversation by sharing knowledge and experiences while designing together. (Persson et al., 2015)

Design drivers are the principles that guide design, and they are often developed through customer research. They bring the experiences of customers and individuals into focus. These crystallize the needs of users and clarify the need for which the design is being made. (Tuulaniemi, 2011) This is also seen as essential for sustainable design. It is important to identify the right needs to be able to design for them. As there does not seem to be much design for or from the perspective of sensory overload, it is important to start with what the target group needs to ease their travel in public transportation. Design drivers help to create guidelines in which the design should be taken forward.

2.6 Research Questions

Based on the literature and the objectives of the study, the following research questions were defined to fill a gap in previous research on the topic:

1. Main question: How to improve accessibility in public transportation for people who experience sensory overload?
    a. Sub-question 1: How sensory overload is present in public transportation from the perspective of passengers?
    b. Sub-question 2: What design drivers improve accessibility in public transportation for people who experience sensory overload?

3 Implementing the Study

Part of the Sustainable Societies and Digitalisation master programme is a company collaboration project between the student, Tampere University, and pre-selected companies. This research team was formed with Tampere University, KONE Corporation, and Solita LTD. KONE is a company in the elevator and escalator industry and Solita is a technology, strategy, and design company. The companies selected for this collaboration were interested in human mobility in the urban environment, and the work started with the title Mobility & Sustainable Mobile Urban Flow.

The project team consisted of five to six people, in addition to the student. There were two participants from each of the parties. The team changed during the project but was able to continue without interruption.

Company suggestions were set out to narrow down the topic. The idea was to research the 'Wicked problem' related to mobility. Wicked problem is a term borrowed from urban planners to describe problems that are not well-defined, involve multiple domains, and cannot necessarily be solved once and for all, but have to be solved over and over again (Rittel & Webber, 1973). For this reason, the problem was also approached collaboratively between different actors to take as broad a perspective as possible.

First, the topic was approached at a more general level from the perspective of travel chains, with the aim of combining both mobility data and the physical environment. However, the topic was eventually chosen as sensory overload and public transport after the author drew attention to the phenomenon in discussions on various platforms. The work started with the idea of developing a digital tool. However, the data soon showed that it was worth broadening the scope to include both the built and the digital environment. Thus, a more precise delineation of accessibility and design drivers related to the phenomenon emerged from the final interview data.

This perspective combines both the built environment and technology, thus connecting the interests of both the author and the other parties involved. The framing of the topic in terms of human mobility came from both the university and companies, but the more precise framing, topic, and research questions have been shaped by the author's interests.

For this work, the course collaboration provided a platform for discussion between experts in different fields with a common interest in mobility. The cooperation consisted mainly of meetings to discuss the different topics of the subject. The experts proposed different approaches, and methods and commented on the text in different phases. However, the final work is the student's own, although it was supported and worked on together.

3.1 Course Collaboration

Part of the project was also a cooperation with three other students in a course Methods in Human-Centered Design at the University of Tampere. In this collaboration, short demo interviews were conducted with the focus group and a preliminary design idea was created based on the interviews.

The group of students on the course wanted to focus their work on technological solutions. They implemented a demo based on the existing public transportation application Nysse in Tampere and developed functions for the application that aimed to make the journey more comfortable for people living with sensory overload. The team interviewed four public transport users who experienced sensory overload. Based on these interviews, they came up with the following features for the Nysse application:

- **In-vehicle announcements:** brought in vehicle announcements through one's smartphone to one's headphones.
- **Navigation announcements:** auditory guidance of the trip, which indicates the arrival of a vehicle and the approach of a stop by either sound or vibration.
- **Vehicle congestion alerts:** reports a busy shift.
- **Loud noise level alerts:** reports an increase in noise levels.
- **Automatic lighting adjustments:** the user can choose the lighting level that suits them, and the phone automatically adjusts it according to where they are sitting.
- **Histograms of congestion:** the user is presented with a histogram of the congestion levels on the selected public transport line.

They also created a new section in the settings, where users could decide which functions to enable. These features were used as examples of possible digital solutions to refine the discussion in the interviews and to show attitudes toward digital solutions. These prompts were used as a help in defining digital design drivers by providing input on ideas and reactions to them. In this way, stakeholders were included in the design process along the way, which is typical for design for all concepts.

3.2 Selected Methods

This study is qualitative research, which is empirical and serves as a method of analysis for examining and arguing from the data (Tuomi, & Sarajärvi, 2017, p. 22). Since the research aims to explain how interviewees experience the world around them, it belongs to the interpretivism paradigm. Interpretivism is tightly bound up in qualitative research and it means a way of interpreting meaning and action according to the actor's own subjective frame of reference. (Williams, 2000)

The data was collected through semi-structured thematic interviews. Thematic interviews were a suitable method for data collection, as the aim was to gather the interviewees' experiences on a topic for which thematic interviews are well suited. The semi-structured approach was chosen because it was assumed that experiences differed and by keeping the situation interactive, it was possible to explore in depth the themes that were of particular relevance to each interviewee. (Hyvärinen, et al., n.d.)

The themes of the interviews were divided into five different categories: 1. transport mode choices, 2. different senses, 3. situational factors, 4. symptoms, and 5. assistive methods. Transport mode choices focus on how and when individuals move, and how they choose certain modes of public transportation. Different senses map out which senses trigger sensory overload and whether is there a difference between senses in significance to the experience. Sensory overload might be triggered in certain situations, such as when stressed or tired, and situational factors focus on that and how it affects commuting. Symptoms focus on how different outcomes affect well-being and how the symptoms are treated by individuals. Assistive methods tell how people try to avoid and control sensory overload. In aids and strategies are also discussed what help individuals might need and hope for in the future and some ideas are presented for their evaluation.

Each interview went through these same themes, but in the themes varied in emphasis according to the interviewee's experience. After each interview, the main themes that emerged were written down in separate document, which had been emphasized in the interviews.

The interviews used a funnel technique, moving from general to more specific questions (Hirsjärvi & Hurme, 2008). The aim was to make the interviewee feel that they could answer the questions. The opening question was simple and broad, from which the focus was gradually increased. The interview questions were created based on earlier literature, research questions, and course collaboration at Tampere University. People were involved in design ideation already at the interview stage by giving and asking for ideas and watching their reactions and further ideation on the topic.

Participants were contacted and selected through social media, which makes them conveniently available. Therefore, the method of selecting participants is convenience sampling, which means recruiting participants who were available at the time of recruitment at the selected arena (Baxter et al., 2015). The interviewees were not asked about diagnoses that might be linked to sensory overload, but their own experience was sufficient to justify their participation in the interview. The data withholds seven interviews. Due to the small size of the sample, this study does not comment on quantities unless they are significant for the results.

Given that the focus group may have different needs and abilities caused by sensory overload, four different approaches were implemented based on the person's own choice.

1. Interview face-to-face and discussion in public transportation, 2. Face-to-face discussion, 3. Remote interview and discussion remotely in public transportation, 4. Remote interview. The interviewee was encouraged to take breaks if needed and to express their needs throughout the interview. The chosen data collection method may leave out people with more limiting sensory overload experiences since interviews are a demanding process for an individual.

Respondent 1	Pirkanmaa, 31. Preparer. Avoids public transportation, prefers walking.	Interview face-to-face and discussion in public transportation (tram).
Respondent 2	Pirkanmaa, 34 years old. Uses tram and makes choices based on the tram route.	Interview face-to-face and discussion in public transportation (tram).
Respondent 3	Capital Region, 32 years old. Avoids buses and prefers rail transport.	Interview face-to-face and discussion in public transportation (bus).
Respondent 4	Capital Region, 33 years old. Travels with children. Commuter, who chooses to work remotely when possible.	Face-to-face discussion.
Respondent 5	Capital Region, 44 years old. Commuter. Chooses to walk for aesthetic reasons. Enjoys the silence.	Interview face-to-face and discussion in public transportation (commuter train).
Respondent 6	Pirkanmaa, 36 years old. Avoids public transportation. Travels with a child.	Face-to-face discussion.
Respondent 7	Päijät-Häme, 31 vuotta. Uses trains, enjoys the dim lighting in long-distance buses.	Remote interview.

Figure 3. Description of interviewees.

3.3 Analysis

Qualitative analysis was used for this study, as the aim was to find basic information about the phenomenon, which was then constructed from the data (Eskola & Suoranta, 1998). As the work was qualitative in nature, more detailed methods of analysis were selected only after the data had been collected. The analysis of the data proceeded in three main stages, which also coexisted with each other: 1. reduction, 2. clustering, 3. abstraction, and creation of theoretical concepts (Tuomi, & Sarajärvi, 2017 p. 91).

It should be noted that the progression was not as straightforward as this, but rather, the steps were returned as needed. The stages can also be broken down into smaller parts. Categories were redefined between the different stages as the perspective became more precise. The overlapping of the sections was also influenced by the fact that the analysis started briefly after each interview by writing down the main ideas.

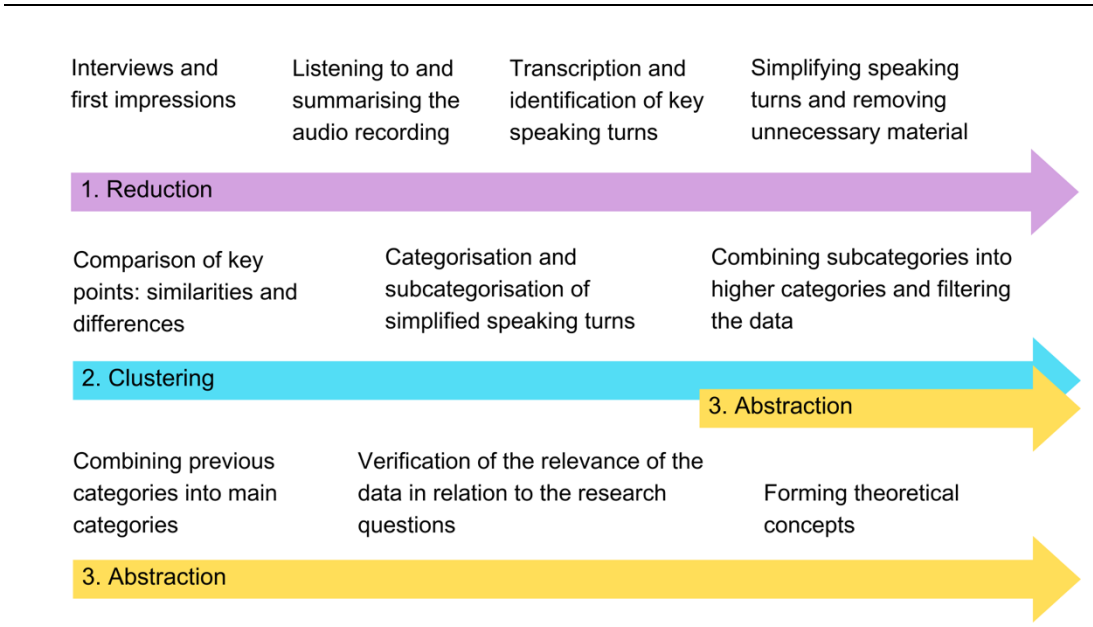

Figure 4. Analysing process illustrated.

- **Reduction:** the analysis started with listening to the material and summarizing the key points and general impression of the recording. The interviews were then transcribed to facilitate comparison between the materials. The material was then underlined and the key observations from the speaking turns were extracted and written down in a separate document. The speeches were described more concisely afterward to summarize the material. The most irrelevant elements of the material were set aside. This was repeated for each piece of data.

- **Clustering:** after reduction, the key points found in the data were compared with each other, and similarities and differences were identified. These were grouped into different categories, which were refined as the work progressed. Gradually, the expressions that had been reduced in the previous stage were categorized into their subcategories. These categories were then combined into higher categories and main categories. Still, at this stage, irrelevant topics that were of interest but not relevant to the research questions were dropped.
- **Abstraction:** clustering is part of the abstraction phase (Tuomi, & Sarajärvi, p. 93, 2017), where theoretical concepts are formed. In this stage, the previously collected categories were combined into larger entities and theoretical concepts relevant to the research questions.

