UTRECHT UNIVERSITY

Faculty of Science

Human Computer Interaction Master Thesis

How Safe Do We Feel? Development and Validation of a Scale to Measure Perceived Personal Safety Fostered through Technology during Door-to-Door Transportation

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Abstract

As concerns about personal safety during door-to-door transportation continue to rise, the need for an effective way to measure how well technology addresses these concerns has never been more urgent. This project introduces the Perceived Personal Safety Scale (PPSS), a new tool designed to measure the effectiveness of technological innovations in enhancing travelers' perceived personal safety. We developed this scale by first diving into existing research and then conducting focus groups to uncover the key factors that affect feelings of safety. This approach helped us create and a list of scale items. After an expert review to refine those items and exploratory factor analysis, we reduced them down to a concise thirteen-item scale. We thoroughly tested the PPSS to ensure it was both reliable and valid. Now, researchers and personal safety technology developers can use this scale to measure—and effectively compare—the impact of various technologies on personal safety, paving the way for more effective safety solutions in transportation systems.

Key Words: Perceived personal safety, Door-to-door transportation, Scale development, Evaluation of technologies, Personal safety technologies, Technology in Transportation

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1. Introduction

In the busy world of transportation, the importance of feeling safe cannot be overstated. The issue of perceived personal safety during transportation has the attention of researchers around the world [15, 60, 11, 89]. Various studies explore the reasons behind the low perception of personal safety in public transport and during door-to-door transportation, also known as "the whole journey approach" [90, 15, 18, 97].

What does perceived personal safety mean to you when you are traveling? It is more than just the absence of danger; it is also about feeling comfortable and at ease during the whole journey, from your front door to your destination. This concept is not just about preventing incidents but also about fostering a sense of safety. Unfortunately, many still find public transport unsettling, discouraged by fears of crime [33, 38], fear of victimization [11], their perceived vulnerability [45], feelings of insecurity [97] which are all manifestations of low perceived personal safety. These feelings of safety can shape the travelers' behavior [60], choice of transport modes and routes [45] and even limit their use of public transport to the minimum to mitigate them [43, 97].

The solutions so far are addressed through multiple technologies that have been created to overcome this feeling of unsafety [8, 66, 22, 85, 23, 82]. Such applications either focus on reactive measures for keeping the users' feelings of personal safety high, while others pay attention to education or distraction mechanisms like fake calling [51]. But despite these good intentions, there is no evidence that they are effective at their purpose, as there is an absence of systematic evaluations of these apps' outcomes [95, 51, 24].

Thus, we need to investigate this matter to develop solutions that genuinely meet travelers' needs. Although studies have measured perceived personal safety in contexts like the workplace, there is a gap in our tools for

evaluating how technology influences personal safety perceptions during transportation.

This research aims to bridge that gap by quantifying how technology affects personal safety perceptions considering the transportation experience from start to finish, covering all forms of public transport and walking. Our goal is to identify the factors shaping these perceptions and create a scale that can guide the development of more effective safety technologies. To align with this goal the research question that guides this study is as follows:

RQ: *What is a reliable scale to measure perceived personal safety fostered through technology during door-to-door transportation?*

This thesis aims to contribute to the field of Human-Computer Interaction by advancing the theoretical understanding of perceived personal safety in transportation. It identifies and integrates key factors to provide an understanding of personal safety perceptions, an area previously underexplored in the context of technological solutions. The importance of tailored technological solutions is emphasized in this project and offers valuable insights for developers of personal safety technologies. The final scale can be used to evaluate and compare the effectiveness of various safety technologies, guiding the development of more targeted and effective safety solutions. Ultimately, with the developed scale, we aim to influence user experience and enhance feelings of personal safety in public transportation systems.

The remainder of this thesis is structured as follows: Chapter 2 provides a literature review, Chapter 3 describes the methodology followed to create the scale, Chapter 4 where the process of developing items for the scale is described, Chapter 5 for developing the scale, Chapter 6 to evaluate the developed scale, Chapter 7 for the discussion and Chapter 8 includes conclusions.

2. Literature Review

Since this study focuses on perceived personal safety, we start by defining and understanding its concepts. Following this, we examine perceived personal safety within the context of door-to-door transportation and identify the factors influencing it. Afterward, we present state-of-the-art technologies that aim to improve perceived personal safety. Lastly, we show the necessity for a scale that evaluates technologies designed for perceived personal safety.

2.1 Defining Perceived Personal Safety

Despite existing studies on people's perceptions of personal safety, a clear, research-based definition is missing. However, Jansson et al [38] provided an insight by noting that *"perceived personal safety is an experienced feeling, distinct from actual safety, security or risk, and therefore needs to be approached differently"*. This quote is indeed insightful, as it captures its difference from actual safety and the need to be approached differently. However, it cannot be considered a definition as it does not explain what constitutes perceived personal safety. It also does not identify key components of the term, other than it being an "experienced feeling".

So, to develop a clear understanding of "perceived personal safety" and eventually formulate a definition, we first aim to create an understanding of the two main components: "perceived safety" and "personal". The next subsection focuses on clarifying "perceived safety" (Subsection 2.1.1) highlighting its distinction between fear of crime and actual safety. In the subsequent sections, the "personal" aspect is explored (Subsection 2.1.2) and lastly, these insights are integrated to formulate a definition of "perceived personal safety" (Subsection 2.1.3).

2.1.1 Perceived Safety

To understand the meaning of perceived personal safety, we first need to distinguish it from actual safety. In an interview, Loukaitou-Sideris [30] highlights that crime statistics show actual risk, while perceived safety reflects people's feelings. She argues that focusing only on crime rates without considering perceived safety fails to fully address urban safety issues. This is because perception is "as significant as the reality" [30]; even if crime rates are low, people will avoid areas where they feel unsafe.

Furthermore, we need to closely examine "perceived safety" to understand how it differs from related concepts like fear of crime. Hinkle et al. [33] highlight the need to distinguish between fear of crime and perceived safety in research. They warn that not doing so can lead to inaccurate representations of people's experiences. When using perceived safety as a proxy for fear of crime, it is important to be careful, as different demographic groups, like gender, may vary in how they express their fear of crime [33].

Adding to this perspective, Uittenbogaard et al. [86], as cited in Jansson [37], define perceived safety as *"an individual's experience of the risk of becoming a victim of crime and disturbance of public order"*. This definition acknowledges the subjective nature of safety perception, acknowledging that it is rooted in one's experience rather than objective data. However, as it lacks the term 'personal' and focuses on public disturbances rather than individual safety, we find this definition board. The "personal" aspect here is crucial, as it emphasizes that safety perceptions are deeply individual and are investigated in Subsection 2.1.2.

2.1.1.1 Importance of Perceived Safety in Transportation

After understanding what perceived safety is, we should also recognize its importance in life but also in transportation, as this is the study's objective.

In this context, considering Maslow's Hierarchy of Needs [50] is essential. In this pyramid, safety and security are the basis of human motivation,

directly above physiological needs (Figure 2.1). This theoretical perspective argues that improving perceived safety is not merely about reducing crime rates but about building trust and a sense of security among public transportation users. The intersection of perceived safety with basic human needs highlights the significance of designing public transportation systems that prioritize not only physical safety but also psychological well-being. This is also supported by Van Hagen [88] who proposes the pyramid of needs for travelers using the Nederlandse Spoorwegen (NS) [59] (Figure 2.2). On the base of this pyramid, as it can be seen in Figure 2.2, is the need for "Safety", showing its importance similar to Maslow's hierarchy [50].

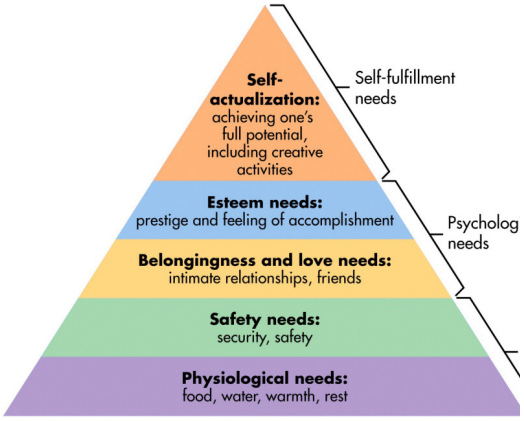


Figure 2.1: Maslow's pyramid of Needs [53]

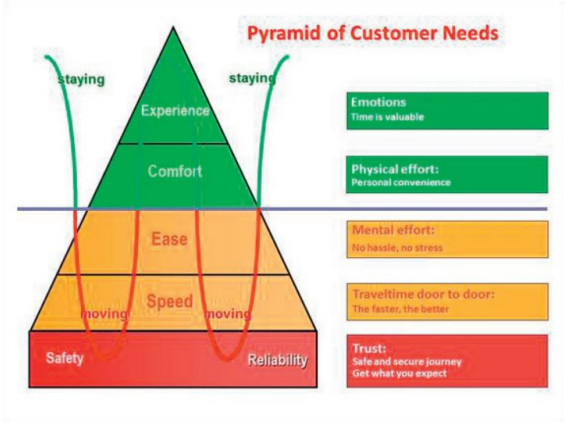


Figure 2.2: Van Hagen's pyramid of customer needs [88]

2.1.2 Personal

According to the Oxford Dictionary, "personal" is most generally defined as *"Of, relating to, concerning, or affecting a person as a private individual (rather than as a member of a group or the public, or in a public or professional capacity); individual, private; one's own"* [62]. This definition highlights the individual nature of experiences and perceptions. It emphasizes that what is "personal" is unique to each individual, reflecting their specific circumstances and views. Furthermore, the definition extends to *"Affecting one's body; relating to one's physical safety or well-being"* [63], emphasizing the deep connection between personal experiences and one's physical safety. So, we can

say that the term "personal" means that an individual's experiences shape their sense of safety, making safety subjective.

2.1.3 Defining Perceived Personal Safety

Taking into account past research on perceived safety and definitions of the term "personal", this study attempts to formulate a definition of "perceived personal safety", that fills a gap in the existing literature.

Perceived personal safety refers to an individual's subjective assessment and emotional response regarding their sense of safety in a specific context. This concept emphasizes the individual nature of safety perception, recognizing that it is deeply influenced by one's unique experiences, background, and circumstances. Unlike broader notions such as "fear of crime", perceived personal safety is intimately tied to one's immediate environment and situational context. It is a reflection of the individual's internal evaluation of their surroundings, distinct from objective measures of safety or statistical crime rates.

Consequently, this study proposes that perceived personal safety is defined as *"an individual's subjective assessment and emotional response regarding their safety, uniquely shaped by personal experiences and context"*. This definition will used as a base for the study, guiding the analysis and discussion of all related findings and arguments. It provides a foundation for the study, ensuring clarity and providing consistency throughout the research process.