4 Ethical Aspects of the Study

Ethics refers to the idea of right and wrong action and includes reflection on what it takes to make ethical choices. In the context of conducting research, it means considering the different stakeholders in terms of impacts and perspectives. (Anderson & Corneli, 2018) For this study, ethical reflection has been particularly important, as previous research has shown that this is a phenomenon that affects health and well-being, making it important to take care of the safety and anonymity of participants.

4.1 Sampling Method

One of the most important issues to consider is the privacy of the interviewees and the data should be presented in such a way that the interviewees cannot be identified or traced. This is done, for example, by deleting information that refers to them (Anderson & Corneli, 2018). For example, employers may have preconceptions about the phenomenon, which may be a barrier to recruitment (Anderson & Corneli, 2018). For this reason, the data do not reveal the interviewees' place of residence, place of work, gender, name, or through which channel they were contacted.

The home city was not highlighted as interviewees also talked about their experiences with public transport in other cities and countries. Furthermore, no nicknames were given to the interviewees in order not to create assumptions about the gender of the interviewees. This was done to enhance the privacy of the interviewees, as gender identity was not assumed to have an impact on the experience. These choices are also influenced by the way the data are collected. Since convenience sampling was used, with the aid of social media, it is expected to bring participants from the interviewer's social circle. Therefore, particular care must be taken with hiding the origins of the data.

Convenience sampling also contributed to the fact that the interviewees were roughly the same age as each other, as the message mainly reached this age group based on the age of the researcher. It should also be noted that those with the most severe symptoms may be excluded, as the interview situation alone may be too overwhelming to contemplate. In addition, Baxter and others (2015) criticized the convenience sampling method for not providing certainty about the representation of the collected data for the whole population.

4.2 Creating Save Environment

The relationship between the interviewees and the interviewer also requires reflection from an ethical point of view. Since the method used brought the interviewees from a pre-established social circle, some of them already had some kind of pre-existing relationship with the researcher. Since the relationship with some of the participants was already pre-existing, it is assumed that the steps in the relationship-building process in the research process accelerated (McConnell-Henry et al., 2009). In McConnell-Henry and others'

(2009) experience, in this case, the data being studied has been rich in breadth and depth because no time has been taken to create a space in which it is easy to open up.

Creating a safe space has been particularly important, and when traveling together, there is the courage to stop the journey if the symptoms become too overwhelming. Familiarity can both lower the threshold to say something and make it more difficult because one does not want to disappoint the acquaintance in terms of continuing the relationship.

It is important that the interviewee has the option to interrupt the interview if they wish (Anderson & Corneli, 2018) and this option was also reminded in the middle of the interview. This was also to consider any special needs of the target group if sensory overload had become excessive during the interview situation. For the same reason, each interviewee was allowed to choose the interview method that best suited their needs, including in terms of sensory overload.

If some kind of relationship already exists, it is particularly important not to base information on prior expectations and assumptions, but to seek information from the data collected (Asselin, 2003). In this study, the interviewer kept a 'logbook' of the whole process and their feelings and thoughts during the process. In addition to this, the researcher had an ongoing discussion about their ideas with other experts, such as the collaborators. Asselin (2003) also recommends careful record keeping, reflection on one's own role, and discussion with other experts. Furthermore, in the interview situation, the discussion was limited to the topic at hand and the researcher was conscious of their questions and how to frame them to avoid making preconceived assumptions.

Although Anderson and Corneli (2018) point out that it is good to limit the possibility of others seeing the respondent taking part in the interview, this aspect was not fully taken into account in this study, although it is an ethically interesting question. However, the risk of being put in an ethically questionable situation was tried to be limited by the structure of the interviews. When the interviews involved traveling on public transport, the interviewee could be seen to be participating in the research. When traveling on public transport, more general observations were made, rather than focusing on personal experiences of the subject. These could be further elaborated after the interview in a more private setting, as was done with some of the participants. The respondents themselves could choose whether to participate in this part and it was stressed to them at the beginning and during the journey that they could withdraw from the situation at any time.

4.3 Permits and Considerations

Respondents must permit the study, which must be informed consent. This means that the interviewee must understand the purpose of the study and that they are participating voluntarily. (Anderson & Corneli, 2018) Permission was requested verbally on a recording at the beginning of the interview, describing the purpose of the study and how the data

would be used. They were told that the data would be treated confidentially and anonymously. They were also told that in addition to the actual work, the results might also be published on other platforms, such as a blog related to the topic or on social media. Interviewees were told that the recordings would be deleted after the evaluation of the work. It was further stressed that the interviewee can interrupt the situation if they wish and also the permission to request the deletion of the recording.

However, it is interesting to consider whether the interviewee is ever really fully informed, as Husband (2020) discusses in an article where previous interviews had an impact on the interviewees' future choices. Husband pointed out that although ethical considerations had been made, they did not know at the time of the interviews how they would later affect the interviewees' lives, even though life changes were not the purpose of the interviews.

According to Husband (2020), researchers should be aware that interviews can have an impact and should also inform the participants of this possibility. According to this research, researchers cannot just assume that they are data collectors but acknowledge that they can also have an impact on the interviewee. While a direct cause-and-effect relationship cannot be automatically assumed, interviews can be a catalyst for a change. (Husband, 2020)

This is also an essential aspect of this study. In particular, previous research suggests that sensory overload may play a role in a person's health. Relevant questions may include: 1. Can the interview lead to more attention to triggers and thus more exposure to sensory overload in the future? 2. Can the interview then have an impact on future choices? These questions remain unanswered at this stage but may be interesting aspects for further research. Reflection may also have an impact on the ability to take better account of one's own needs in the future and to understand their importance for one's well-being.

4.4 Research Practices

When doing research, the aim is always to benefit science and society by answering new questions or providing more knowledge. Similarly, it can also benefit the interviewees themselves, even if this is not the main purpose of ethically conducted research (Anderson & Corneli, 2018). This study aims to achieve these goals and therefore, reflection on ethical issues is an integral part of the research process.

Furthermore, due to the limitations of previous research, secondary sources have been used for the sake of content relevance, as not all the material is accessible to the original source, for example, due to language limitations. Wherever possible, the original source is referred to.

The interviews were conducted in Finnish and later translated into English. Part of the interviews are translated by the author, and they are formed in a way that reflects the

intent in the best way. Therefore, no direct translations have been made, as the vocabulary and way of speaking differ between languages.

The research aims to follow the basic principles of good scientific practice: reliability, integrity, respect, and accountability (Tutkimuseettinen neuvottelukunta, 2023). Reliability has been taken into account in the choice of methods, the design of the study, the analysis, and the opening of this process. This study seeks to honestly open up the processes through which it has emerged, the discussions have been conducted openly between the different actors without secrecy. Collaboration has sought to emphasize and show appreciation for other authors and likewise, for example, through referencing practices in this work. The aim is to take responsibility from start to finish, right up to publication and any subsequent post-publication discussions.

5 Findings

Through different stages of analysis, the following conceptual categories were found: effects of sensory overload in public transportation, situational factors, and strategies for managing sensory overload. The themes were partly the same as in the interview categories, but further analysis revealed links between them, and thus the categories were refined during the analysis phase.

Participants were allowed to define for themselves what they considered to be public transport, which also partly reflected their travel habits. Some included trains, planes, and ships in addition to local transport. For example, some people actively moved between cities for work, making the train to another city a natural means of public transport.

It soon became clear that the previously planned limitation to digital solutions alone did not work, as the digital and built environments seemed to merge closely together. People spoke very naturally about both the built and the digital environment and, as an experience, the two became intertwined. The smartphone was used in a variety of ways to manage sensory load before, during, and after the trip. For example, the route planner was perceived as contributing to the travel experience, and digital tools were used to plan the journey, which was an important part of the travel experience and sensory overload management. For example, HSL, Nysse, and Google Maps were used for trip planning.

> Respondent 6 describes the impact of the route planner on the travel experience:
>
> "When I think about it, using this is strongly linked to travelling and the comfort of use. When in a way I feel that I've thought about them quite a lot still separate”
>
> They continue:
>
> “Well, this makes things easier since I know when I can get off the bus. That I can see where the bus is moving as a dot."

Rail transport (train, tram, and metro) was the most pleasant means of public transport, for reasons such as the sense of space, predictability, acoustic comfort, and temperature. Only respondent 7 said that they mainly preferred buses, which were the least preferred option for most people, who avoided them to the very end. Respondent 4 said they found trams suffocating and preferred the fastest mode of transport, which was often the metro or bus.

The car was also mentioned as the most pleasant mode of transport as it allowed one to be at peace from sensory pollution. However, there was a perceived conflict with it, for example in terms of environmental friendliness and safety, which is why public transport was still the main mode of transport used. Respondent 2 reflects that if they had a car, they would replace all bus journeys with it.

5.1 Effects of the Sensory Overload in Public Transportation

Results from interviews suggest that sensory overload affects each person on many levels. It affects where people live, where they work, where they move, and how wide is their area of living, based on where the preferred vehicle operates. In addition, sensory overload causes avoidance of public transportation. It also affects on person's wellbeing and health and can cause emotional struggle. Respondents felt that sensory overload had a strong impact on their well-being, due to the different symptoms and their consequences. Respondent 3 also described the impact on their relationships, as they sometimes had to leave a place quickly due to sensory overload, which can seem rude.

Some avoided public transport altogether. For example, respondent 1 does not use public transport even on a monthly basis due to sensory overload, in which case the location of the place of residence also plays a role. They needed to be able to walk from their home to places that were most convenient for them. Respondent 6 also tried to avoid public transport and chose walking instead because of the sensory overload. The same respondents also mentioned a part of the city they would like to visit but could not since there was no suitable means of transport for them.

A few mentioned that sensory overload had affected their life choices, such as where to work or live. Respondent 1 emphasized that they needed a location at home where they could walk to most essential places. In addition, respondent 2 says that they chose a workplace where they could get to by their preferred mode of transport (tram) rather than the worst (bus).

Several people mentioned that they would stop the trip if the sensory overload became too much to cope with, although on the other hand it was often seen as something that they just had to learn to tolerate. For example, respondent 2 describes sensory overload in public transport as an agony that has to be suffered.

Another issue that emerged from the material was the desire not to be a nuisance. Many felt that it was awkward to consider their needs and they didn't want to be a nuisance to others. For example, they did not want to put earplugs in their ears in the presence of a crying child, so that the mother would not feel uncomfortable about the gesture. Changing seats also seemed difficult, as it was seen as offensive behavior towards the person sitting next to them.

When traveling in company, it was not always possible to communicate how one felt for fear of not being understood and of being seen as difficult. Many wondered if they were the only ones who had such a problem with sensory overload and public transport. One interviewee pointed out that the subject was not discussed in their childhood so their symptoms did not feel real, simply something to be endured, something that everyone else knew better. Interviewees seemed to 'accept' the situation and did not necessarily expect it to be resolved. Despite the fact, that there seem to be significant impacts on their lives. They also wonder whether providing assistive devices would be a problem and a nuisance.

> **Respondent 3:**
>
> ”And then, on the other hand... There are also feelings of guilt and shame. Especially of feeling of anger, because it's very uncontrollable about certain sounds. And it's like a very.... I mean uncontrollable in the sense that the feeling is very strong, and I can't do anything about it. And of course, I can control my own reactions, but the feeling comes in a real tidal wave kind of way and... That's why, of course, sometimes I wonder why. Why me? I know that everyone is not like that, or why am I so sensitive or touchy-feely, and why do I get angry about such simple things, that other people don't even notice?"
>
> **Respondent 5:**
>
> ”You can't think of it as a thing, because it's something you've learned to live with and it's something that nobody can or wants to do anything about."
>
> **Respondent 6** on taking needs into account in design:
>
> ”So I immediately thought that I don't want to be a burdensome person. I immediately thought of it from the point of view that I was somehow demanding too much or that I would be a burdensome person when I wanted to know such things."

5.1.1 Symptoms

The sensory overload caused a wide range of symptoms, some more severe than others. In the interviews, common symptoms were exhaustion, anxiety, strong emotional and physical stress reactions, panic, anger, irritation, nausea, trouble with breathing, and even physical pain. These findings are in line with previous studies. All the mentioned symptoms were:

- Exhaustion
- Anxiety
- Stress
- Heart palpitations
- Panic
- Anger
- Irritation
- Nausea
- Troubled breathing
- Physical pain (or idea of feeling like physical pain)
- Feeling like fainting
- Physical discomfort
- Fatigue
- Need to withdraw
- Muscle tension

These symptoms can also be related to each other, for example, when feeling anxious, the heart can start beating faster. Furthermore, people felt the need to withdraw and sometimes to escape. Some have left the vehicle in the middle of transportation when the sensory overload felt too much to handle.

> **Respondent 3** on reaction to triggers, especially to sound:
>
> ”They trigger very strong emotional reactions. It's anger, really, kind of aggressive anger. Or then distress, that I want to escape from the situation and cry.”
>
> **Respondent 5** about the sensory load caused by sounds:
>
> ”But on a bad day, it's physical pain, what it causes."

5.1.2 Triggers

Six out of seven participants mentioned noise to be the biggest trigger for sensory overload and the seventh also mentioned noise multiple times as one of the main triggers. For some biggest triggers were noises created by the vehicle, such as audible warning sounds, ventilation, and tremor. Some felt the noise coming from other people was the most triggering. Noise and sudden sounds were the most disturbing triggers, but a steady chatter without peaks was tolerated. Noise was already present in the waiting area before the actual journey and could trigger sensory overload.

Sound (described as noise)	Vehicle: audible warning sounds, ventilation, tremor.
	Other people: discussions, talking loudly on the phone, crying child
	Uncontrollable sounds (people, vehicle, construction sites)
	Sounds from devices, such as a smartphone.
Sight	Strong lights
	Strong colors
	Strong contrasts e.g. between light and shadows while moving
	Info screens: movement, strong colors, rapidly changing content,
Smell	Unpleasant smells
	Poor air quality
Touch	Touch of other people
	Materials: Leather causing sweat, fabric is made of long hair which stings, slippery seat
	Heat
	Movement of the vehicle
	The driver's driving style
	Uncontrollable movement of people in and out of vehicle

Figure 5. Mentioned triggers divided into sections.

As we can see from the results and figure 5, no one mentions taste as one of the triggers. **Respondent 2** put it this way:

> Maybe the sense of taste is the only thing that doesn't get overloaded, because I don't taste or lick anything there that much."

Strong lights and contrasts were also mentioned multiple times, as well as strong colors and info screens. Sensory overload related to overcrowding was mentioned through the noise, touch, heat, unpleasant smells, and poor air quality. In addition, stops and waiting areas felt overwhelming, especially if they were crowded.

Several interviewees mentioned the loud alarm sounds of vehicles, for example when the doors open, as particularly strong triggers. One had even measured the decibels caused by the alarm sound. A few interviewees point out that sounds do not have to be long-lasting to have great effects.

5.2 Situational Factors

It should be noted that sensory overload was not always present for all participants in public transport and the intensity varied. People also mentioned different situations, which increased the risk of experiencing sensory overload. For example, stress, tiredness, and a new environment. However, in some cases new environment helped since it moved the focus to following the route instead of triggers. The same attributes had the effect of lowering the barrier for triggering and intensifying the experience of sensory overload.

> **Respondent 6:**
>
> ”Or just like fatigue and stress, they're all the ones, which in my opinion make that sensing just... They inflate that experience. So that the more tired and stressed you are, the more terrible it feels to be there. That if you are feeling good, then it will be easier to tolerate. And sometimes you don't even notice that there is noise. And you think that it was nice when there were so many happy people or something like that. That then, of course, the experience changes accordingly: that the darker you feel, the more terrible everything else is. "

The sensory overload may have been active even before boarding the vehicle. Especially if one is stressed or waiting in a place with lots of people, movement, and noise.

Respondent 1 described sensory overload as a cumulating experience, where the first reaction created by one trigger made it easier to notice and react to other triggers as well. For example, respondent 1 described sensory overload as a 'washing over' experience.

> **Respondent 1**:
>
> "If I can't breathe well or I feel like it's too hot or something, then I'm also much more sensitive to all the other sensory experiences."

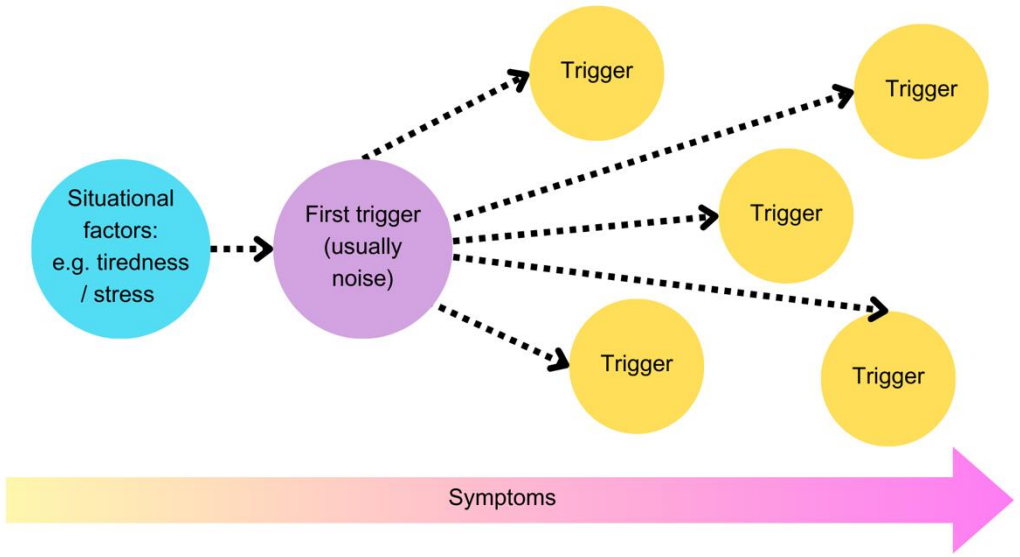

Figure 6. Situational factors intensify symptoms of sensory overload.

5.3 Strategies for Managing Sensory Overload

Traveling with sensory overload was full of coping strategies. Each respondent had different strategies for managing sensory load and these were an important part of preparing, traveling, and recovering from the trip. The following strategies to control sensory overload were brought up in the interviews: creating own space, planning, and anticipation of different situations, and avoidance of overcrowding. One mentioned using beta blockers as a help to cope with traveling with public transportation. Digital tools were used through a smartphone to manage noise, plan routes, and direct concentration away from triggers.

A variety of tools were used as instruments and support for the above strategies. For example, headphones, earplugs, smartphones, and sunglasses were mentioned several times. If a personal aid was forgotten at home, a few described the situation as 'catastrophic'.

> **Respondent 4** always experiences sensory overload and describes the difference if an aid is forgotten at home:
>
> "You can tell if you forget your headphones at home or something. That my own personal aid is missing. Then it feels quite unbearable sometimes. It rarely happens, I'm really careful that I have at least the headphones and sunglasses, or something like that. So, when they're missing, you realize how strong it suddenly is compared to that."

The choice of seating also played a role. Many felt it was important to be able to leave easily, without feeling trapped or stuck behind others. They felt it was important to be able to move around and take their coat off if necessary. Some also preferred to sit next

to a window in order to be able to look out of the window and thus manage sensory overload. Breathing techniques provided support during and after the journey.

5.3.1 Creating Own Space

Many assistive devices aim to prevent the effects of triggers, but they also aim to create their own space in which the journey is more comfortable. Participants described creating their own space as ‘their own bubble’. For example, the use of headphones communicated their own space to others.

> **Respondent 4** talks about using headphones and creating a space of one's own:
>
> ”It is a kind of bubble that I create for myself....”
>
> They continue:
>
> “And it can also help the fact that I do not want to be social in public transportation, so it also sends a message to other people that I do not want to add on top of it any kind of sound distraction. That I am not so ready to talk to anybody, so it may also protect me from that kind of communication that I do not want in that situation.”

Traveling with others created one's 'own space'. This was not used as a strategy in itself but was seen as a helpful factor. However, a couple of participants commented that the presence of others prevents you from becoming immersed in your own world, which also makes it easier to notice triggers.

> **Respondent 7** describes travelling with others:
>
> ”Maybe it can be that if you have someone really good friend or something else like that along, so in a way then it becomes a bubble of its own. That it is not like one where you have to struggle alone, but then you can get away with it easier."
>
> **Respondent 4** on the same topic:
>
> “I travel with my kids quite a lot, so of course then I can never have headphones on. And then they have their own soundscape and movement and everything. And especially when I have to hold my youngest child in my arms sometimes. Or they want to be held, then, well... it's much more difficult. For sure. But then there's the good thing that when you go out with them it's like a real... It's nice. Then the fact that they help me then in a way to take my attention away from the situation very quickly, when you go out, so do not need recovery so much. Children also create a certain space.”

5.3.1.1 Sound as a Tool for Creating Own Space

Sound was the worst trigger, but also one of the best and most used solutions for creating your own space. The problem with the soundscape of public transport was its multiplicity, drawing attention to many different sounds. Interviewees felt it was important to use sound to focus attention on one thing at a time, and headphones were used to do this.

Respondent 1 describes headphones as providing a sense of security so that the outside world is not so intimidating. They say that they take their focus elsewhere so that they do not concentrate so much on other sensory experiences. The sound through headphones is so clear in the ears that it masks the sonic clutter of the outside world. A similar experience was shared by other interviewees, with the headphones creating a soundscape that they could control and choose what to focus on.

Participants listened mostly to music and sometimes podcasts or audiobooks through their phones. Some mentioned that it was more difficult to concentrate on speech than on music, why music was preferred. Music was also described as more absorbing of environmental sensory stimuli and easier to focus on instead of speech.

> **Respondent 3** on speech and music:
>
> "I don't know if it's like anybody else, but listening to speech doesn't work as distracting for me as listening to music. In a way, I can't concentrate on speech so well that I would choose to listen to a podcast on a bus, for example. But I prefer to always choose music because it blocks more. Both the attention and then the noise."
>
> **Respondent 4**:
>
> “Many people have recommended podcasts or audio books. Yes, I sometimes listen to those too. But usually, it's the music that's the best. That it somehow takes all the attention. That you don't focus on the lyrics so much, but it's the... Well, the music takes you away. (laughter)”.

In addition, earplugs, for example, were used to muffle sounds from the surroundings. However, earplugs and headphones were considered a safety risk and created a feeling of insecurity, since important information from the surroundings does not come through. For example, in emergency situations. In addition, announcements were also missed because of headphones. One mentioned that as a reason to prefer using the earplugs to dim down the noise since they wanted to be aware of the surroundings to feel comfortable.

5.3.1.2 Traveling With Smartphone

In addition to listening to music, smartphones were used to create their own space and shift concentration from triggers by using different applications. When focusing on the screen, other visual stimuli could be avoided. Participants scrolled social media, played games, and sometimes read news, forums, or books. However, the content or application needed not to be too complex, which could increase stress and be triggering itself. This included graphics and how the content was presented. Some felt videos were too overwhelming when they were more helpful for others. However, participants mentioned that sometimes this coping mechanism could be more burdensome than the actual surrounding environment, even though at the moment it could feel different.

The phone helped focus attention and it was used as an aid. However, attention needed to be focused on things that do not overload and thus further expose to sensory overload. Interestingly, although the smartphone was used as an aid, it was also perceived as a source of conflict and was also seen as worsening the situation. Some felt that the visuals were distracting and made them feel unwell.