2.2 Perceived Personal Safety in Transportation

Loukaitou-Sideris [2] suggested that *"the relationship between crime and physical activity may be dynamic, where each influences the other over time"*, where physical activity in her study includes walking and biking in public spaces such as streets, parks, and bike paths. Similarly, we look at how feelings of personal safety and transportation from one place to another, such as walking to a bus stop or riding the train, also affect each other. In

the subsections below this relationship is discussed (Subsection 2.2.1 and Subsection 2.2.2).

2.2.1 Influence of Perceived Personal Safety on Door-To-Door Transportation

Concerns regarding safety and the perception of personal safety within transportation have been consistently discussed in the literature. For instance, statements from car owners highlight a conditional willingness to transition to public transport [26], emphasizing the need for reliability, cleanliness, and safety [34, 46]. It has also been found that rail users perceive their personal safety to be significantly higher than what official statistics suggest and this perception consequently discourages many from using rail transport [13].

Furthermore, research from various countries encompassing diverse transportation systems has shown that perceived risks and threats to personal safety significantly influence travel patterns among specific demographics. Certain demographic groups, particularly women [1, 89] and the elderly [1, 97] tend to prioritize their safety perceptions while traveling as opposed to men. This tendency is noticed by a study in Nigeria, where women, along with higher income earners, foreign nationals, and older visitors, reported increased feelings of unsafety in public transportation settings [60]. Moreover, other research findings show that women often feel apprehensive about waiting times at terminals, with personal safety being one of the three factors that influence their perception of waiting times [11].

However, research on men's feelings of personal safety is limited because studies have focused more on women's safety concerns, as they tend to report more often fear in public spaces [97]. These limited studies suggest that the feeling of low safety restricts men's public activities too [17, 13]. For example, as mentioned by Day et al. [17] traits associated with masculinism, such as control, competition, aggression, and physical strength, can lead to increased fear when these traits are being challenged in public

spaces. Specific issues that cause low perceived personal safety for men include unfamiliar places, fear of confrontation, and the need for heightened awareness while traveling in a group has the opposite effect [17]. Another study also uncovers that men are most likely to be concerned about their personal safety in car parks, both during the day and night, while worrying about their car safety too [13]. However, not all cisgender males experience privilege similarly or in all circumstances.

Moreover, it is not only research on men's perceived personal safety that is scarce, studies focusing on the perceived personal safety of individuals within the LGBTQ+ community are also limited. Some insights that they offer are for instance that they develop skills to detect risks, affecting the way they commute and their presence, as they try to "pass", for example, as non-trans or non-queer; a quite calculated attempt that requires further attention in research [93]. These self-expression alterations, which are triggered by social stigma, demonstrate mobility injustice [73].

2.2.2 Factors Affecting Personal Safety Perception in Door-to-Door Transportation

According to research, multiple factors influence perceived personal safety during transportation. These are person-related as well as environmental characteristics, trustworthy real-time information, and natural surveillance. In this section, these factors are investigated in "Person-Related Factors" (Subsection 2.2.2.1), "Environment Characteristics" (Subsection 2.2.2.2), "Waiting times" (Subsection 2.2.2.3), and "Human Presence & Surveillance" (Subsection 2.2.2.4) respectively.

2.2.2.1 Person-Related Factors

The way safe/unsafe is perceived by individuals can vary from one to another [60]. In this section, these factors are categorized and explored. It is important to note that the factors discussed may extend beyond these categories, reflecting the complexity of personal safety perceptions in transportation.

Demographics and Identity. Although Currie et al. [15] found that gender has a comparatively smaller impact on personal safety perceptions than trust, vulnerable groups, such as women, older individuals, and the younger population, are more inclined to prioritize personal safety considerations during their travel [15]. Distinct characteristics such as age, race/ethnicity, income levels, and sexual orientation are crucial in shaping the interactions between masculinity and fear in public spaces, like streets and public transport [17]. The existing, yet limited, research on men's feelings of personal safety supports that situations and environments that challenge traditional notions of masculinity may invoke fear, while those perceived as safe can reinforce masculinist identities [17].

However, while discussions in the literature may have characterized women as a group with uniform concerns and feelings toward personal safety during door-to-door transportation, research by Vanier [89] challenges this assumption. The study supports that women are a diverse group of passengers, each with unique sensitivities and potentially different reactions to the same situations. This insight highlights the importance of recognizing and addressing the varied safety needs of the individuals who are part of a bigger group in transportation planning.

Social Interactions, Trust and Immediate Environment. Research into the factors impacting personal safety perception in door-to-door transportation reveals an interaction of social comfort and trust. It has been found that feeling comfortable with unknown people on public transport plays a crucial role in shaping personal safety perceptions [15]. Trust in people and feeling secure in one's immediate environment (home, street) also has a significant impact [18]. Moreover, living in a better neighborhood is supported to result in lower feelings of personal safety on public transport [18].

During a study by Day et al. [17] participants expressed apprehension in unfamiliar public places and stated that they often avoid them, while a significant number of them highlighted the importance of being aware of their surroundings to feel safe. A study by Delbosc et al. [18] supports this statement by noting that "less familiarity with public transport contributes

to greater safety fears". However, Abenoza et al. [1] discuss that familiar places and routine behavior do not affect safety perceptions.

Previous Experiences. Research supports that personal safety perceptions are strongly influenced by previous experiences of victimization [1, 2]. Interestingly, Currie et at. [15] suggest that direct personal safety incidents have a smaller impact on personal safety perceptions when compared to trust.

2.2.2.2 Environment Characteristics

Research indicates that environmental conditions significantly influence individuals' perception of safety during door-to-door transportation. A study by Friman et al. [25] highlights that unclean and cluttered buses not only deteriorate the quality of the travel experience but also increase the travelers' feelings of threat, therefore diminishing their sense of personal safety.

Additionally, various studies support that poor lighting [44], darkness [15], and isolation [26] have a negative impact on perceived personal safety, whereas threats to personal safety occur most often in crowded spots [26] and in broad daylight [20]. Moreover, participants in a study in 2020 expressed concerns about safety at night, with reasons primarily related to fear of victimization (for example fear of theft, fear of being followed) [11].

Concerns regarding personal safety extend to railway station car parks at night, particularly among men [13], while also fearing their car's safety, because they are well-known for having their car broken into. Moreover, the architectural design of bus stations has been found to significantly impact passengers' personal safety perceptions. Stations equipped with transparent shelters foster a heightened sense of personal safety compared to opaque shelters, with the participants of the study attributing it to better visibility, allowing passengers to see and be seen through the shelter [97].

Contrary to common beliefs, travelers felt less worried at bus stops associated with high crime rates, preferred opaque shelters at night, and felt

safer when stops were located in areas of mixed land use [1]. This finding supports the argument that perceived personal safety may not directly correlate with actual crime rates.

2.2.2.3 Waiting Times

Research has consistently shown that waiting times are perceived as significantly more burdensome compared to walking times [91][36], with public transportation users estimating waiting times to be almost three times longer than the actual duration [28] [92]. Unreliable timekeeping, leading to extended waiting times in interchanges, and leaving travelers without satisfactory information have been found to make them feel exposed [25].

The significance of frequent and on-time service is particularly pronounced among male passengers, who associate punctuality with feelings of safety [97]. Furthermore, women express their concern about their personal safety when approaching railway stations and while waiting for trains on platforms [13]. Notably, in a study by Chowdhury et al. [11], ethnic minority women report feeling less safe during the day than Caucasian women, with differences in mobile app usage for determining waiting times.

2.2.2.4 Human Presence & Surveillance

The role of human presence and surveillance in public transportation settings is a critical aspect of perceived safety. Female travelers frequently mention lonely bus stops, unstaffed stations, and pedestrian subways among the places that cause fear [83].

Despite the technological advancements in transit security, women illustrate a preference for staffing over technological solutions and are skeptical towards the replacement of staff with automated machines [43]. In a study by Yavuz et al. [97], respondents showed a preference for railway stations that were staffed and where they felt that others could observe them (when approaching the railway station and while waiting on the platform) and which were well-maintained with CCTV in operation [97]. On the other hand, Wallace et al. [90] uncovered that safety enhancements on-board

video cameras, when these are noticed by travelers, were limited in their ability to affect their feelings of safety after dark. Although, they are by no means powerless.

According to the participants of a study by Jansson [37] a mix of people around, engaged in several activities, would make the most street users feel safe. However, the impact of the number of passers-by was found to be insignificant as revealed in another study [1].

2.2.2.5 Conclusions for Person and Non-Person-Related Factors

The study of factors affecting perceived personal safety during transportation provided by literature shows that both personal factors as well as environmental and situational factors, influence significantly travelers' safety perceptions. However, the environmental and situational factors cannot exist in alone as their impact is mediated by personal factors. Notably, these non-person-related factors are mentioned to be perceived and experienced differently depending on individual differences such as gender and ethnicity. A good example supporting this is provided by Chowdhury et al. [11] ethnic minority women report feeling less safe during the day than Caucasian women while waiting for their commute.

Additionally, for example, an individual's background and prior experiences shape how they perceive and react to environmental conditions like poor lighting or crowded spaces. A person who has experienced crime while waiting for the train may perceive this situation as more threatening than someone without such a history, regardless of the objective safety measures in place. Similarly, the presence of surveillance or waiting times might be interpreted differently based on one's trust levels and prior interactions in similar settings. This dependency shows that while environmental and situational factors provided by literature are important, they are inherently interpreted through and influenced by personal factors.

2.2.3 Strategies to Mitigate Low Perceived Personal Safety

Findings from various studies highlight the proactive strategies women adopt to enhance their perception of personal safety. One approach involves cutting out the use of public transport, reflecting a deliberate attempt to mitigate exposure to perceived risks [97, 43]. However this strategy comes with significant trade-offs, notably limiting women's freedom, depriving their enjoyment of public life, and restricting their ability to access opportunities and conveniences [17, 47].

Other approaches were investigated in a study conducted in Auckland, New Zealand, on women's perception of safety in transportation while waiting at terminals [11]. Researchers found that half of the participants stated they use their phones (e.g., talking on the phone) to feel safe while walking home at night. Other techniques were also used by the participants of this study such as pretending to be confident and preferring crowded stations. This behavior demonstrates an intentional use of technology to simulate social support, thereby enhancing personal safety.

In summary, in this subsection, we explained different factors that can affect peoples' perception of personal safety when they travel door-to-door. These include personal factors, the environment, how long they wait, whether there is surveillance, and what they do to make themselves feel safer. These factors show that feeling safe can be complicated, and different people might feel safe or unsafe in the same situations. Next, we will look at technologies that were developed aiming to help people feel safer. We will see what is already out there, their features, and how effective they are.