The smartphone was also perceived to give alternatives, as doing one thing for too long tires the senses. Social media was mentioned by many as a poor option because of its nature. It was perceived as too addictive and there was too much information to focus on while browsing. It was overwhelming, although on the other hand, it diverted attention away from triggers. However, it was ultimately perceived as worsening the symptoms.

> **Respondent 3**:
>
> "In general, maybe the kind of browsing and scrolling is more tiring than helpful, especially in the long run. It might make the situation easier, but I myself would see that it is more of a burden in general."

5.3.2 Preparation and Planning

Reducing stress and feeling of being in control was an important strategy in managing sensory overload. Most of the participants emphasized the need to plan and anticipate the trip and make needed preparations as a coping strategy. Time and effort were used to plan out the whole travel chain in advance, which included looking at the maps of the station and comparing route options. Navigation and clear guidance were important aspects for the participants.

A lot of the triggers were related to overcrowding, which was mentioned as one of the main challenges for public transportation. Some used Google Maps to identify busy areas and avoided them during peak hours. However, they did not use it with public transportation or for route planning. For public transportation, they used local route planners, for example, HSL and Nysse applications, as their main guidance and information seeking.

Peak hours were perceived as distressing, and avoiding peak hours was one coping strategy. For example, closeness to people, heat, touch, noise, and poor air quality were particularly present during peak hours. The experience was described as "being in a jar", where the choice of seat was an attempt to ease the situation if a busy shift could not be avoided. Many also associated congestion with noise and, as this was the worst trigger for interviewees, there was a desire to avoid these shifts.

For many, the coping strategy was careful preparation and planning to make the experience as enjoyable as possible. However, planning can also cause additional stress, as described by respondent 6:

> ”It's just that the planning in a way...It prevents the stress from growing, I guess. Although, on the other hand, it also stresses. I don't know. It's a bit of a double-edged sword. Now that I think about it. But yes, I'm clearly trying to prevent myself from getting stressed out about travelling. Or that all the travelling would be smooth and easy and wonderful, when I've anticipated and planned everything, scripted it all."

> **Respondent 5** has to plan the trip in advance:

> "But it mainly affects the fact that I can take more of the sensory stimuli, because I don't have to stress about where I'm going. That when there is a plan ready, then it is easier to endure the inevitable stimuli. Than being already stressed about where the hell I'm going (laughter)."

5.3.3 Visual Stimuli and Unpleasant Smells as a Challenge

For the visual stimuli, there were different coping strategies depending on the source. Few interviewees used sunglasses to avoid harsh light and flashing displays on vehicles. Also, for visual triggers, a smartphone was used to divert attention from distracting visual content to self-selected content.

Smells were often mentioned as a triggering factor, but few solutions or strategies had been developed. Changing seats could feel awkward in order not to offend a fellow passenger. One used perfume left on a scarf as a distraction. Otherwise, smells were difficult to control, although they were one of the main triggers.

5.4 Reaction to Digital Tools

Reactions to the course collaboration planned features and the digital tools that were already in use were sought to identify the need for different features. Vehicle announcements brought directly to headphones divided opinions but were mostly undesirable. It was described possibly as ‘shocking’ in the middle of their own soundscape.

All the interviewees found the idea of representing busy shifts as useful and important information and wished for that feature in the local route planner. Congestion information raised strong interest among the interviewees.

The announcement of a noisy shift divided opinion. Some found the feature interesting and desirable, while others thought that announcing a congested shift would do the same thing. They also raised the point that sometimes the sound that causes sensory overload may be short, but its impact is significant. Respondent 3 said that many times the disturbing sounds are uncontrollable and therefore cannot be predicted.

Design ideation in the course collaboration had guidance, which informed the user when the vehicle was arriving and when the person was about to get out of the vehicle. This was designed to be mainly auditory or optionally vibrational and text format. These functions were felt useful to reduce stress, especially in new environments, where stress levels were already higher. Thus, exposing to stress and sensory overload.

Respondent 1 raised the point that it would be great to know which way to go when leaving the vehicle, based on the route choice in the route planner. This would make it easier to orient oneself in advance to continue the journey, as one often ends up in a crowd of people, which can be a difficult place to look for directions in peace. They also wished that the route planner would provide information on how to stop the vehicle, buy and stamp a ticket, find your way to the platform or stop, when your stop is approaching, or where to find the information board and other services such as ticketing and toilets. They felt that not having to guess at procedures eased the burden. Similar desires for features emerged in other interviews. However, they stressed that information should not be too much on the screen immediately but should be easy to find when needed and should be timely.

> **Respondent 6** on the VR application and the timeliness of information:
>
> "Well, it's not new anymore, but the app that's on your phone now, it gives you enough information at the point where you need it. At first, where you're going and what the times are. I think it comes in a really logical order. Of course, it also has its shortcomings and annoying menus."

Clear and multi-channel information on delays and substitutions was also requested. It was felt that all information should be available on the app, as it is used throughout the whole travel chain, if possible. Several people also wished to save their favorite routes, so that they could monitor the situation of that particular service and route, for example in terms of congestion. This can be a very relevant feature especially for sensory overload, as the fastest route is not the best option for everyone. Some may emphasize the aesthetically pleasing environment over the speed of the journey, as respondent 5 did. They pointed out that their perception of the best route is not necessarily the same as that of the application designer:

"I'd like to see my options. That's the thing. That I don't want that.... Because I don't trust in technology when it....

There's always some dude's assumption behind where people want to go. And then I don't trust that it's the same as mine."

They go on to reflect on the issue from the perspective of crowdsourcing:

”So it (route planner) would not know how to guide according to what is pleasant for me at what time of the day.”

They continue:

“Here we come to the crowdsourcing. That if at a certain time of day I choose a certain route and people like me probably chooses the same, so could they suggest that 'show me people like me route choices for this route'. Yeah, that would be awesome. "

6 Discussion

As the results show, sensory overload in public transport seems to have a significant impact on people's well-being, lives, and choices. For example, sensory overload can limit the range of life and mobility as a result of avoidance of public transport, which in turn has an impact on more aspects of life. For participants, not all parts of the city were accessible because there was no public transport that suited them. This can affect the limitation of job opportunities, the constraints of everyday life, and the choice of where to live, as highlighted by some interviewees.

The triggers for sensory overload are diverse and strongly present in public transport. Nielsen (2023) highlighted sound, lights, and smells in her study, but did not highlight other triggers, of which there were several in this study. For example, the materials used in the seating, strong colors, touch, heat, and movement.

Figure 7. There are several triggers in public transportation, which causes the symptoms while traveling.

Although sensory overload is not yet widely defined as an accessibility issue, it can be seen as such. Nielsen (2023) identified sensory overload as a barrier to using public transport. The findings of this study show that sensory overload may prevent people from fully participating in society and in matters that are important to them. Potential hobbies, experiences, work, studies, social circles, and other things may remain at a distance that cannot be traveled to. This affects life as a whole. Not being able to move around or take part in society is a major issue of fundamental rights, which are defined in the Universal Declaration of Human Rights (United Nations, 1948).

Therefore, sensory overload is an accessibility issue because it restricts mobility, which is defined as an important strategy and fundamental right in the EU Accessibility Directive (European Parliament, Council of the European Union, 2019). United Nations Convention on the Rights of Persons with Disabilities (2006) continues with the same theme and argues that accessibility must ensure the full and independent participation of people with disabilities in all aspects of life.

In this case, sensory overload creates an obstacle, that threatens these fundamental rights defined by the UN and EU. Even if the sensory overload is not directly thought of as a disability. Furthermore, this topic can be seen as a social model of disability, where the environment creates a barrier. For many people, mobility is a necessity and a duty, for example for work. Furthermore, this may also have economic implications, as it affects, for example, the choice of where to work and live, and possibly the ability to work, as work mostly involves traveling by public transport. The target group is always exposed to the risks of sensory overload and its consequences in public transport.

Furthermore, following the definition of social exclusion, this excludes individuals from society's relations and activities, which are possible for the majority and therefore, have an impact on their life quality and the equity of society (Levitas et al., 2007). This is also linked to travel-related social exclusion, which is the process where people are prevented from participating in social activities such as social and political life because services, opportunities, and social networks are not accessible due to insufficient mobility in a society built on the assumption that mobility is high (Kenyon, 2003; as cited in Lucas, 2012).

Nor can the harm to health be underestimated, as symptoms are important for well-being. For example, sensory overload causes intense stress, anxiety, fatigue, pain, and irritation, which is in line with a previous study by Scheydt and others (2017). Stress emerged strongly from the data and as Legrain and others (2015) say, stress is one of the biggest health risks when traveling. This concern is highlighted for user groups who experience high levels of stress and experience it frequently. These are not only physical symptoms, but also psychological ones.

In addition, the experience is associated with shame and reflection on whether one is the only one who has such a difficult time. On the other hand, for example, the flexibility of the workplace in terms of remote working without prior notice may already help. The risk of getting stigmatized lowers when there is no need to explain the difficulties experienced, and one can adapt their mobility to their own needs and abilities. For example, if you want to save energy for traveling for leisure activities.

In general, the issue needs to be more widely recognized, as it affects a wide range of people. Sensory overload should not be trivialized as a problem for individuals, as it is a broad phenomenon, and its effects are visible in the context of public transport. There is

a need to extend the research beyond the autism spectrum, as the experience relates to a wider group. It is interesting that, for example, the need for quiet visits in museums has already been identified and the Helsinki Accessibility Policy 2022-2025 (2022) takes into consideration sensory sensitivities in the school environment.

If there is a wish to support and encourage the use of public transport, this aspect must also be taken into account. The comfort of the journey is one of the most important factors in the quality of public transport (Friman et al., 2020; Flamm & Kaufmann, 2006). Hence, the experiences of people with sensory overload can be a key factor in designing and developing more comfortable public transport for all. As is typical for accessibility solutions, solutions designed for sensory overload can also benefit the wider community by increasing travel comfort and thus public transport use. Design for specific groups often translates into quality for other users (Persson et al., 2015).

Furthermore, many solutions designed for accessibility also support people experiencing sensory overload. For example, a good acoustic environment and clear signage design are important factors in addressing sensory overload. A multi-sensory signage system will benefit not only other user groups but also the selected target group by facilitating journey planning and navigation in a sensory-loaded environment. However, some of the later proposed design solutions conflict with other accessibility solutions for public transport, which will be discussed later.

6.1 Towards Design Drivers

As discussed in the Implementing the Study section, it became very quickly apparent from the data that one cannot speak of the digital environment and the built environment separately, as they were blended in the interviews and these worlds were carried alongside each other throughout the discussions. Therefore, it was also not meaningful to propose design solutions for the digital environment only. Hence, a solution to the issue requires design for both the built environment and the digital environment. Together, these can form a coherent system that can possibly make travel as pleasant and easy as possible. This is in line with the study by Bühler & Wallbruch (2017), who argue that improving accessibility in public transport must take place in both built and digital environments.

If solutions are only designed for a digital environment, they can easily become a quick band-aid, leaving people outside in the form of expensive devices such as good headphones and smartphones. This in itself contradicts accessibility, as the EU Accessibility Directive raises that accessibility solutions should also be accessible in terms of price (European Parliament, Council of the European Union, 2019). It is not always possible to travel with digital aids such as headphones or a smartphone, for example when traveling with others. In the data, traveling without one's own aids was described as a catastrophic situation where one could see the difference and effect of sensory overload.

In the built environment, on the other hand, not everything can be solved. Some triggers are always present, for example in the form of unpredictable sounds, and as the data shows, not all triggers are the same. Digitalization allows us to fine-tune solutions to support the individual. However, the foundation must be laid in the built environment by investing in solutions that support everyone, such as a good acoustic environment.

In the context of accessibility, there is often talk of multisensory considerations, which is very much present in sensory overload as it is strongly linked to the sensory world. Since all the senses are present in sensory overload, they must also be taken into account. For example, digitally one can influence the triggers that come through hearing with sound, but digitally it is more difficult to influence, for example, smell, which was one of the worst triggers. As mentioned, it is therefore key to consider both the digital and the built environment.

It's good to remember that the whole journey, from planning to arrival, is part of the travel chain, as is highlighted for example in the Ministry of Transport and Communication of Finland Accessibility Vision (2023). Therefore, managing the situation requires taking the whole travel chain into account before departure so that design drivers cannot focus only on the journey duration. From planning the journey, to waiting at the stop, buying the ticket, to traveling, changing from one vehicle to another, and getting to the destination. For this reason, transport hubs such as stations and stops must also be made peaceful, in addition to the actual vehicle and journey. In addition, planning was an important part of sensory load management, aimed at reducing stress in advance of the trip. Traveling when already stressed or tired had the effect of intensifying the experience of sensory overload.

The data suggests that design should focus on sound management in both digital and built environments. Sound was the strongest and clearest trigger, as also shown by research such as Malhotra (1984). But on the other hand, it was also one of the best and most used strategies for managing sensory overload. Controlling the soundscape, for example with headphones or earplugs, was also the most commonly used strategy for managing sensory overload. Based on the data, it seems that the strongest trigger was also the strongest inhibitor of sensory overload. Therefore, emphasis on the sound is key to the design. Patterson (2020) also talks about how technology allows you to carry your own sound archive with you, which allows you to exclude unwanted sounds and enables your own personal sound design.

However, it is important to keep a balance here. The sound must not be too demanding, i.e. too much of a strain. Speech did not work for everyone, but music was the preferred way to control the external sound load with headphones. It should also be noted that not all sound outside one's own bubble is not noise, but also important information is missed. Creating your own space with sound, for example with headphones, can be a

safety risk, as several interviewees said. One then blocks out messages from the environment and, for example, emergency situations can be ignored.

6.2 Design Teams and Design Approach

The design for this topic cannot move forward without a diverse design team. The complexity of the subject and the different experiences of individuals require a broader perspective. Furthermore, a diverse design team can bring original design solutions (Trischler et al., 2018). While some of the solutions already designed for accessibility support those traveling with sensory overload, others may cause strong triggers. Such as door alarms or bright lighting, which are vital for people with visual impairments.

This is another reason why the design team should be composed of a diverse range of designers so that the many aspects of accessibility are taken into account. On the other hand, it cannot be ruled out that people with visual impairments, for example, may also experience sensory disturbance from sounds, so a wide range of solutions, weighed up from many angles, guarantees the best outcome. In this way, the benefits can be multiplied for diverse groups of people.

Design for all framework can be helpful here, as it aims from the outset to design for as many people as possible, noting at the same time, that one solution would not fit all (Persson et al., 2015). This is essential from this point of view since the experience of sensory overload varies, and possible solutions might have an effect on other accessibility features in public transportation. Including the stakeholders in every step of the way is vital, as it is in design for all approach (Persson et al., 2015).

This will also help to identify and possibly take advantage of solutions already designed for accessibility, which will also benefit people living with sensory overload. Such as multisensory information provided through mobile phones. It is also useful to identify common interests for possible funding and continuity of design development. This can highlight more clearly that accessibility solutions are not a marginal issue, but that the benefits extend beyond the group for whom the solution was originally developed. For example, clear communication and intuitive use of route guides can also reduce the cognitive load for other groups.

In addition to the need for diversity in the design teams, taking this perspective into account requires cooperation across a wide range of stakeholders. Public transport involves many different actors from information systems to cities, different operators, maintenance, and planners in both digital and built environments. Public transport systems and operators differ from one city to another, and accessibility should be guided throughout the country so that the travel chain does not suffer when traveling between cities. It is not enough, for example, to identify the issue in train transport, as the journey often starts or continues through other modes of public transport.

In addition to multiple modes of transport, the travel chain also includes a wide range of digital services, which need to be taken into account in terms of accessibility. For example, cooperation between VR, HSL, Nysse, cities, application designers, developers, and urban planners is very important. In many cases, it is worth putting things in order at the design stage, whether the design is for a built or digital environment, as it is often expensive or even impossible to fix things afterward.

6.3 Designing the Built Environment

A good basis must be created in the design of the built environment, which can be refined through digitalization. Some triggers cannot be even influenced by digital tools, at least for the time being. Therefore, the design of the built environment solutions is vital. This is the case, for example, with smells, for which no effective solutions had been developed, even though they were one of the most significant triggers.

As mentioned, accessibility of the built environment in general also supports people experiencing sensory overload. Essential aspects include a good acoustic environment, a good indoor climate, glare-free lighting, a good sound system, and clear and uninterrupted signage, just to mention a few (Ministry of the Environment, 2018). There are also contradictions here, for example with lighting. Lighting in vehicles may be too bright for the target group but is essential for people with visual impairments. The same applies to strong contrasts. This again highlights the need for design for all thinking and diverse design teams, as well as coordination between different actors.

In the built environment, good acoustics are important for many different groups of users, including people with hearing impairments (Ministry of the Environment, 2018) and people who experience sensory overload. It is important that relevant information is audible, for example in the form of announcements, and is not obscured by noise. Noise and amplified sounds are particularly challenging, for example for people who experience sensory overload, as the data show.

Given the above-mentioned contradictions and the common needs, acoustically pleasant, quiet, fragrance-free, and softly lit waiting areas or passenger compartments can be a good solution. Falkmer and others (2015) recommend a similar solution from an autism spectrum perspective. In addition, Nielsen (2023) highlighted the higher noise levels in station areas as a factor in sensory overload. It is essential to have a comfortable environment before and after the journey to prevent situational factors from triggering and intensifying the experience of sensory overload.

This is why waiting and arrival areas must also be calming so that people can wait for the journey without feeling stressed before and after the journey. For example, respondent 1 pointed out that sensory overload can be present even before boarding the vehicle if you are stressed or waiting in a space with lots of people, movement, and bustle. Similarly, after the journey, they wished they could take a moment in the waiting room to

breathe, drink, organize their belongings, and orient themselves to where to go next. Clear and logical signage is helpful here as well.

The sensory overload aspect should be taken into account when building or renovating transport hubs. Many transport hubs are already old and therefore may not have taken into account accessibility in its broadest sense.

On the other hand, it's not just about design, but also about better travel etiquette. For example, watching phone content on silent mode and traveling calmly and respectfully toward other passengers.

6.3.1 Design of Transport Vehicles

Reducing visual noise is important both in vehicles and in waiting areas. Flashing screens with a lot going on were found to trigger sensory overload. On the one hand, they made traveling easier, for example in terms of stop information. However, excessive movement, colors, and lights were perceived as distracting. A solution could be to make the content of transport vehicles static. Making the screens staticto c onvey travel information only, could also be a good solution of being able to read and study the content in peace. If other content is displayed on the screens, the presentation of this content could be guided and constrained, for example in terms of movement and the use of color.

As mentioned, vehicles with soft lighting and contrasts, shielded from speech and other sounds, can be a good alternative in terms of sensory pollution. For example, the length of trams and train carriages allows for separate spaces that are quietened from the most intense sensory loads. At the same time, other accessibility needs, such as bright lighting, can also be guaranteed in other compartments. These same spaces could also be made scent-free, as a solution had not yet been found, although for many people this was one of the worst triggers.

Buses often do not offer the possibility of separate facilities, in which case individual quiet and scent-free shifts with dim lights could be helpful. Dimming lights and quieter areas were also highlighted in a study by Kong and Maha (2019), and sensory-friendly seats and areas by Falkmer and others (2015).

Figure 8. Two different lighting situations. Above, bright lights reflected from the surfaces of the vehicle. Below, dimmer lighting, with lights placed under the benches to help people move around, lights on the hat racks pointing to information boards. Above the door and on the threshold, lights to facilitate safe passage. A sense of security must be ensured by decreased lighting and routes must be clearly marked and illuminated.

Several interviewees mentioned the use of quiet carriages on trains when traveling abroad, which they had found a good practice. These were not charged extra in the ticket price but were mainly reserved for commuters. Here again is a good example where several groups benefit from the solution. This practice also lowers the threshold to address disturbing noises and may also increase people's awareness of their behavior.

The data also revealed that people found it distressing to leave and board the vehicle uncontrolled. The design of clear exit and entry routes on vehicles would help with this. Furthermore, it could also facilitate other groups requiring accessibility solutions to ensure that movement is as smooth and accessible as possible.

Designing the soundscape of the vehicles themselves to be pleasant is also beneficial for a good acoustic environment. For example, the damping of vehicle noise in the passenger compartment and good maintenance of the equipment can help. On the other hand, redesigning the alarm sounds of loud door openings so that they still serve the visually impaired but are not so overwhelming in terms of intensity, are possible solutions to calming the soundscape of the vehicle.

When designing vehicles, it is important to pay attention to issues such as creating a sense of space, material choices, use of color, ventilation, and lighting. In the data, these attributes were mentioned several times. Trams were perceived to have more space, which was felt to ease the sensory load. It is also important to have good, non-sticky, and non-abrasive material choices for the seats, which emerged as a disturbing factor in the data. Good ventilation facilitates control of temperature, smells, and air quality, which were strong triggers. Lighting design for multiple groups can also be considered to be clear and bright enough for people with visual impairments, for example, but at a level of intensity that does not cause sensory distress. The placement of the lights could be considered in light of sensory overload and the needs of other passengers.

6.4 Digital Design

The use of smartphones featured strongly in the data concerning the digital world. It was used both for trip planning and for managing sensory load during the trip. The phone helped to focus attention and was used as an aid. As in Julsrud and Denstadli's (2017), the use of digital devices in this study seems to increase the positive travel experience.

Many of the sensory load management tools used in the digital world already exist but on different platforms. It would be beneficial for the target group and other users, to bring these features together in one platform, such as Nysse and HSL, that are used in navigating public transport. As an example, congestion alerts and more detailed navigation. Findings from Rezae and others (2020), course collaboration, and interviews suggest the same. These attributes would be beneficial and quality features for other users.

Furthermore, it may not be necessary to create a dedicated application to manage sensory overload, as needs differ, and good self-developed solutions already exist. Development should focus on developing and improving existing solutions, such as the information and structure of the route planner, which emerged as an important factor influencing the journey. The same idea is supported by Bühler and Wallbruch's (2017) study, in which they mentioned that the development of information and route planners is important for ‘total accessibility’ in public transportation.

In addition, as many applications are already used throughout the whole travel chain, the design should pay attention to how the applications interact with each other. Interruptions during the journey were found to be difficult, where when the route planner is ac-

tively on to monitor the progress of the route, other notifications and content can be distracting. Interruptions make it difficult to focus attention away from triggers, as described by respondent 1. For example, the option to ‘turn off notifications during the journey’ can be a simple solution to this situation.

VR, AR, and XR technologies can create interesting solutions in the digital world, for example by removing visual clutter on screens and providing a clear route, making it much easier to navigate difficult stations and stops. This became a challenge in the data when trying to move on quickly in a congested space to get away from the distraction. For example, augmented reality can be used to mark the fastest route out on the phone screen. On the other hand, one can also focus on, for example, the calmest or most beautiful route if it is better for the user.

Again, however, it is worth considering the question of what makes the most sense and is also the most accessible to implement directly in the built environment. For example, the calming of displays can be easily arranged without digital augmentation. The technology may also be expensive and therefore out of reach for many. However, the potential options are interesting. Again, both the built environment and the digital must be designed to support each other, and the "flaws" and problems of one cannot be entirely fixed with the other.

Figure 9. Example of AR-guidance.

6.4.1 Creating Own Space With Digital Tools

Creating one's own space with digital tools emerged strongly in the data as an important coping strategy, strongly linked to the digital world. For example, interviewees used smartphones and headphones to create their own space. The space was described as a bubble of its own, created for example by sound, as in the Patterson (2020) and Hagood (2011) studies. All of the participants used headphones to cope with noise and create their own space, which is in line with a previous study by Hagood (2011). Headphones were also used to signal a personal space that they did not want to be disturbed, and the use of headphones also communicated this to other passengers, for example in a study by Haas and others (2020).