2.3 Personal Safety Applications

As public transportation systems often fail to meet the specific safety needs of female passengers and vulnerable groups, there is a pressing need for tailored safety measures [45]. Reflecting on Chowdhury's [11] question, *"For whom is the [transportation] system being designed?"*, and Loukaitou-Sideris's [44] emphasis on *"transportation justice"*, this section shows how

personal safety applications try to bridge this gap. These apps, featuring location-based services and personal alarms, claim to enhance safety through mainly reactive measures, however, their effectiveness is questioned. In this section, we explore the features of these apps and assess their overall effectiveness.

2.3.1 Application Features

Maxwell et al. [51] identified location-based services as the most common feature in personal safety applications, where the apps utilize GPS tracking to share the user's location with designated contacts through panic button activation. Following in popularity are personal alarms that emit loud noises to attract bystander attention and deter potential offenders, without tracking location. Crowd-sourced hot spot data and geofencing rank next, offering advanced functionalities like mapping risky areas and alerting contacts upon the user entering or exiting predefined zones.

2.3.2 Examples of Applications

Among the various applications available in the Netherlands, such as *PROtect* [66], *Emergency App* [22], and *uAlert* [85], and wearables like *Flare* [23] the methods predominantly focus on reactive measures during or after unsafe incidents. *bSafe* [8] stands out by incorporating traditional features alongside innovative ones like fake calling, suggesting a potential for further research into its effectiveness in enhancing personal safety perception.

A notable observation is the preventive nature of a few applications, with only 5 out of 505 in Australia being preventive, among which *Women Safety Totem SOS* not only offers educational content on avoiding potential threats but also provides self-defense tips, aligning closer with this study's preventive approach [51].

Transportation applications are very limited, with the Netherlands having textitTransitMate [82], as the only available option. This application includes location-based features, such as sharing your location with your

friends and watching your friends progress on their journey. Nothing more than other personal safety applications have.

2.3.3 User Engagement and Effectiveness

User engagement with personal safety applications is crucial in understanding the public's perception and the technology's effectiveness. McCarthy et al. [52] highlighted a low download rate among smartphone users, with a mere 1.7% usage rate in Dublin, despite a high willingness to report anti-social behavior. This study further revealed that cost is a significant barrier, discouraging nearly half of the potential users at a price point of €1.79.

Criticism arises regarding the design and functionality of these applications. The literature points out the reactive nature of most personal safety apps, which act during or after an incident, thus failing to prevent it. Such approaches, together with technological failures and the necessity for in-app activation in dangerous situations, contribute to user skepticism towards these apps' practical utility in enhancing safety.

Moreover, the engagement gap, despite the willingness for usage in reporting, indicates a trust issue and doubts about the apps' efficacy. Few apps focus on preventive measures, such as educating users about risk factors and methods to reduce personal vulnerability — a feature that could significantly enhance the sense of personal safety among users [51][97].

2.4 Related Existing Scales

Measurement is a fundamental part of science [77]. We learn about people, objects, events, and processes by observing them. To understand these observations, we often need to measure and quantify them [19]. Researchers often face challenges when aiming to measure specific phenomena in their field of study, knowing that using poorly designed measurement tools can lead to unreliable data. For this reason, creating their own measurement

tools often becomes the only viable solution, even if that was not their primary interest [19]. Numerous scales have been created to measure a variety of social, psychological, and health behaviors and experiences [6]. In the context of perceived personal safety, many researchers have tried to quantify it.

For instance, Xie et al. [96] developed a scale to measure how safe tourists feel at their destinations (Tourist Perceived Safety at Destinations - TPSD). Their 20-item scale looks at five areas: people, facilities, the natural environment, the social environment, and management practices. Similarly, Hayes et al. [31] created a Work Safety Scale (WSS) to measure employees' perceptions of workplace safety. This 50-item scale evaluates factors like job safety, coworker safety, and supervisor, aiming to understand the safety climate and its effects on job satisfaction and accident rates.

Moreover, Milam et al. [57] developed a scale to measure perceived safety in schools and neighborhoods, particularly focusing on how these perceptions influence academic performance among urban school children. Their study utilized the School Climate Survey and the Neighborhood Inventory for Environmental Typology (NIfETy) to assess safety perceptions and neighborhood violence. Lastly, Syropoulos et al. [75] in a very recent research introduced a multidimensional model to measure perceived personal safety (PS), emphasizing the complexity of this construct by dividing it into three factors: Feeling of Safety, Fear of Crime, and Safety Confidence. This scale captures how individuals perceive their safety in various environments and situations.

These scales for measuring perceived personal safety mainly focus on specific groups like tourists or employees, which do not quite fit with everyday commuters who travel door-to-door. For example, the scale by Xie et al. [96] is great for tourists but misses out on the everyday experiences of people commuting to work or school. The Work Safety Scale by Hayes et al. [31] is thorough for workplaces but it only considers indoor and work-related situations that can occur, rather than the situations commuters face daily, like different times of day, being outdoors, or the varying number

of people around them. These scales fail to capture the factors that matter for assessing safety during door-to-door transportation. Furthermore, these scales fall short as they do not take into account the impact of technology on feelings of personal safety.

Among them, the most closely related to our research is the scale by Syropoulos et al [75]. However, our approach differs by focusing specifically on perceived personal safety during door-to-door transportation and the role of technology in enhancing this perception. While Syropoulos et al.'s scale [75] provides a broad assessment of personal safety across different contexts, our scale aims to explore how technological solutions foster feelings of safety during transportation.

The vision for our scale differs significantly from existing scales like that of Syropoulos et al. [75], which provides a broad assessment of personal safety in various contexts. Our scale looks into how technology can influence perceived personal safety during door-to-door transportation. It focuses on how effectively current technologies make travelers feel safer and identify areas where they fail to live up to expectations. This allows assessing the current transportation technologies related to personal safety but also guides the development of innovations that can lead to improvements in traveler safety. This way, developers of such applications can create more effective personal safety-enhancing technologies based on reliable insights.

2.5 Literature Gap

Current studies often treat groups of people, like women or the elderly, as if everyone within those groups feels the same about their personal safety. However, personal safety perceptions can vary greatly even within these groups as supported by literature due to different personal experiences, income levels, and other factors. This lack of attention to individual differences within groups shows that we need better evaluation scales that can measure their different perceptions of personal safety more accurately.

Moreover, many personal safety technologies, mainly focus on actions to take after an unsafe situation has already happened. There is less research on how to prevent these situations from occurring in the first place. To develop such preventive technologies, it is essential to first establish a reliable method for measuring the perceived personal safety that these technologies aim to enhance.

Another significant issue is that existing scales are insufficient for assessing the impact of technology on perceived personal safety during door-to-door transportation. These scales are not designed with the integration of technology in mind, nor do they address the context-specific factors that affect travelers. This limitation in understanding how well current personal safety technologies function makes it challenging to develop new safety technologies tailored to meet the diverse needs of travelers.

To address these gaps, we need a scale that can measure how people perceive their personal safety while traveling door-to-door across different situations and demographics. Such a scale would evaluate how well current personal safety technologies are working and guide the creation of new safety measures that better meet the varied needs of people.

3. Methodology

In this section, we describe the steps taken to develop and validate the scale measuring the impact of technology on perceived personal safety during door-to-door transportation (Figure 3.1). The process began with focus group sessions to gather insights, which led to the generation of 77 items. These items underwent an HCI expert review, resulting in a refined list of 65 items (See Appendix C).

An initial survey was then created, asking participants to use the scale based on state-of-the-art technology. This was followed by Exploratory Factor Analysis (EFA) to assess the scale's structure, which helped further refine it to 13 items (see Table 5.1). Next, another survey was conducted to evaluate this 13-item scale, using Confirmatory Factor Analysis (CFA) to ensure the scale's dimensionality. The final validation step was to measure the scale's reliability using Cronbach's alpha.

Before conducting the research, the Ethics and Privacy Quick Scan of the Utrecht University Research Institute of Information and Computing Sciences was conducted, which classified this research as low-risk with no fuller ethics review or privacy assessment required. (see Appendix A).

The following chapters will explain in detail this process from item development (Chapter 4), to scale development (Chapter 5) and scale evaluation (Chapter 6). Each one of these sections presents the results of the surveys and analyses.

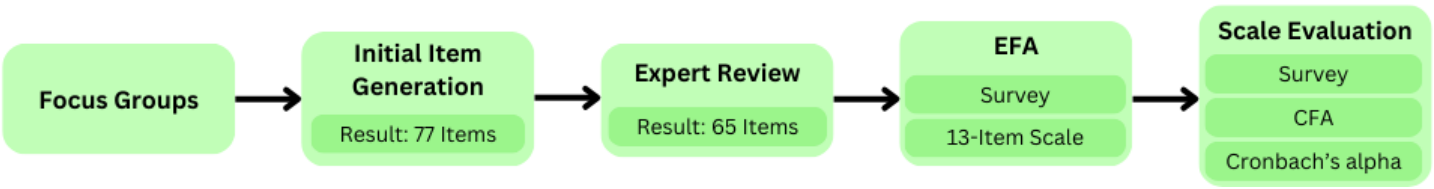


Figure 3.1: The scale formation process

4. Item Development

In this chapter, we are discussing the process of developing the initial items of the PPSS. Starting from the conduction of focus groups for the identification of factors and their analysis (Section 4.1), moving to the generation of items (Subsection 4.2.1) and their refinement by an expert (Subsection 4.2.2).

4.1 Focus Groups

The focus groups aimed to further understand the factors that influence people's perception of personal safety. The results from these focus groups, together with the insights from the literature, provided the basis for the initial items of the scale.

4.1.1 Participants and Recruiting

For this study, we aimed to recruit a diverse sample to ensure a broad understanding of perceived personal safety during door-to-door transportation. For that reason, convenience sampling was employed, as it facilitates the selection of people who are readily available and willing to participate. However, as studies have shown in the past [15], women tend to be more willing to take part in such studies, and purposive sampling was proven needed to achieve an equal split between men and women.

To make the requirement process easier for the researcher and the potential participants, a brief survey was set up using *Qualtrics XM*. The survey included an information page detailing the study's purpose, the researcher, her supervisors, study procedures, data collection and handling methods, participants' rights, approval details and the content for the focus groups.

As for the selection criteria of the participants, we needed the participants to be 18 years old or older, as perception of personal safety may

significantly differ between adults and children. Furthermore, including participants who are 18 or older ensures adequate experience with public transportation systems. We also aimed to include participants who are not originally from the Netherlands to capture a broad range of factors that influence perceived personal safety while ensuring that the developed scale would be widely applicable. Lastly, a balanced gender distribution among participants is targeted.