However, it was important to focus attention on things that do not cause stress and thus further expose to sensory overload. However, the use of the smartphone was also perceived as a contradiction and its use was described as a double-edged sword. On the one hand, the smartphone helped to draw attention away from triggers, but on the other hand, the content could also add to the load.

Again, the main focus was on sound and controlling the soundscape by listening to music on the smartphone. This is also in line with Neave-DiToro and other's (2021) research, where headphones were used to block out unpleasant sounds. Sound was also a good tool for creating one's own space because it did not require staring at a screen, which could make one feel worse and increase sensory overload at the wrong content. It also freed the gaze to look out of the window, which was one of the strategies used to control sensory overload. Hagood (2011) also highlights that noise-canceling headphones can also help to create personal space in a crowded vehicle, in addition to the reduction of noise.

This is why focusing on the control of the soundscape is one of the most important design drivers. Furthermore, some interviewees found the visuals distracting, which also supports the idea that design should be focused on sound. This also emphasized the importance of good headphones that do not let too much sound through or leak out. This also came up in the interviews.

However, silence or quiet spaces may not always be the best solution, as silence can also amplify unpredictable sounds. An acoustically comfortable environment and, for example, ambient sound that is not overpowering may be more effective in masking sudden sounds. What is important based on the data is the predictability and controllability of sound, not necessarily total silence.

> **Respondent 5** on short unpredictable sounds:
>
> "Yes, and then that volume would be quite difficult... Because those are the kind of... It's impossible to predict whose child is going to get a tantrum. So it's like... And they can be very short-lived. But then the load effect is big."

It is good to take into account how people create their own space with digital tools and focus the design on that. For example, whether you want to communicate to other travelers that you are 'in your own space' during the journey may also be an interesting consideration. There was also talk in the material about using one's own body language and headphones to try to communicate to other passengers that one is not open to conversation, which also caused sensory distress. The same emerged from the use of headphones in Haas and other's (2020) research. In addition to creating one's own space, communicating it can be effective. However, this also carries the risk of stigmatization.

Julsrud and Denstadli (2017) highlighted the use of smartphones during travel as a positive influence of mobile media on the experience of public transport. However, they add that other studies also suggest that portable communication devices can negatively affect the travel experience, as they are also associated with the risk of constant interruptions to one's own space and unwanted communication. So while the smartphone creates a personal space, it is also more easily disrupted by interruptions and can affect travel satisfaction. This should also be taken into account in the planning so that own space during the journey can be maintained without interruption and at the same time safely.

There needs to be an opportunity to create and manage one's own bubble without a smartphone, since for some it added to the burden and made them feel uncomfortable. For example, respondent 4 used a smartwatch because they got motion sickness from looking at their phone. From this point of view, using sound to create one's own space can also be more effective and needs to be controlled by means other than the phone screen.

6.4.2 Route Planner

The data showed that the travel guide used influences the travel experience both before and during the trip. It was an important tool for planning and also for focusing attention. For example, on an unfamiliar route, as it was possible to follow the journey on the phone screen. Good and timely information helped to manage stress during the trip. However, there were also problems with the use of the route planner, which had a negative impact on the travel experience. Given the benefits of the route planner in terms of managing sensory overload, there is a need to improve the design of the route planner in digital design. Bühler and Wallbruch (2017) emphasized the development of route planners in terms of ‘total accessibility’.

The course design ideas used in the interviews revealed needs that were either already being used or were perceived to improve the travel experience in terms of sensory overload. Participants wanted route planners to provide more detailed information about navigation and information about crowding at stops. At major transport hubs, the app could

direct people to the right place along a quiet route or show them where benches and corners are for resting. Heck and Wallbruch (2017) also mentioned information on accessibility as important in terms of developing accessibility.

All the interviewees found the idea of representing busy shifts as useful and important information and wished for that feature in the local route planner. Congestion information raised strong interest among the interviewees. Similar ideas were also presented in the autism-specific application OrienTrip created by Rezae and others (2020). For example, one feature was the traffic congestion information, which also came up in the course collaboration. Firstly, this information would help people to prepare themselves. Secondly, they would avoid the busiest shifts, if possible. A few interviewees also mentioned that this may also indicate a noisy shift.

In addition, for example, the occupancy rate of a vehicle when buying a ticket for a train would be a useful feature, as it would allow you to choose a less crowded train. This could also be in the menus, where the app would notify you when a certain occupancy rate becomes full and offer you the option to switch to a less crowded train.

Information on noisy shift were found as an interesting idea, however, it did not get full support from the respondents. They pointed out that congestion is often an indicator of noise levels and that short and unexpected noises can also be triggering. Therefore, the indication of noise levels does not work. Furthermore, perhaps telling a noisy shift does not work because the sound triggers are so personal and unpredictable. Many were also disturbed by noises from vehicles, so the degree of noise level is also not indicative of the amount of noise causing disturbance.

Both course groups and Rezae and others (2020) also included more detailed navigation. Rezae and others (2020) had a “start trip” button, which showed the trip and the stops in real-time, making it easier to follow. This was seen as useful in reducing stress and the different and customizable ways to get information during the journey were seen as important features. In addition, information on how to pay and how to act in the vehicle were wished features, if they were simply presented. These features would be beneficial also for people who are using the vehicles first time, such as tourists.

As people put different emphasis on different things when choosing the best route, the desire to save their own route choices emerged in the interviews. This would be a useful feature, as some people prefer a particular environment over speed, which is often the first way suggested by route planners. Crowdsourcing can also work, as highlighted by respondent 5. When a route guide suggests routes that are chosen by similar users, the travel experience can be more pleasant, even if the journey takes longer. At the same time, once a route has been taken, the user can monitor its congestion level, which is the most desirable feature.

A single route guide between different modes of transport can also be useful, as nowadays travel and guidance can be interrupted, for example when changing from bus to train. However, this requires good cooperation between different actors and a willingness to develop an application that covers the whole travel chain. For example, respondent 1 found it a challenge that all route guides work slightly differently. This was particularly noticeable if the app was used infrequently. Standardization of information and format can also be helpful, as suggested by Heck and Wallburch (2017).

As emerged in interviews. digital solutions are already affecting the travel experience, but one application cannot solve everything because needs are different. More important is the ability to select the information that is relevant for the user from the route planner and, for example, to mute the notifications during the journey. The key is to develop the route planner and make the applications interact with each other so that the device and the route planner do not create an extra burden during the journey. The point may not be that one app provides everything and one product solves the problem, but that they can communicate with each other. For example, when traveling, the phone automatically goes into a certain mode, enabling the most comfortable travel experience possible by removing unnecessary notifications so that stress levels don't rise.

6.4.3 Multimodal Information and Customizability

As usual, designers should take multimodality into account when designing, as it brings in more users and also allows for a more versatile use of the designed product. At the same time, the designer should take into account different user groups with different needs and backgrounds. (Reeves et al., 2004) Multimodal information is an important aspect of accessibility and furthermore, for sensory overload. Since information received through the senses is also a strain, it is important to design in such a way that the user can choose the most appropriate way to receive and process, for example, travel-related information.

An important theme in the data was the accessibility of information when using headphones and earplugs. Important information was lost on them, as they were used to shut out the outside world. As a result, important announcements during a journey, for example, might not reach the users and this was also perceived as a safety risk.

Digital design should therefore take into account the multimodal nature of information. The same announcement should also be available as text on the phone screen or directly in your headphones, for example. This is where the interviewees' wishes differed. Some preferred the text, while others preferred the sound of the headphones. For example, some wanted the vibration to indicate changes, while others did not. This is why customization is also important.

Delivering information in a multimodal way would also serve other users, as it usually does (Oviatt, 1999), such as the hearing impaired. It is interesting to consider whether, for example, the content of vehicle announcements can be entered directly into the device as text and, on the other hand, whether, for example, emergency announcements can be interpreted by automatic text input. This would again serve a wider range of users, as information would not be available only by hearing. Thinking about multimodal point of view when designing broadens the target audience.

On the other hand, because the solutions are different for everyone, not everyone can be offered the same solution. Therefore, everyone chooses their own package based on their own sensory needs, but these need to work together. And if trying to solve with a single product, customization must be easy and not too confusing.

6.5 Design Drivers to Improve Accessibility

Based on the data, the following design drivers were derived to improve accessibility for people experiencing sensory overload on public transport:

Design driver	**Description**
1. The design considers both the built and digital environment.	The experience of sensory overload is influenced by both the built and digital environment and cannot be separated. Therefore, it is important to design solutions for both worlds.
2. All senses must be considered in the design, but particular attention must be paid to sound and sound environments.	Sensory overload can be triggered by many different senses, but often sound is the first and most acute. All senses must be considered in the design, but the main focus should be on sound.
3. Individual needs are taken into account when designing for sensory overload.	This is where versatility and customization are important, allowing everyone to choose the tools that are relevant to them. Digital tools can be used to fine-tune individual triggers that cannot be solved in the built environment.

4. The travel chain is understood as a whole, starting with the planning of the journey and ending with the final destination.	Development work should be done on the route planner as well as on other journey planning tools. Waiting areas and transport hubs should be developed. Public transport facilities should be designed for sensory experience point of view.
5. The design uses a diverse design team and a design for all approach.	As needs and experience vary from one individual to another, it is important to take many perspectives into account. This perspective may conflict with other accessibility solutions, while many accessibility solutions are also beneficial for people who experience sensory overload. The design team needs to include many different perspectives on accessibility. In addition to the need to have diverse planning teams, cooperation across a wide range of parties is needed, as travel chains include many different stakeholders and actors.
6. When travelling, one must be given the opportunity to create one’s own space and stay in it undisturbed.	Creating one's own space is an important tool to increase travel comfort and manage sensory overload. There are different ways to do this, depending on the individual needs. The creation and maintenance of this space must be enabled in such a way that it has a positive impact on the travel experience and is adaptable to the needs of the individual.
7. While immersed in one's own world, it is important to maintain a sense of security and provide information.	This is why it is also essential to find solutions for the built environment, in order to avoid having to use digital tools to block the outside world completely. It is important to remain aware at some level of what is happening in the environment and of the journey to maintain a sense of security.

Figure 10. Description of design drivers.

Quality has been identified as one of the accessibility factors (Lätmann et al., 2016). In general, quality in travel has been considered to reflect factors such as safety, reliability, comfort, accessibility, dependability, speed, and environmental impacts such as noise (Flamm & Kaufmann, 2006), on-trip information, announcements, and ease of ticket purchase. These in turn are strongly linked to the experience of accessibility. (Lätmann et al., 2016)

The same factors have also been identified in this study, which supports the idea that, from a sensory overload perspective, design can also be a quality factor for other planning in public transport. The feeling of safety was also related to sensory overload, which has also been identified as a quality factor in previous research. A sense of safety can be enhanced by clean and comfortable transport, comfortable waiting areas, and access to real-time information (Friman et al., 2020). The study of sensory overload in public transport can deepen these perspectives and support a quality perspective in public transport research.

Nielsen (2023) identified sensory overload as one of the barriers in public transportation in their study, which focused on universal design in psychosocial disabilities. She also highlights crowding, lack of information, and difficulties in planning as barriers, which were also common to this data and the design drivers sought for solutions. Hence, these proposed design drivers may also be helpful for people with psychosocial disabilities.

Multi-sensory and customizable services will also support others who need accessibility features. The design of the built environment will support those who do not use smart devices as actively when traveling. These may include, for example, the elderly population. For example, people with dementia may find sensory experiences such as lights and sounds distressing and it may have a significant effect on their wellbeing (Dewing, 2009). Other people with sensory sensitivities or migraines may also benefit from taking this aspect into account in design.

By paying attention to accessibility, public transport can reach new groups of users who are currently unable to use public transport for one reason or another. The data shows that sensory overload creates barriers that prevent people from using public transport.