This process initially resulted in the recruitment of 17 participants. However, only 13 participants were able to attend the final focus groups, where 7 participants identified as women and 6 as men. The participants were between 23 and 34 years old, with the majority being 24 to 27 years old (65.5%). As for the participants' nationality, the majority were from the USA (30%). Other represented countries included Greece (20%), Canada, Uruguay, the Netherlands, Germany, and Luxembourg (each 10%).

4.1.2 Apparatus

For the recruitment of participants, a brief survey was considered needed and was created using *Qualtrics XM* [68]. This survey included information about the study's purpose, the student researcher, her supervisors, study procedures, data collection, and handling methods, participants' rights, approval details (see Appendix B.1), consent form (see Appendix B.2), demographic questions and their availability during certain timeslots.

The discussions during the focus groups were structured around several key categories identified from the literature, using scenarios that simulated a door-to-door journey. These scenarios included a person commuting to work and another returning home from a night out and can be found in Table 4.1. The primary categories for discussion were Demographics & Identity, Social Comfort & Trust and Immediate Environment which had been highlighted in the literature as the factors influencing perceived personal safety during transportation. While the category of Previous Experiences was intentionally omitted to avoid sensitive issues, it still emerged naturally

as participants expressed their views and reactions to the fictional characters' experiences. While Social Comfort & Trust and Immediate Environment aspects were included in the scenarios themselves, to assess Demographics & Identity theme, further "What if" questions were planned to be asked and are mentioned in Subsection 4.1.3.

Furthermore, to ensure structure and engagement during the focus group, a presentation was displayed on a screen for all participants to see. This presentation included a welcoming slide, followed by a program slide showing the session's program. Next, a slide encouraging the participants to introduce themselves was included sharing personal details such as name, age, occupation, countries they have lived in, places they usually transport to, transportation modes they typically use, and their favorite activity while traveling. After that, slides introducing the topic were included, along with an explanation of the definition of "perceived personal safety". The following slides covered two travel scenarios and "what ifs" that proposed changes to the initial scenarios and a slide indicating a break.

Lastly, before the participants arrived, the room was prepared for the recording, and snacks and beverages were put on the side of the table for the participants to have as a welcome during the break. Also, pens and yellow and pink Post-it notes were laid out on the table for use during the session.

4.1.3 Procedure

In this subsection, we are going to describe the process that was followed before and during all three focus group sessions.

4.1.3.1 Preparation

Incorporated in the brief survey that was sent out during the recruitment process the content form was included, so only the participants that agreed to participate were taken into account for the formation of the focus groups. The goal was to form three focus groups, each consisting of

Scenario #1
It's rush hour and 25-year-old Mike has to go to work. It's his first day at his new job in a brand-new city. To get to the office, Mike checked the travel planner which indicated a public transport travel time of 40 minutes in total. He leaves the house and walks 5 minutes to the train station. Arriving at the station, he walks to the platform and waits 3 minutes for the train to arrive. When the train arrives, Mike gets on the train and rides it for 20 minutes. After arriving at the station, he gets off and walks to the nearest metro station. After boarding the metro, he spends 10 minutes on it. When Mike arrives at the station, he takes a short walk towards his office on the other side of the road.
Scenario #2
Mia has just had a night out with her best friends for her 18th birthday, and they all get on the last metro to go home. They board the metro together, but since they all live in different areas of the city they have to each get off at a different station. Arriving at Mia's destination, she says goodbye to her friends and exits the metro. Then she walks through the station and gets in the direction of her place, which is a 7-minute walking distance.

Table 4.1: Door-to-door travel scenarios used for the focus groups

four to six participants, to explore the reasons behind low perceived personal safety as identified in existing literature. To examine different group dynamics, the focus groups were intentionally composed of varied demographics: one group consisted of five women, another of four men, and the final group included two men and two women.

4.1.3.2 Upon the Participants Arrival

To foster a welcoming atmosphere, participants were greeted and offered snacks upon arrival. They were asked to be seated around a big table and it was made sure that the presentation was visible to everyone. Next, they were reminded that the sessions would be recorded and the focus group procedures could begin.

4.1.3.3 Warm-Up

To establish a comfortable atmosphere for participants, and to appropriately set the context for discussions related to transportation, the focus

group involved a brief introductory activity, for which they were asked to introduce themselves in 1 minute. After getting to know each other, the participants were introduced to the study's subject matter and the scenarios exercise was explained.

4.1.3.4 Scenarios

The core activity involves presenting scenarios to the participants, which were presented on the presentation for the participants to read. Two scenarios were presented in total, in order to have enough time for discussion, which revolved around fictional characters navigating a journey.

Participants are asked to write down on yellow post-it notes the feelings concerning personal safety they believe the character would experience in these scenarios and the reasons behind them on the pink Post-it notes. After writing down the feelings and the reasons behind them, each participant placed their notes on the board, when they had the chance to elaborate on their thoughts, putting the feelings and their respective reasons opposite to each other.

Upon completing the exploration of the first scenario, participants were engaged with "What if..." questions aimed at diving into the personal attributes of the scenario's character, including gender, age, ethnicity, income level, and sexual orientation. They were then instructed to select one attribute and revisit the process of articulating feelings and underlying reasons associated with that characteristic in the given context, writing them again on Post-it notes. This activity was designed to deepen the understanding of how different personal factors might influence perceptions of personal safety.

Concluding this part of the focus group, participants were provided with small colored stickers for their Post-it notes. Each color represented a different category: red stickers for Gender, green for Age, blue for Ethnicity, yellow for Income Level, and white for Sexual Orientation. This color-coding system facilitated organized data collection and analysis of the participants' insights based on demographic factors.

Then the participants were asked to think about a technology solution that could potentially enhance the character's sense of personal safety. Specifically, they were asked to describe what features or capabilities such a technology should possess to effectively address safety perceptions. This inquiry was followed by an open-ended discussion session, lasting about five minutes, where participants were encouraged to freely express their thoughts and ideas which could potentially serve as a source of inspiration for the design of the enhanced version of the state-of-the-art technology of the survey.

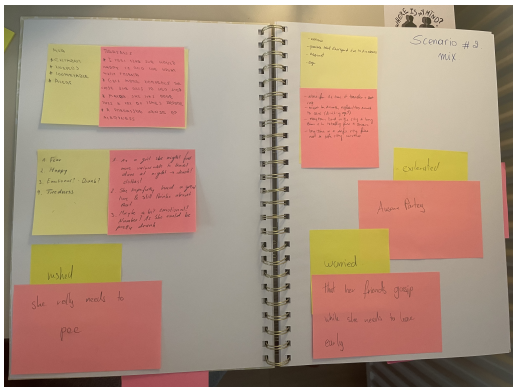
Following, participants were given a brief five-minute break, offering a moment to "reset" before the introduction of the subsequent scenario, while having some snacks and drinks. After this pause, the facilitator presented the next scenario, replicating the same structured approach as before.

To wrap up the focus group session, participants were then encouraged to share any thoughts or insights, effectively concluding the discussion. This open forum allowed for further reflection and conversation, permitting attendees to articulate any additional feedback or observations that extended beyond the provided scenarios.

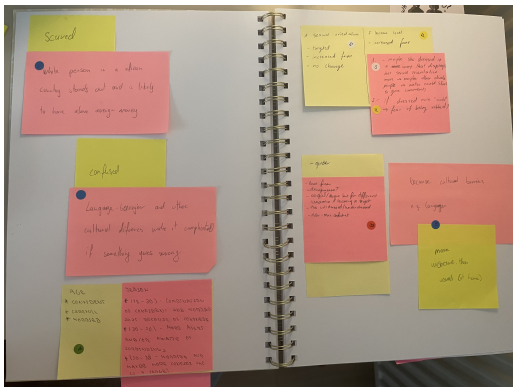
4.1.4 Analysis

To analyze the results of the focus groups, the audio recordings from the focus group sessions were transcribed using *Microsoft Word*'s transcribe feature [56], secured with the researcher's University account. After transcription, the texts were carefully reviewed to identify feelings and reasons not captured on the post-it notes but mentioned during the participants' discussions. Any relevant thoughts concerning the subject were highlighted in the text. These insights were then transferred onto colored post-it notes, exactly as the scenarios activity asked. These additional post-it notes were combined with the original ones and organized by theme in a notebook, ensuring they were placed on the appropriate pages for comprehensive analysis. These Post-it notes were categorized in a notebook by session, specifi-

cally before (Figure 4.1a) and after the "What if" questions (Figure 4.1b) were posed. After organizing all the notes, those irrelevant to personal safety were removed from the collection. The relevant notes were then digitized and transferred into Miro [58] for further analysis and secure storage. In Figure 4.2 you can see how the Post-it notes were arranged for the first scenario of the mixed-gender group.



(a) Post-it created during a focus group organized in a notebook



(b) Post-it with "What if" labels created during a focus group organized in a notebook

Figure 4.1: Comparison of Post-it notes created during a focus group

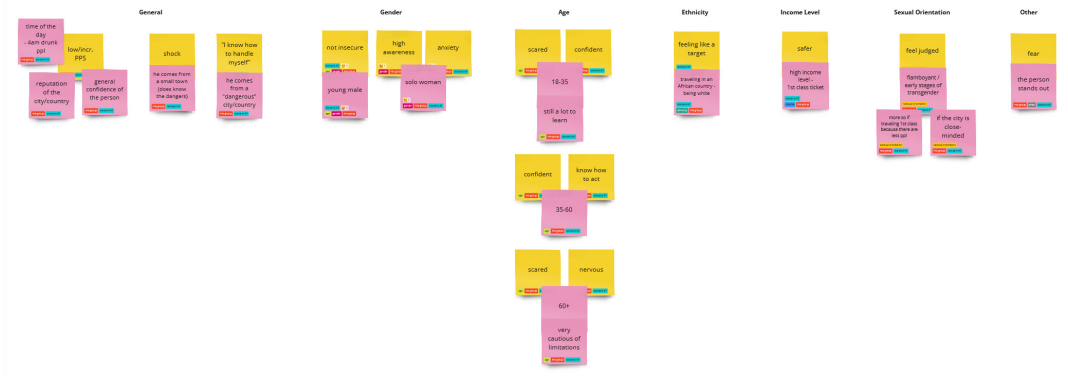


Figure 4.2: Digitalized Post-it from a focus group notes in *Miro*

Each digital Post-it was appropriately tagged to indicate the specific focus group and scenario it originated from. Additionally, tags were used to classify whether it belonged to one of the "What if" categories: "Gender", "Age", "Ethnicity", "Income Level", "Sexual Orientation", and "Other". This tagging system facilitated the next step of the analysis which is coding.

Using the tags, the Post-it notes were grouped into observed categories following the inductive method. After reviewing all the notes and their tags, each note was placed under a theme identified by the researcher. These initial themes were then grouped into larger themes. After this step, although there was potential for additional factor categories to emerge, it became clear that these larger themes matched those found in the literature. Nevertheless, the insights derived from these notes provided interesting perspectives that were not previously highlighted in the existing literature. An example of the categorizing process can be seen in Figure 4.3 and a more detailed explanation of the codes hierarchy can be seen in the schema in Figure 4.4.

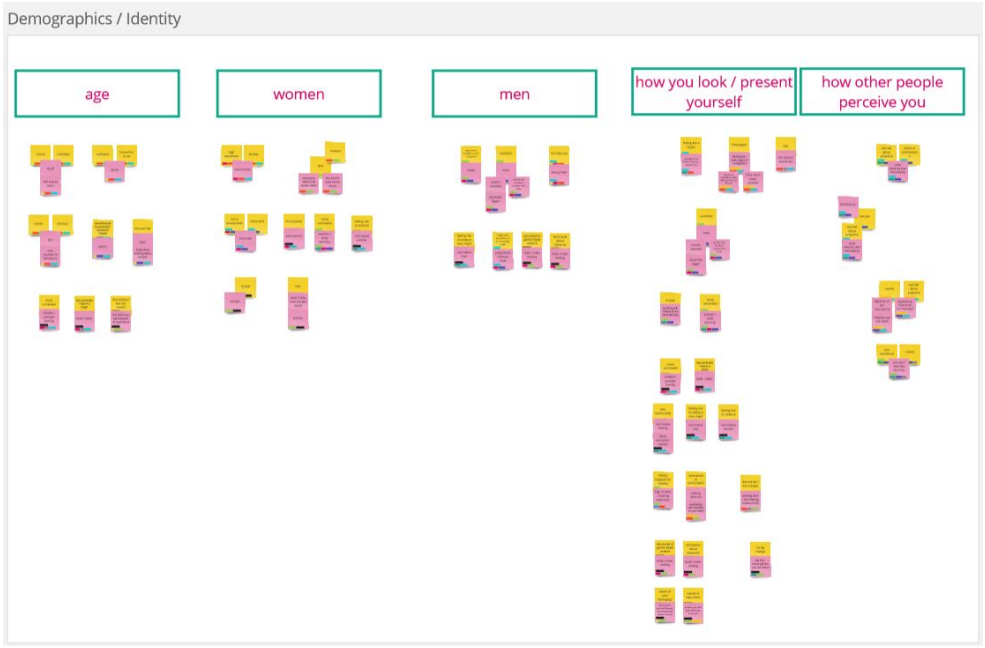


Figure 4.3: Demographics/Identity code with its sub-codes and Post-it notes in *Miro*

4.1.5 Focus Group Results and Observations

When discussing feelings of personal safety in the first scenario, participants from all groups did not mention actual feelings of safety. Instead, their concerns revolved around time management and making a good impression at work. One participant from the men's group noted:

"Many feelings but not about safety"

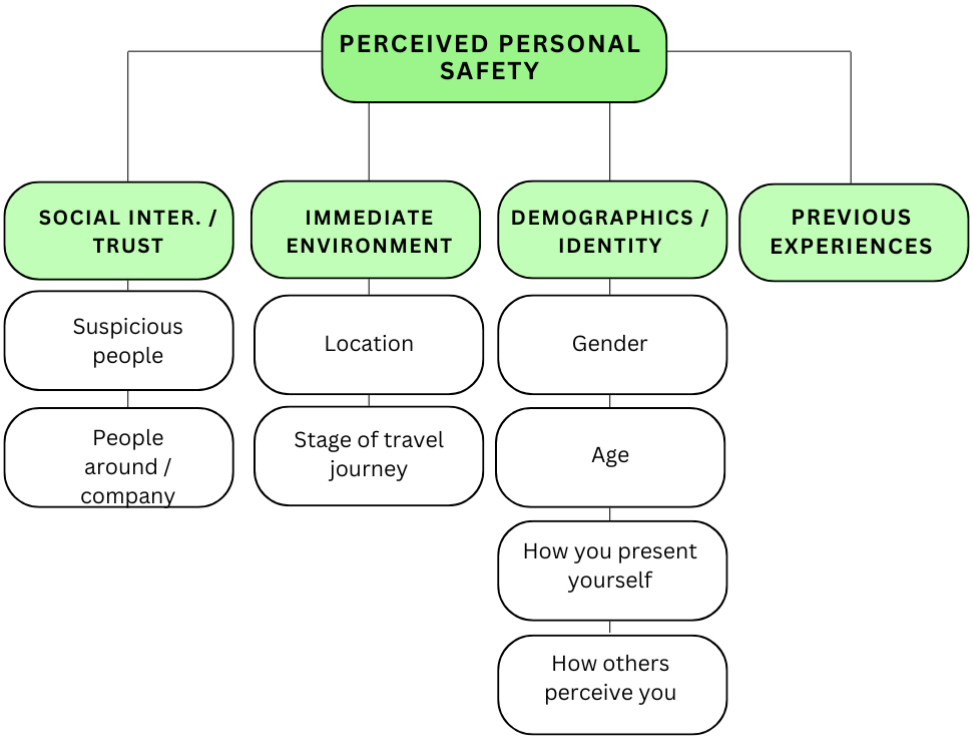


Figure 4.4: Final codes from focus groups

Geographic Safety. Also, all participants, regardless of group composition, agreed that perceptions of personal safety are heavily influenced by the country or city they live in. This was supported by the level of familiarity that one has traveling in an area but also a place's reputation.

"I mean, it depends on crime, right? It depends on what the city is known for"

"If you're from a small town, traveling in a huge city all of a sudden can be scary."

Unknown Motives. Additionally, a recurring concern across all groups was the behavior of drunk people. Participants were very wary of the actions of intoxicated individuals around them. However, this was not limited to other people being drunk, but was extended to strangers in general and their unknown motives.

"The character is with a bunch of strangers and doesn't know what their motives might be. Most people are probably fine, but it still gives them a heightened alert."

Appearance. In every focus group, people talked about how the way someone looks can lead to unfair treatment by others. These discussions showed that people often face prejudice based on their style choices rather than who they are. Wearing something unusual, for example, can sometimes lead others to make unfair assumptions based on what's considered normal or acceptable in their culture.

"If you really what I would dress for example extreme, then some people might find the chance to act on their prejudice."
"The character would think: If I present myself in a way that's like an alternative from other people, is that something that is going to cause violence against me?"

Minorities and Income Level. Moreover, being a minority was noted to increase feelings of fear and vulnerability. Building on this every group identified women traveling in countries where they are perceived as foreigners as the most vulnerable group. The last point that was common in all groups was that level was not seen as a factor in perceived personal safety during transportation from all groups and was only mentioned for fear of theft.

"If you are part of a minority people might have a prejudice against you and the possibility of confrontation is high!"

Physical Build. In both the men and women groups, physical build was a notable topic. Participants noted that individuals who are physically smaller or look younger are seen as more vulnerable.

"They would be less scared because they're like physically bigger."
"I'm a very small person, I would feel less safe than if I was built bigger and taller or if I looked older.

Confidence as a Trait. The common topics that only the mixed and women groups shared were mentioned by women. One was the personal trait of confidence makes you feel less unsafe while traveling. The other topic was the concern about your friends traveling alone and also not wanting to be the last one of your group to be on public transport.

"If you are a confident person in general, then you might not feel so unsafe while traveling."
"She is worried about your friends after she left."
"In my own experience, I would be happy that I wouldn't be the last one in the metro."

Traveling with Friends. The men's group had unique discussions on traveling in groups or with friends. Men felt more vulnerable when they were without their friends, highlighting the importance of group travel for perceived safety. Feelings of ease were also mentioned when traveling with friends of the same ethnicity or race.

"It's nice to travel with friends to be able to keep track of each other."
"You feel more vulnerable without your friends."
"I think if they are males, they probably feel even more confident, just like confident, especially when they're in the group."

Masculinity. Additionally, men discussed acting "macho", assertively or intimidatingly to project confidence and prevent being targeted. One participant mentioned:

"I guess he is feeling kind of scared, but they're acting assertive or trying to be intimidating, very deliberate, like, walking through whoever is there"
"Being macho asserted so that he intimidates people who might want to harm him."

Companionship as Protection. In contrast, in the focus group with only female participants the importance of companionship while traveling was mentioned more strongly. As opposed to men, mentioning traveling in

groups for feeling more confident, women mentioned it to protect, with a preference for someone with a bigger physique and male.

"Travel with my boyfriend or someone less of a target than me. Like my boyfriend is who is over a foot taller than me and a guy."

Gender. In the women-only group, the participants were also observed to be more likely to project their own experiences and feelings onto the scenario compared to the other groups. They were also sharing their feelings more openly than any other group. Also in this group only there was a significant discussion about gender differences in safety perceptions. Women felt that men were generally more confident and secure while traveling. One participant mentioned:

"A guy would feel more secure and confident on maybe his first day or while traveling in general, but I know that's a very gross generalization."

Reputation. In the mixed group, although all groups mentioned it, the discussion really highlighted the dependence on crime rates and the reputation of the city of perceived safety. In group specifically consisted of people who have lived in many different countries and were discussing their perceptions of personal safety in them and how they differ from living in the Netherlands, or their home country.

"I mean, it depends on crime, right? It depends on what the city is known for."

Proposed Technologies. As for the proposal of technological solutions for perceived personal safety enhancement during transportation, participants suggested several technologies. These include real-time navigation apps, the use of panic buttons, automatic notification systems for safe arrivals, and wearable safety devices like panic-button-equipped bracelets. These technologies are already widespread as seen in Section 2.3, however, interesting additions were mentioned. For example, an application that calculates the average travel time for a trip and takes action — such as notify-

ing the police — if the travel time significantly exceeds it. Another creative proposal was a fake call feature, where the user talks with an AI bot that can respond to specific keywords and execute safety measures based on the conversation.

4.2 Item Formation

In this section, we describe the process of building the Perceived Personal Safety Scale (PPSS) from conceptual considerations to a final list of items and evaluating it.

4.2.1 Generating Initial Items

Two researchers generated initial items for the PPSS, in line with Boateng et al. [6], following the inductive method which involves the generation of items from the responses of individuals [32], as the literature was oversubscribed by the results of the focus groups. Each researcher first created items, based on the feelings of personal safety and the corresponding reasons from the digital Post-its on their own (see example item in Figure 4.5). We then arranged a discussion session in which all the generated items were merged and duplicates were removed, resulting in an initial list of 77 items.