7 Conclusion

This study aimed to investigate how to improve accessibility from the point of view of sensory overload. First, however, it was necessary to define how sensory overload is perceived from the passenger's point of view. Once this perspective had been explored, the aim was to determine what design drivers could serve as a basis for developing solutions.

This research aimed to answer the following questions:

- Main question: How to improve accessibility in public transportation for people who experience sensory overload?
    a. Sub-question 1: How sensory overload is present in public transportation from the perspective of passengers?
    b. Sub-question 2: What design drivers improve accessibility in public transportation for people who experience sensory overload?

Firstly, this topic can be seen as an accessibility issue, as it has a significant impact on people's lives, well-being, and choices, and sensory overload creates a barrier to public transport use and full participation in every aspect of life. Based on the data, it can be improved through design from the sensory overload perspective, which can improve quality for other users as well.

Secondly, the effects on the individual are manifold. Effects on well-being arise from physical and psychological symptoms, such as stress, fatigue, and anxiety, which recurred in the data. This was triggered by different sensory triggers such as sounds, smells, bright lights, unpleasant materials, and colors. Public transport contains many different triggers, the intensity of which cannot be controlled by the individual. Fatigue or stress before the journey intensified the experience. These triggers and symptoms resulted in avoidance of public transport, a narrowing of the living environment, a decrease in well-being, interruption of journeys, and an impact on life choices.

Interviewees had developed their strategies to improve their travel experience and manage triggers. Sound was the most triggering, but it was also the best way to protect against sensory overload. Headphones and earplugs were used to manage the uncontrollable and chaotic mass of sound. The headphones were perceived to be in control of the surroundings and both the earplugs and the headphones dampened the environment. Music worked better than speech, for example. Music was also used to create a space of one's own, which was also done by using a smartphone.

Creating one's own space was important but one could be distracted by the company of others or by a feeling of insecurity. Other coping strategies included careful route planning to reduce perceived stress in advance and to anticipate the journey. The choice of seating also aimed to influence the experience. Lights, colors, and smells were difficult to control but were dealt with by using things like sunglasses or perfume left on a scarf.

Thirdly, different design drivers can be used to design improvements to both the built and digital environment. Solutions cannot be made in just one world, as these worlds are interdependent and interact with each other, including in the context of the travel experience. Formed design drivers aim to improve the accessibility of public transport for the target group. The following design drivers were identified and could be inferred from the data to inform the design:

- The design considers both the built and digital environment.
- All senses must be considered in the design, but particular attention must be paid to sound and sound environments.
- Individual needs are taken into account when designing for sensory overload.
- The travel chain is understood as a whole, starting with the planning of the journey and ending with the final destination.
- The design uses a diverse design team and a design-for-all approach.
- When travelling, you must be given the opportunity to create your own space and stay in it undisturbed.
- While immersed in one's own world, it is important to maintain a sense of security and provide information.

In addition, the design must take into account balance. The designed and selected aids aim to divert one's attention, but they shouldn't require too much concentration. This is because some aids, such as using the wrong kind of application with a smartphone, were perceived to cause a worse load in the long run.

The sound solution may be the most essential and key to controlling sensory overload. It was the main trigger, however, and also the best strategy to control sensory overload. Music worked better compared to speech. However, the solution may not lie in digitality, but rather in combining accessibility in built and digital environments. Calm and quiet compartments in the vehicle could support the experience.

In general, the whole material was characterized by the fusion of the digital and the built environment, which is why the best solutions come from a combination of both. One cannot completely replace the other and the whole travel chain must be included. In addition, customization is important, as needs and experiences differ, even if there are similarities.

Furthermore, these solutions would be potentially beneficial for other user groups as well, such as the elderly, commuters, and groups with health risks. For example, the ability to avoid crowded shifts could be beneficial such as people with a lot of luggage and groups with health risks. Overall, design from this perspective can be seen as a quality factor for other passengers. This aspect could also be potentially beneficial for other groups requiring accessibility solutions. The needs are much the same, although there are

also differences. It would be good to see the common benefits and design from the perspective of different groups to achieve the greatest benefit for all.

7.1 Future Research and Actions

This study expands the perspective outside of the autism spectrum, which is an important perspective in itself, but may exclude many other groups and individuals who experience sensory overload. This is a broad phenomenon, and it may not be worth limiting the study to one group, although it would suggest that a broader perspective should be considered.

Going forward, sensory overload must be taken into account as an accessibility factor, since it has such a holistic impact on life, decisions, and quality of life. Overall, the topic needs to be more widely recognized, also in the context of accessibility, to generate more research. In addition, more debate and information on the subject is needed because of the experience of stigma it causes. It is also useful to identify other groups that are affected and potentially benefit. Further research could take into account the common and different needs of different groups.

For further research, it is essential to broaden the sample, as this study is only indicative due to its small size and therefore not generalizable. It would also be interesting to know whether the experience varies between groups. There was variation in experience and a future study could explore differences and similarities with a wider data set. Also, a different methodology for selecting interviewees may yield different results. This study and the design drivers it generated could be used to develop a follow-up study or even a demo of the activities. However, this should be done in consultation with the stakeholders, as recommended by the design drivers.

Design and accessibility measures require that sensory experiences are taken into account beyond the constraints. We live in a multi-sensory world, where sensory information has an impact on us. However, this is not yet widely recognized in design. For example, urban planning and research based on sensory experiences could bring interesting insights into people's experience of cities.

In conclusion, consideration of which of all the groups could potentially benefit from this perspective in the design, and thus, increase the use of public transport, which is essential for urban emission strategies, as mentioned at the beginning. This perspective shows how sustainability perspectives are linked. To make public transport a viable alternative to, for example, the private car, the sensory experience must also be taken into account as a factor in the choice of public transport.

8 References

Accessibility. (n. d.). Cambridge Dictionary. Retrieved December 19, 2022, from https://dictionary.cambridge.org/dictionary/english/accessibility.

Akenji, L., Bengtsson, M., Toivio, V. & Lettenmeier, M. (2021). *1.5-Degree Lifestyles: Towards A Fair Consumption Space for All: Summary for Policy Makers.* Hot or Cool Institute, Berlin. https://hotorcool.org/wp-content/uploads/2021/10/Hot_or_Cool_1_5_lifestyles_FULL_REPORT_AND_ANNEX_B.pdf

Anagnostopoulou, E., Urbančič, J., Bothos, E., Magoutas, B., Bradesko, L., Schrammel, J. & Mentzas G. (2020). From mobility patterns to behavioural change: leveraging travel behaviour and personality profiles to nudge for sustainable transportation. *Journal of Intelligent Information Systems*, *54*(1), 157-178. http://dx.doi.org/10.1007/s10844-018-0528-1

Anderson, E. E., & Corneli, A. L. (2018). *100 Questions (and Answers) About Research Ethics* (1st ed.). SAGE Publications. https://doi.org/10.4135/9781506348681

Asselin, M. E. (2003). Insider Research: Issues to Consider When Doing Qualitative Research in Your Own Setting. *Journal for Nurses in Staff Development, 19*(2), 99–103. https://doi.org/10.1097/00124645-200303000-00008

Baxter, K., Courage, C., & Caine, K. (2015). *Understanding your users : a practical guide to user research methods* (2nd ed.). Morgan Kaufmann.

Bolt, D. (2006). From blindness to visual impairment: Terminological typology and the Social Model of Disability. *Disability & Society*, *20*(5), 539–552. https://doi.org/10.1080/09687590500156246

Brozynski, M. T. & Leibowicz, B. D. (2018). Decarbonizing power and transportation at the urban scale: An analysis of the Austin, Texas Community Climate Plan. *Sustainable Cities and Society*, *43*, 41–54. https://doi.org/10.1016/j.scs.2018.08.005

Burchardt, T. (2004). Capabilities and disability: the capabilities framework and the social model of disability. *Disability & Society, 19*(7), 735–751. https://doi.org/10.1080/0968759042000284213

Bühler, C., & Wallbruch, R. (2017). Definition of "total Accessibility" for Public Transport. *Studies in Health Technology and Informatics, 242*, 703–708. https://doi.org/10.3233/978-1-61499-798-6-703

Cavagnaro. E. (2017). *Three Levels of Sustainability.* Taylor and Francis.

Eskola, Jari., & Suoranta, Juha. (1998). *Johdatus laadulliseen tutkimukseen*. Vastapaino.

European Parliament, Council of the European Union. (2019). Accessibility of products and services. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0882

Dewing, J. (2009). Caring for people with dementia: noise and light. *Nursing Older People (through 2013), 21*(5), 34-8.

Falkmer, M., Barnett, T., Horlin, C., Falkmer, O., Siljehav, J., Fristedt, S., Lee, H. C., Chee, D. Y., Wretstrand, A., & Falkmer, T. (2015). Viewpoints of adults with and without Autism Spectrum Disorders on public transport. *Transportation Research. Part A, Policy and Practice, 80*, 163–183. https://doi.org/10.1016/j.tra.2015.07.019

Friman, M., Lättman, K., & Olsson, L. E. (2020). Public transport quality, safety, and perceived accessibility. *Sustainability, 12*(9), 3563–. https://doi.org/10.3390/SU12093563

Fuchs, & Obrist, M. (2010). HCI and Society: Towards a Typology of Universal Design Principles. *International Journal of Human-Computer Interaction*, *26*(6), 638–656. https://doi.org/10.1080/10447311003781334

Haas, K., Wilson, N. J., Cordier, R., Vaz, S. & Lee, H. C-Y. (2020). The experiences of young autistic adults in using metropolitan public transport. *Cooperative Research Centre for Living with Autism.*

Hagood. M., 2011. Quiet Comfort: Noise, Otherness, and the Mobile Production of Personal Space. *American Quarterly*, *63*, 573–589. https://doi.org/10.1353/aq.2011.0036

Heck, H., & Wallbruch, R. (2017). Towards Standardised Information Exchange Regarding the Accessibility of Public Transport in Germany. *Studies in Health Technology and Informatics, 242*, 695–702. *https://doi.org/10.3233/978-1-61499-798-6-695*

Helsingin kaupunki. (2022). Helsingin kaupungin esteettömyyslinjaukset 2022-2025. Helsingin kaupunki / Kaupunkiympäristön toimiala. https://www.hel.fi/static/hki4all/esteettomyyslinjaukset/helsingin-kaupungin-esteettomyyslinjaukset-2022-2025.pdf

Hirsjärvi, S., & Hurme, H. (2008). *Tutkimushaastattelu : teemahaastattelun teoria ja käytäntö*. Gaudeamus Helsinki University Press.

Husband, G. (2020). Ethical data collection and recognizing the impact of semi-structured interviews on research respondents. *Education Sciences*, *10*(8), 1–12. https://doi.org/10.3390/educsci10080206

Hyvärinen, M., Suoninen, E., & Vuori, J. (n.d.) Haastattelut. Retrieved October 24, 2023, from https://www.fsd.tuni.fi/fi/palvelut/menetelmaopetus/kvali/laadullisen-tutkimuksen-aineistot/haastattelut/#Teemahaastattelu.

James, P., & Magee, L. (2016). Domains of sustainability. *Global encyclopedia of public administration, public policy, and governance*. DOI 10.1007/978-3-319-31816-5_2760-1

Julsrud, T. E., & Denstadli, J. M. (2017). Smartphones, travel time-use, and attitudes to public transport services. Insights from an explorative study of urban dwellers in two Norwegian cities. *International Journal of Sustainable Transportation, 11*(8), 602–610. https://doi.org/10.1080/15568318.2017.1292373

Kong, M. & Maha, J. (2019). Sensory processing: shifting our mindset to improve care delivery. *Pediatric Research, 86*(4), 544–545. https://doi.org/10.1038/s41390-019-0489-2

Legrain, A., Eluru, N., & El-Geneidy, A. M. (2015). Am stressed, must travel: The relationship between mode choice and commuting stress. *Transportation Research. Part F, Traffic Psychology and Behaviour, 34,* 141–151. *https://doi.org/10.1016/j.trf.2015.08.001*

Levitas, R., Pantazis, C., Fahmy, E., Gordon, D., Lloyd, E., Patsios, D. (2007). The multi-dimensional analysis of social exclusion. Department of Sociology and School for Social Policy, Townsend Centre for the International Study of Poverty and Bristol Institute for Public Affairs. https://repository.uel.ac.uk/download/469129f180d3060ed6707d32474ae3d29ac0b9635ca19758f989a09936a3a319/1819926/multidimensional.pdf

Linton, S., Clarke, A., & Tozer, L. (2021). Strategies and governance for implementing deep decarbonization plans at the local level. *Sustainability, 13*(1), 1–22. https://doi.org/10.3390/su13010154

Little, D. L. (2014). Defining Sustainability in Meaningful Ways for Educators. *Journal of Sustainabilty Education. 7*.