The initial pool of items was nearly (5.93) times larger than the final version, aligning with the higher end of recommendations suggesting it to be five times the size of the final scale, to provide the requisite margin to select an optimum combination of items [72], while the lower end recommends two times [42].

Using this technology helps me reduce my **fear of hate crime** when I **express my individuality while traveling**

Figure 4.5: Generated item example with the feeling in yellow and the reason in pink

4.2.2 Expert Review

A round of expert review was conducted to refine the list of possible scale items for assessing user experience. The reviewer, a professor specializing in Human-Computer Interaction (HCI), provided detailed feedback by suggesting modifications to some items and recommending the removal of others. This process helped ensure content validity [6] and resulted in a revised list of 65 items (see Appendix C).

The items were provided to the expert in an *Excel* [55] file with columns indicating the items, the code the item belongs to, an alternative version of the item, and two extra empty columns named "Needed?" and "Expert's comments." In those columns, the expert could indicate if she considered the item one that should be kept, removed, or rephrased, along with her comments about the reasoning.

An example of rephrasing an item was the statement: "Using this technology helps me feel less scared while I travel even if I am not experienced in public transportation." This item was found to be "hypothetical" and should be changed to something widely applicable, suggesting: "Using this technology helps me feel less scared when using a public transport mode which I have not used before". An example of an item that should be removed is "Using this technology helps me feel less scared as a young individual" because this could be filled in by an old individual.

5. Scale Development

After the expert review, we designed an online survey using *Qualtrics XM* [68] including state-of-the-art technology and the items generated for the participants to put their input. This data was later used to perform Exploratory Factor Analysis and item reduction.

5.1 Participants

A sample size of 100–200 participants was targeted, aligning with the development and validation of other scales in HCI [49, 54, 81]. This goal was successfully met with a total recruitment of 223 participants via the platform *Prolific* [65].

Initially, a test round with 20 participants was conducted to ensure the questionnaire was clear and understandable. Once confirmed, an additional 180 participants were recruited. The questionnaire included three attention-check questions to identify respondents who were not paying adequate attention, which could compromise the validity of the data. We coded a *Python* script [67] to identify participants who answered any attention-check question incorrectly. his process led to the rejection of 53 participants, making necessary an additional round of recruitment. The final valid responses were 170 from an overall recruitment of 223 participants.

The dataset showed a diverse age distribution with participants falling into three age groups: 21-24 years (23.53%), 25-34 years (41.18%), 35-44 years (23.53%) and 45-54 years (11.76%). In terms of gender, the majority of respondents are female (58.82%) as compared to male (41.18%). Ethnically, most respondents identify as White (76.47%), followed by Black (17.65%) and Asian (5.88%). Nationally, the largest group is from the United Kingdom (23.53%), with notable representations from South Africa (17.65%) and

Germany (11.76%). Other nationalities such as Australians, New Zealanders, Canadians, Italians, Russians, Basotho, Latvians, and Croatians account for 5.88% of the sample.

5.2 Apparatus

The initial online survey (for the questions see Appendix C) and its consent form (see Appendix B.4) were created using *Qualtrics XM* [68].

Before answering the questionnaire on their perceived personal safety, participants were introduced to a chosen state-of-the-art technology, through a video shortly demonstrating its features. The application of *bSafe* [8] was selected due to its significant popularity online and numerous recommendations considering it the best option available in the market. The video was available on their website.

The survey consisted of 65 items, each rated on a 7-point Likert scale that ranged from "strongly disagree" to "strongly agree". This approach aligns with the recommendations by Boateng et al. [6], who suggest using a seven-point scale for bipolar items to capture the full spectrum of responses effectively. The items were presented in an ordinal manner, ensuring clarity in the response options. Participants were recommended to complete the survey on a computer or tablet for optimal experience, though it was also accessible via smartphone.

5.3 Exploratory Factor Analysis

In this part of the study, Exploratory Factor Analysis (EFA) was employed to ensure that the scale includes only items that effectively measure how technology affects perceived personal safety during door-to-door transportation. EFA examines all pairwise relationships between individual items, extracting latent factors from the measured items [61]. The analysis was conducted using a program coded by the researcher in *Python* [67] which can be found in Appendix D.1.

5.3.1 Cleaning the Data

The data cleaning process involved several steps to ensure the quality and reliability of the dataset, which were automated using a program written in *Python* [67] and the library *Pandas* [64] to create a DataFrame from the initial data file. First, the program identified participants who failed the attention questions by checking their answers and returning their participant IDs. These participants were then rejected using *Prolific* [65].

Before beginning the process of factorial analysis, three researchers reviewed the items, leading to the removal of 11 from the list (for the list of initial items see Appendix C). Three items were excluded for lacking a sole safety dimension (items #12 - #14), while the remaining eight were considered too general and vague (items #1 - #3a and #5 - #9).

After that, the program was extended so that the file became suitable for the analysis. For that rows with empty values were deleted and non-essential columns were removed from the dataset. This means that only the answers to the items-questions, while information such as the date, time, duration, etc were excluded along with the added attention questions. All the excluded columns from the data frame can be seen in the code snippet in Appendix D.1.

5.3.2 Assessment of the Suitability of the Data

Following this, two tests were conducted to determine if the data were suitable for factor analysis, written in *Python* [67] using the library *factor analyzer* [5]. The first test was the *Kaiser-Meyer-Olkin (KMO)* Measure of Sampling Adequacy [40], which evaluates whether the sample size is sufficient for factor analysis. More specifically, it assesses sampling adequacy for each variable and for the entire model [74]. The result of the *KMO* test was 0.95, indicating that the sampling adequacy is “marvelous” for the analysis according to [74, 21].

The second test was *Bartlett's test of Sphericity* [3] to examine whether the correlation matrix is equivalent to an identity matrix [74]. Simply put,

this test checks if the variables in the data are related enough to be grouped. The resulting p-value of Bartlett's test was below 0.05 and very close to zero, indicating a significant result, meaning that the items are related and appropriate for factor analysis [94, 74].

5.3.3 Factor Extraction

After testing the suitability of the data, two techniques were employed to determine the number of factors to retain, as suggested by A.G. Yong et al. [98]: *Kaiser's Criterion* [41] and the *Scree Test* [9]. For both of the techniques the library *factor analyzer* [5] was used along with *matplotlib* [35] for creating the scree plot.

The *Kaiser's Criterion (Eigenvalue Criterion)* [41] involves retaining factors with eigenvalues greater than one. These are considered significant as they explain more common variance than unique variance [29, 40]. Applying this criterion resulted in the test proposing the retention of 6 factors.

Subsequently, the scree plot was created, showing the eigenvalues on the vertical axis and the number of factors on the horizontal axis. Factor extraction should ideally stop at the "elbow", where the plot levels off, indicating the point where common variance ends, and unique variance begins to dominate [74]. A similar way, described by the literature [94] is to draw a straight line through the smaller eigenvalues where a departure from this line occurs. Both methods proved useful for analyzing the scree plot, with the "elbow" observed at the fifth factor, suggesting that four factors should be retained (Figure 5.1).

The significant difference between the results of the two tests needed consideration, as both methods are subjective and require researcher judgment [76, 80]. Since each test suggested a different number of factors to retain, finding a compromise that aligns with both recommendations was proved a wise approach.

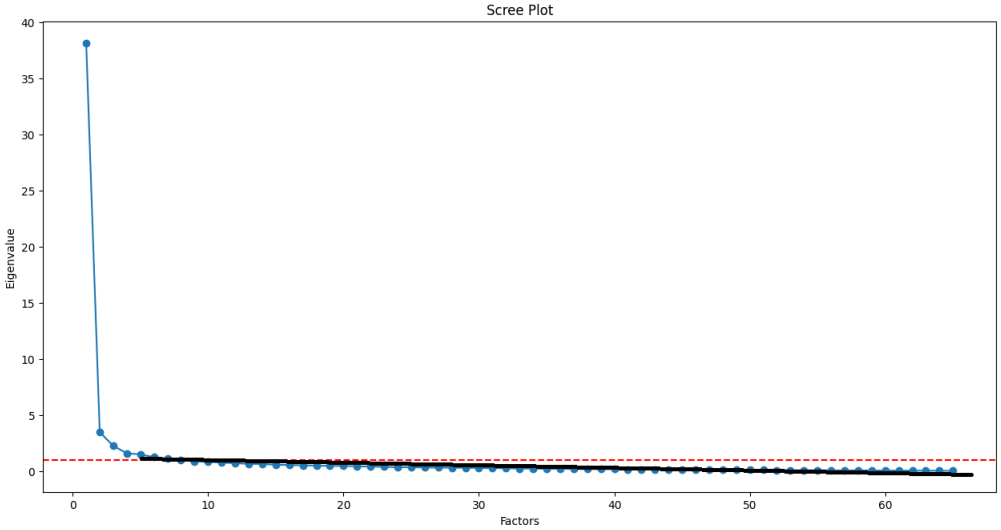


Figure 5.1: Scree plot presenting the factors on the x-axis and the eigenvalues on the y-axis

5.3.3.1 Rotation

Factors obtained in the initial extraction phase can be challenging to interpret due to significant cross-loadings, where many factors are correlated with many variables [74]. To address this, there are two main approaches to factor rotation: *orthogonal* and *oblique*. For this study, *oblique rotation* was used for the EFA as it allows correlations between factors [61], which is consistent with the hypothesized relationships among the items generated by the researchers. Furthermore, by allowing the factors to correlate, oblique rotation offers a nuanced understanding of the data, reflecting the true complexity of human feelings and perceptions. More specifically *direct oblimin* rotation was used as it attempts to simplify the structure and the mathematics of the output, while *promax* is preferred for its speed in larger datasets, which was not the case in our study [98].

After running the EFA, the next step, as suggested by the literature, was to identify and delete items with communalities below 0.2 [10]. The EFA was then re-run. Upon examining the loadings with six factors, multiple items exhibited cross-loadings close to 0.4 [6]. While it is often recommended to retain items with factor loadings of 0.40 and above [70], these items were deleted, along with those with loadings lower than 0.4. This de-

cision about the cross-loadings was based on their limited contribution to the analysis, especially since many other loadings were above 0.7, which is considered very strong.

After the item removal, the EFA was run again. This time, the sixth factor had no loadings above 0.4, leading to a reduction in the number of factors from six to five. The EFA was then conducted with five factors, which resulted in more cross-loadings similar to the previous analysis. The same removal technique was applied, and the EFA was re-run, with the fifth factor having only two significant loadings of 0.42 and 0.41. Given the low loadings and the limited number of items, the number of factors was further reduced to four.

The EFA was repeatedly run and items were iteratively removed until no more cross-loadings existed. At this stage, item removal was based solely on the significance of the loadings and the semantic coherence of each factor.

Ultimately, the EFA resulted in four factors: the first with five items, the second and third with three items each, and the fourth with two items. Although literature typically suggests that each factor should have three to five items [48, 69], it was decided to retain the fourth factor with two items. These items had high loadings (0.81 and 0.95) and were considered significant for the scope of the study, as well as semantically coherent. While retaining a factor with only two items is not common practice, it has been applied by other researchers in the past in the field of psychology, such as in "The Big-Five" by Samuel D. Gosling et al [27].

5.4 The PPSS

The final scale consists of factors/dimensions that describe the feelings of individuals traveling door-to-door about their personal safety while using a certain technology. Table 5.1 shows the items that were included in the final scale and their loadings.

Identity	
Using this technology helps me ease my concerns about standing out due to my appearance or presentation in areas with different religious or cultural norms	0.824403
Using this technology helps me reduce my discomfort in diverse social settings where my ethnic or racial identity might be more noticeable while traveling	0.825346
Using this technology helps me reduce my fear of hate crime when I express my individuality while traveling	0.822
Using this technology helps me feel less worried about prejudice based on how I express myself	0.909779
Using this technology helps me maintain my confidence even in areas where my ethnicity is not well-represented	0.756453
Traveling Alone	
Using this technology helps me feel less scared when traveling alone	0.805274
Using this technology helps me feel less anxious when walking alone	0.968733
Using this technology makes me less anxious when walking through a station alone	0.694997
High-Risk Context	
Using this technology helps me feel more confident while maintaining an appropriate level of caution when walking alone in a dangerous area	0.75159
Using this technology helps me feel less scared while maintaining an appropriate level of caution when walking alone in a bad neighborhood	0.845819
Using this technology helps me feel less nervous while staying vigilant when using public transportation or walking in an area with a bad reputation	0.798329
Interactions with Strangers	
Using this technology helps me feel more comfortable when unwanted interactions with strangers occur	0.815322
Using this technology helps me feel more confident when unwanted interactions with strangers occur	0.953153

Table 5.1: Final scale and item loadings

5.4.1 Identity

The first dimension assesses how effectively the technology helps users navigate social settings where their appearance, presentation, or cultural identity might be more noticeable. It has to do with concerns related to standing out due to diverse factors such as religious, and cultural norms. This dimension is crucial for users who frequently find themselves in culturally diverse settings or expressing individuality.

5.4.2 Traveling Alone

The second dimension of the PPSS is Traveling Alone. This dimension evaluates the system's ability to reduce anxiety and enhance the feeling of safety when users travel alone. It compacts how the technology helps users feel less anxious and more secure when traveling alone and walking through stations.

5.4.3 High-Risk Context

The third dimension measures a technology's effectiveness in maintaining confidence in high-risk areas. It assesses how it helps travelers feel more confident while ensuring an appropriate level of caution in dangerous areas. This dimension includes the technology's role in reducing fear while traveling through neighborhoods with bad reputations or using public transportation in such areas.

5.4.4 Interactions with Strangers

The fourth dimension of the PPSS assesses how technology assists users in managing interactions with strangers. It measures the system's effectiveness in helping users feel more comfortable and confident during unwanted interactions, ensuring that users can handle these situations.

6. Scale Evaluation

After developing the PPSS, its evaluation followed. To conduct it, a survey identical to the previous one but with the updated scale was created to ensure consistency in measurement and evaluation. Confirmatory Factor Analysis was then used to verify the dimensionality of the scale and Cronbach's alpha for its reliability. The analysis was conducted using a program coded by the researcher in *Python* [67] which can be found in Appendix D.2 and D.3.

6.1 Participants and Recruiting

A sample size of 60 participants was aimed, following the example of Bentvelzen M. et al. [4] who for the CFA recruited 56 participants. This goal was exceeded with the recruitment of 71 people through convenience sampling. From the people that participated 14 were 25-34 years old (63%), 45 were 25-34 years old (63%), 5 were 5-54 years old (7%) and the last 5 were 55-64 years old (3%). Regarding the participants' gender, 30 of them were male (42%), 39 were female (55%) and 2 were non-binary (3%).

6.2 Apparatus

The online survey was created using *Qualtrics XM* [68], the questions of which can be found in Appendix C. Initially, participants were presented with a consent (see Appendix B.4) form that introduced the topic, the aim of this part of the research, and the handling of their data. Upon consenting, participants were introduced to a chosen state-of-the-art technology through a video that briefly demonstrated its features, similar to the initial survey. The application used for this demonstration was again *beSafe* [8].

The survey consisted of the 13 items of the PPSS, each rated on a 7-point Likert scale ranging from "strongly disagree" to "strongly agree." After completing the questionnaire, participants were thanked for their participation.

6.3 Test for Dimentionality

Next, CFA was conducted by coding a program in *Python* [67], using the libraries *pandas* [64], *factor analyzer* [5] and *pingouin* [87]. The CFA was used to determine the correctness of the PPSS, and to confirm the factors and items by checking the model fit [79, 4]. After cleaning the data, similarly, as it was done for the EFA, code for the CFA and calculation for some indicators were programmed.

In Table 6.1 the item loadings resulting from the CFA are shown. As it can be observed all loadings are strong with only one loading scoring under 0.71, being 0.65.

Item	Identity	Traveling Alone	High-Risk Environment	Interactions with Strangers
# 1	0.75087517	0.0	0.0	0.0
# 2	0.78090797	0.0	0.0	0.0
# 3	0.71491585	0.0	0.0	0.0
# 4	0.6696622	0.0	0.0	0.0
# 5	0.7468345	0.0	0.0	0.0
# 6	0.0	0.72522478	0.0	0.0
# 7	0.0	0.82373671	0.0	0.0
# 8	0.0	0.76788422	0.0	0.0
# 9	0.0	0.0	0.76929376	0.0
# 10	0.0	0.0	0.71986329	0.0
# 11	0.0	0.0	0.65074957	0.0
# 12	0.0	0.0	0.0	0.76532823
# 13	0.0	0.0	0.0	0.75422747

Table 6.1: Standardized CFA loadings of items

The Comparative Fit Index (CFI) evaluates the fit of a model by comparing the discrepancy between the observed data and the proposed model. A CFI value close to 1 indicates a 'very good' fit [71]. In this case, a CFI of 0.97361 is considered very good, showing that the model has a high degree of fit with the observed data. The Tucker-Lewis Index (TLI) [84] was

measured as 0.965112, being "very good" [71]. Last the Root Mean Square Error of Approximation (RMSEA) was calculated equal to 0.073684. This is considered a reasonable model–data fit as it is smaller than 0.8 [7, 39].

6.4 Test for Reliability

To assess the reliability of the scale, Cronbach's alpha [14] was calculated for each of the factors and the entire scale, as presented in Table 6.2. The Cronbach's alpha for the overall scale was $\alpha = 0.95$. This coefficient assesses reliability by comparing the amount of shared variance among the items making up an instrument to the amount of overall variance [12]. More simply put, Cronbach's alpha measures the internal consistency of the scale items.

All factors and the overall scale have Cronbach's alpha values around 0.90, which is typically considered excellent [78, 16], and the values between 0.80 and 0.95 are preferred for the psychometric quality of scales [6]. The narrow confidence intervals for all factors support the conclusion that the items are highly reliable. These results indicate that the measurement instrument is consistent and dependable for assessing the underlying constructs represented by the factors [78].

Factor	Alpha value	Confidence interval
Identity	0.93	[0.90, 0.953]
Traveling Alone	0.9	[0.849, 0.934]
High-Risk Context	0.93	[0.903, 0.957]
Interactions with Strangers	0.88	[0.815, 0.928]

Table 6.2: Cronbach's Alpha values and confidence intervals for the factors and the scale

7. Discussion

As explored in this study the matter of perceived personal safety during transportation is complex, more so when investigating how technology fosters it. We identified the key components that influence perceived personal safety including: Identity, Traveling Alone, High-Risk Context, and Interactions with Strangers. Consistent with the literature [15, 17, 89], we found that identity plays a significant role in shaping perceptions of personal safety. However, it is important to distinguish between the general influence of identity factors, such as age, race/ethnicity, and sexual orientation, and their role within the context of our scale. The importance of these identity traits could be linked to societal structures and biases that can shape individuals into feeling less safe while traveling.

Our scale is designed to measure changes in perceived personal safety due to technological applications, rather than the baseline feelings of safety that may be influenced by identity. While someone's sexual orientation, for example, may affect their overall sense of personal safety, the PPSS focuses on how technology impacts perceived safety across different demographics. This does not mean that age or sexual orientation cannot affect someone's perceived safety; rather, these factors might not be the best indicators for measuring the specific impact of technological innovations. Therefore, including demographic questions alongside the PPSS can provide insights into whether these characteristics influence perceived personal safety fostered through technology.

Again consistent with the existing literature, social interactions and trust [15, 18], as well as the immediate environment [17] were confirmed as important factors influencing perceptions of personal safety and are included in the last two elements of our scale. These factors directly impact how safe individuals feel in different contexts. More specifically, our findings revealed that perceived personal safety depends not only on the specific place

or individual but also on the unknown intentions of others, as many mentioned in our focus groups. Also, our findings align with those of Aboneza et al. [1] in pointing out that familiar places and routine behavior do not affect personal safety perceptions. Additionally, the aspect of companionship was proved to be significant, as people reported feeling more secure in groups while traveling, making "Traveling Alone" a distinct factor.

Lastly, because the factor of previous experiences was not investigated directly, as it is a sensitive issue, we do not have quantitative results of how it can affect one's perception of personal safety. However, the first part of our research was successful in making the focus group participants project themselves onto the fictional character presented to them. This suggests that the influence of previous experiences is implicitly embedded in all of the factors that were developed for the final scale and is consistent with the existing literature supporting its effect on perceived personal safety during transportation [1, 2, 15].

7.1 Guidelines for Using the Scale

If developers of personal safety applications wish to use our scale as an opportunity to evaluate their technology, we would recommend they familiarize themselves very closely with what perceived personal safety demands. Our research is a useful starting point for this. Once done, this insight gives a base for considering how technology can impact personal safety perceptions. Understanding the reasons behind these impacts is crucial for developing applications that are effective and truly meet users' basic safety needs.