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013

Lättman, K., Friman, M., & Olsson, L. E. (2016). Perceived Accessibility of Public Transport as a Potential Indicator of Social Inclusion. *Social Inclusion, 4*(3), 36–45. https://doi.org/10.17645/si.v4i3.481

McConnell-Henry, T., James, A., Chapman, Y., & Francis, K. (2009). Researching with people you know: Issues in interviewing. *Contemporary Nurse : A Journal for the Australian Nursing Profession, 34*(1), 2–9. https://doi.org/10.5172/conu.2009.34.1.002

Malhotra, N. K. (1984). Information and sensory overload. Information and sensory overload in psychology and marketing. *Psychology & Marketing, 1*(3-4), 9–21. https://doi.org/10.1002/mar.4220010304

Merriam-Webster.com Dictionary. (n.d.) Mobility. Retrieved May 9, 2023, from https://www.merriam-webster.com/dictionary/mobility.

Ministry of the Environment. (2018). Esteettömyys: Ympäristöministeriön ohje rakennuksen esteettömyydestä.

https://ym.fi/documents/1410903/38439968/Ohje_esteettomyys_2018-A2B183D6_3C10_40A3_AE1F_DB0898AAC3D8-137003.pdf/86e77f87-c19d-4139-f744-531b500b9a86/Ohje_esteettomyys_2018-A2B183D6_3C10_40A3_AE1F_DB0898AAC3D8-137003.pdf?t=1603260121408

Ministry of Transport and Communications. (2023) Accessibility vision published – aiming for smooth, safe and independent journeys. December 3, 2023. https://lvm.fi/en/-/accessibility-vision-published-aiming-for-smooth-safe-and-independent-journeys

Neave-DiToro, D., Fuse, A., & Bergen, M. (2021). Knowledge and Awareness of Ear Protection Devices for Sound Sensitivity by Individuals With Autism Spectrum Disorders. *Language, Speech & Hearing Services in Schools, 52*, 409–425. https://doi.org/10.1044/2020_LSHSS-19-00119

Nielsen, A. F. (2023). Universal design for people with psychosocial disabilities – The effect of COVID-19. *Research in Transportation Economics, 98*. *https://doi.org/10.1016/j.retrec.2023.101280*

Oviatt, S. (1999). Ten myths of multimodal interaction. *Communications of the ACM, 42*(11), 74–81. https://doi.org/10.1145/319382.319398

Patterson, A. (2020). Soundscapes for Social Change: Community and Consciousness through Sound Design Rhetorics. https://tigerprints.clemson.edu/all_dissertations/2631

Persson, H., Åhman, H., Yngling, A. A., & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects. *Universal Access in the Information Society, 14*(4), 505–526. https://doi.org/10 .1007/s10209-014-0358-z

Reeves, L., Lai, J., Larson, J., Oviatt, S., Balaji, T., Buisine, S., Collings, P., Cohen, P., Kraal, B., Martin, J., McTear, M., Raman, T., Stanney, K., Su, H., & Wang, Q. (2004). Guidelines for multimodal user interface design. *Communications of the ACM, 47*(1), 57–59. https://doi.org/10.1145/962081.962106

Retief, M., & Letšosa, R. (2018). Models of disability: A brief overview. *HTS Teologiese Studies / Theological Studies, 74*(1). https://doi.org/10.4102/hts.v74i1.4738

Rezae, M., McMeekin, D., Tan, T., Krishna, A. & Lee, H. (2020): Evaluating the effectiveness of autism-spesific public transport app for individuals on the autism spectrum: a pilot study, *Disability and Rehabilitation; Assistive Technology*, DOI:10.1080/17483107.2020.1785563

Rittel H. W. J. & Webber M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4,* 155-169.

Rosenzweig, C., Solecki, W., Hammer, S. A., & Mehrotra, S. (2010). Cities lead the way in climate-change action. *Nature, 467*(7318), 909–911. https://doi.org/10.1038/467909a

Scheydt, S., Müller Staub, M., Frauenfelder, F., Nielsen, G.H., Behrens, J. & Needham, I. (2017), Sensory overload: A concept analysis. *International Journal of Mental Health Nursing, 26*(2), 110-120. https://doi-org.lib-proxy.tuni.fi/10.1111/inm.12303

Shakespeare, T. (2013). The Social Model of Disability. In L. J. Davis. (Ed.), *The disability studies reader* (p. 214-221). Taylor and Francis.

Suen, S. L., & Sen, L. (2004). Mobility options for seniors. Transportation in an ageing society: A Decade of Experience, Proceedings, 27, 97-113. http://onlinepubs.trb.org/onlinepubs/conf/reports/cp_27.pdf

Sullivan, K. & Mauldin, B. (2020). *Accessibility and the Arts Reconsidering the Role of the Artist.* Los Angeles County Department of Arts and Culture with the Center for Business and Management of the Arts at Claremont Graduate University.

Statistics Finland. (n.d.) Liikenne ja matkailu. Retrieved December 3, 2023, from https://www.stat.fi/tup/suoluk/suoluk_liikenne.html.

Trischler, J., Kristensson, P., & Scott, D. (2018). Team diversity and its management in a co-design team. *International Journal of Service Industry Management*, *29*(1), 120–145. https://doi.org/10.1108/JOSM-10-2016-0283

Tuulaniemi, J. (2011). Palvelumuotoilu. Alma Talent.

Tutkimuseettinen neuvottelukunta. (2023). Hyvä tieteellinen käytäntö ja sen loukkausepäilyjen käsitteleminen Suomessa. Tutkimuseettisen neuvottelukunnan julkaisuja. https://tenk.fi/sites/default/files/2023-03/HTK-ohje_2023.pdf

Traficom. (2021, September 9). Joukkoliikenteen kysyntä. https://tieto.traficom.fi/fi/tilastot/joukkoliikenteen-kysynta

Tuomi, J., & Sarajärvi, A. (2017). *Laadullinen tutkimus ja sisällönanalyysi* (Uudistettu laitos.). Tammi.

United Nations. (1948). Universal declaration of human rights. https://www.un.org/en/about-us/universal-declaration-of-human-rights

United Nations. (2006). Convention On The Right Of Person With Disabilities (CRPD). https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd

Webber, S. C., Porter, M. M., & Menec, V. H. (2010). Mobility in Older Adults: A Comprehensive Framework. *The Gerontologist, 50*(4), 443–450. https://doi.org/10.1093/geront/gnq013

Williams, M. (2000). Interpretivism and Generalisation. *Sociology, 34*(2), 209–*224.* https://doi.org/10.1177/S0038038500000146

Williamson, B. (2015). Access. In R. Adams, B. Reiss, & D. Serlin (Eds.), Keywords for Disability Studies. 14-17. New York: NYU Press, 2015.

Appendix 1

Interview Questions

Thematic interview framework:

(Location), (Date), Thesis interview with Tinja Juutilainen on the Sustainable Digital Life Master's programme at the University of Tampere. The research concerns the experience of sensory overload in public transport and the development of digital solutions to address it.

The results of the research will be published online and related reflections may be presented on a related blog and social media. All quotes and interview results will be presented anonymously and data will be treated confidentially. Interview recordings will be deleted after the evaluation of the work. A transcript of the interviews and the final work will be preserved.

The interviewee has been offered different ways to conduct the interview in the way that suits them best. The interviewee has the right to stop the interview and to ask for the interview to be removed at any time.

The interviewee has been contacted on (x) and the interview has been scheduled for (x).

Please state your name, age and give your consent to the interview.

Themes: 1. transport mode choices, 2. different senses, 3. situational factors, 4. symptoms, and 5. assistive methods

Before boarding the vehicle:

Opening questions

- Could you tell me how sensory overload affects you in public transport?
- What happens when you experience sensory overload?
- How does sensory overload affect your mobility?
- Could you give as much detail as possible about where and how you experience sensory overload?

Mobility habits

- How often do you use public transport and where?
- Which means of transport do you mainly use and why?

- For what do you use public transport?
- What do you consider important when choosing public transport? What is most important? Is there a reason why a particular mode of transport?
- Does the sensory load affect your choice of how you move?
- Does sensory load influence your choice of transport mode?
- Does it limit your mobility (e.g. if the bus is not suitable)?
- Do you feel able to use public transport?

Overloaded senses

- What kind of sensory overload have you experienced on public transport?
- Are all your senses affected, or some in particular?
- Can you rank the senses in order from most to least triggering?
- Are there any particular features that are stressful? (e.g. colour of benches, etc.)

Situational factors

- Do you always experience sensory overload when travelling or only sometimes?
    - Can you distinguish between these situations?
- Do you experience sensory overload even before boarding and what causes it?
- Do you feel that any situation or condition influences the degree of overload you experience? (e.g. Discomfort, new environment, life situation, fatigue, stress...)
- Does it make a difference whether you are travelling alone or with others?

Consequences and symptoms

- What are the symptoms of sensory overload?
- Can you describe how you feel when sensory overload hits?
- How do these symptoms affect you or your well-being?
- How do you manage this feeling?
- Are you able to express your needs, for example to a travelling companion?
- Are you able to talk about the experience?

Tools and strategies

- Do you have any aids or practices that help with sensory overload?
    - Pros and cons of these

- Are there any stressors in public transport that you have not yet thought of that could be eased?
- Smartphone...
    - Do you use your smartphone as an aid? If yes, how do you use your smartphone as an aid?
    - Which applications do you use and why?
    - Are there any applications that you cannot use during the trip?
    - Are there any elements of the applications (graphics, sounds...) that make it easier or more difficult for the senses?
- How much do you plan the trip in advance?
- Do you consider anticipation important?
- Does information help you to reduce stress?
- Examples of helpful strategies, (course collaboration and previous literature)
- If you could reduce or avoid sensory overload on public transport by using assistive devices, would you use public transport more?

Questions for additional journey together

After the conversation, the interview continues means of transport of the interviewee's choice.

- Give the interviewee space to act first, as they usually do.
- Provide space for silence to allow the interviewee to observe the environment.
- "Let's have a few minutes of quiet time before the interview starts. You can observe your surroundings and I will start asking questions after a while. If you want to start describing the situation earlier or make observations, you can do that."

Opening questions:

- Could you tell me how you feel about travelling at the moment?
- Do you feel that your senses are overloaded at the moment?
- Can you identify which elements here are causing strain?
- Is the situation different from how you usually feel when you travel?
- Can you describe what sensory overload feels like? (If one says they experience sensory overload)

Overloaded senses:

- Which senses are currently under load?
- Can you rank the senses that are under load from the most to the least triggering?
- Does it make a difference if I ask you to pay attention or if you pay more attention now? Does this interview situation and topic affect how you experience or perceive sensory strain now?

Situational factors:

- Are there any factors today that influence your experience?

Consequences:

- Are you experiencing sensory overload at the moment?
- Can you describe how it feels?

Aids:

- Could you imagine that a technical aid would be helpful right now?
- What kind of functionality would you like to have now?
    - Any of the things we talked about earlier?
- What would you normally do in this situation?

Questions after the trip:

(A place quiet enough, suggested by the interviewee)

- How did you feel about the trip? Was it different from what you were used to?
- Did the interview leave you with any questions?
- What kind of assistance would you have wished?
- Any further comments or thoughts you would like to share?