After this, developers should recruit the participants who best represent the target audience of their application. This ensures that the feedback given is relevant and would accurately represent the real end users of the application. Moreover, including people from different backgrounds would provide a wide understanding of perceived personal safety in diverse populations. This way, an inclusive idea of personal safety concerns can be derived,

helping to easily generalize the findings. Also, this diversity is essential as it can reveal unique personal safety concerns and preferences, crucial for creating inclusive technologies.

Exposure to the technology in question before the use of the scale, in physical or digital form, should be done. Previous exposure will ensure that the respondents are adequately aware of the application and thus will be in a position to accord feedback that is accurate and insightful. How the participants experience the technology can vary depending on the purpose of the study. For applications that are still at an early development stage, providing a rich verbal or video demonstration from developers may offer enough context so that participants can provide valuable feedback, which is useful to direct future steps. For existing technologies, participants should use the application in their everyday lives over an extended period. We advise this period to be at least one month in duration since it will allow participants to pass through the application in different real-life conditions and travel experiences. A substantial period of use will result in sufficient real-life feedback. Lastly, the questionnaire can be administered to the participants.

Finally, the questionnaire should also be conducted in a quiet, non-distracting environment, and all instructions should be standardized for every respondent. This consistency is key to eliminating external variables across various experiences that can distort the data, ensuring that results are based purely on perceptions and interactions with the technology. Clear instructions and consistent procedures minimize biases and errors, leading to more accurate perceived personal safety measurements.

7.2 Implications

The Perceived Personal Safety Scale (PPSS) is an essential tool for assessing how effectively personal safety applications meet user requirements across different travel scenarios. It can allow developers to identify strengths and weaknesses in their applications by measuring features related to iden-

tity, traveling alone, high-risk contexts, and interactions with strangers. This evaluation helps ensure that the apps not only address current user concerns but also adapt to changing personal safety perceptions. Regular use of the PPSS in application assessments can promote ongoing improvements, helping developers refine features and introduce new ones that truly enhance user safety during travel.

As technologies continue improving to enhance perceived personal safety, the PPSS helps foster confident mobility, free from undue fear. Successfully addressing perceived personal safety needs through technology can encourage more people to choose public transportation and walking over traveling by car, reducing CO_2 emissions and promoting eco-friendly transportation habits.

7.3 Limitations

Several limitations impacted this study. One is that participants only viewed a video-assisted review of the technology rather than using it to answer the initial and final questionnaires. This might have resulted in the participants not fully understanding how they would interact with the application in real-life scenarios. This may have led to a lack of understanding of the features and real-life interactions with the application, making the obtained feedback theoretical rather than a practical, hands-on experience. However, the video-assisted review provided a comprehensive overview of the application's features and the scope of the interactions that could potentially be expected, leaving the participants with a better-informed impression in order to provide constructive feedback. Further, it allowed all users to get the same information consequently reducing the variance in their understanding of the technology.

Another potential limitation is the age range of the focus group participants. Their ages were concentrated between the mid-twenties and mid-thirties, resulting in neglecting younger and older individuals' views on personal safety. This age range may have led to missing items on the scale

that could be relevant to younger and older individuals. This may have led to the PPSS not fully reflecting the diverse perceptions of personal safety fostered through technology across different age groups. Yet, the focus group participants provided diverse insights that are consistent with existing literature, suggesting that the scale captures fundamental aspects of perceived personal safety. Also, although the sample size for the evaluation of the scale was small, the methodological thoroughness and the consistency with already established research with our findings favor the credibility of the conclusions drawn.

In the focus group sessions, the scenarios presented and discussed did not encompass every possible real-life condition. Only two scenarios were developed, therefore the number is considered limiting. This could have an effect, limiting the applicability of the findings from the study to all door-to-door travel environments. Nevertheless, participants during the sessions elaborated beyond the context of the scenarios during their discussion and when responding to the "What if" questions, thinking broadly about situations that may arise and problems the characters would face.

Also, due to time constraints, the validation of the scale in this study was conducted at a basic level. Consequently, the validation process did not cover all aspects to the extent required for a robust evaluation. However, the initial validation has laid a solid foundation, demonstrating the scale's capability for reliably measuring perceived personal safety.

Another limitation relates to using *Prolific* [65] to conduct the EFA and test the reliability of the PPSS. We have that very small percentage of American participants because the initial survey was released at a time of day in which only a small percentage of American participants were online. We also did not have control over the equal distribution of men and women, which could affect generalizing our findings. Moreover, each member of the sample is self-selected, which could bias the results because they may differ from the general population, as the participants may be particularly interested in the area under study. Using this platform also has the drawback of participants randomly selecting answer choices without carefully

considering the content, but attention-check questions were used to alleviate the problem. Despite these limitations, Prolific gave us the advantage of fast data collection, getting many participants quickly for this study, which was crucial given the time constraints of our research. This allowed us to get and analyze data quickly, forming a good basis for future studies.

Lastly, while our study benefits from including participants from around the world, enhancing the applicability of the scale, this diversity also introduces certain limitations. More specifically, while the scale is designed to be widely applicable, it may not fully capture region-specific factors critical to measuring perceived personal safety. Different regions may have unique cultural, social, and environmental variables that influence personal safety perceptions, which are not fully addressed by a generalized scale.

7.4 Future Work

To better understand how personal safety technologies affect our perceptions, we plan to have participants use the technology in question for a certain amount of time rather than showcasing its characteristics. This method, though time-consuming, offers more reliable insights into the items and factors that should be included in the scale. The period that we propose for the participants to use the technology is a month since it is sufficient time for them to experience various situations and contexts while traveling door-to-door.

Additionally, to enhance the reliability of our scale, we propose to include 130 more participants from a wide range of backgrounds and demographics. This larger and more diverse group will help ensure the findings accurately reflect the general population, improving the clarity and dependability of our study's results.

As a limitation of this study was the time, in the future research could include further validating the scale. This would include further ensuring content validity but also tests for construct and criterion validity. For the content validity, we propose to incorporate an additional round of expert

review with the expert being in the psychology field. Such an addition can adjust the scale's questions to better capture the different ways people experience safety. Also, since perceived personal safety relates to individual thoughts and feelings, a psychologist's insights can ensure that each question on the scale accurately reflects what we need to measure.

To establish construct validity "known groups" could be used, and t-tests could be conducted, to investigate if the PPSS scores differ between the two technologies. One questionnaire would contain *bSafe* [8] and the other a revised version, based on the concerned and the technology solutions that were mentioned during the focus group sessions. To further establish construct validity we could investigate the discriminant validity by verifying that the PPSS is not a subset of the PS scale developed by Syropoulos [75].

Due to time constraints, we were also unable to develop an enhanced version of the *bSafe* application. This enhanced version would have incorporated improvements aimed at enhancing travelers' perceptions of personal safety. These improvements would be based on feedback gathered through our scale, which would assign a "score" to the app. By identifying and addressing the items and factors that contributed to a lower score, the app could be refined. We would then test this enhanced version of the app to see if it achieves a higher score, indicating improved performance in fostering a sense of increased personal safety for users.

Moreover, our research indicates that while our scale for measuring perceived personal safety effectively in global contexts, it may not capture all regional nuances. This shows the necessity for further research aimed at refining the scale. Future initiatives could focus on adapting the PPSS or developing new items and factors specifically tailored to address the diverse cultural, social, and environmental factors that influence personal safety perceptions in different regions. By doing so, the scale will become more relevant and beneficial to a broader range of users, ensuring it accurately reflects specific needs and provides precise assessments of personal safety worldwide.

Furthermore, in future research, it would be valuable to look at creating new features for safety technologies by using what we learn from the current study. For example, we could implement artificial intelligence (AI) in personal safety applications. This AI could analyze patterns in the places travelers and by understanding these patterns, it could suggest when and where users might need extra safety precautions, making the technology smarter and more helpful in real-time situations. This approach could lead to more effective safety solutions for users.

8. Conclusions

For this paper, we aimed to answer the research question: "What is a reliable scale to measure perceived personal safety fostered through technology during door-to-door transportation?". To do that we conducted focus groups to identify and specify the factors influencing perceived personal safety during door-to-door transportation and generate the initial items of our scale, Exploratory Factor Analysis to find out which items explain it, Confirmatory Factor Analysis, and Cronbach's alpha to evaluate it.

The resulting scale includes the factors of Identity, Traveling Alone, High-Risk Context, and Interactions with Strangers, each containing five to two items. These items reflect feelings and reasons expressed during focus groups, such as discomfort, fear, worry, confidence, anxiety, nervousness, and comfort, each contextualized by participant experiences.

The results of this study, show that perceived personal safety fostered through technology during door-to-door transportation can be quantified using the developed PPSS scale.

A. Ethics and Privacy Quick Scan

Response Summary:

Section 1. Research projects involving human participants

P1. Does your project involve human participants? This includes for example use of observation, (online) surveys, interviews, tests, focus groups, and workshops where human participants provide information or data to inform the research. If you are only using existing data sets or publicly available data (e.g. from Twitter, Reddit) without directly recruiting participants, please answer no.

- Yes

Recruitment

P2. Does your project involve participants younger than 18 years of age?

- No

P3. Does your project involve participants with learning or communication difficulties of a severity that may impact their ability to provide informed consent?

- No

P4. Is your project likely to involve participants engaging in illegal activities?

- No

P5. Does your project involve patients?

- No

P6. Does your project involve participants belonging to a vulnerable group, other than those listed above?

- No

P8. Does your project involve participants with whom you have, or are likely to have, a working or professional relationship: for instance, staff or students of the university, professional colleagues, or clients?

- No

Informed consent

PC1. Do you have set procedures that you will use for obtaining informed consent from all participants, including (where appropriate) parental consent for children or consent from legally authorized representatives? (See suggestions for information sheets and consent forms on the website.)

- Yes

PC2. Will you tell participants that their participation is voluntary?

- Yes

PC3. Will you obtain explicit consent for participation?

- Yes

PC4. Will you obtain explicit consent for any sensor readings, eye tracking, photos, audio, and/or video recordings?

- Not applicable

PC5. Will you tell participants that they may withdraw from the research at any time and for any reason?

- Yes

PC6. Will you give potential participants time to consider participation?
- Yes

PC7. Will you provide participants with an opportunity to ask questions about the research before consenting to take part (e.g. by providing your contact details)?
- Yes

PC8. Does your project involve concealment or deliberate misleading of participants?
- No

Section 2. Data protection, handling, and storage

The General Data Protection Regulation imposes several obligations for the use of **personal data** (defined as any information relating to an identified or identifiable living person) or including the use of personal data in research.

D1. Are you gathering or using personal data (defined as any information relating to an identified or identifiable living person)?
- Yes

High-risk data

DR1. Will you process personal data that would jeopardize the physical health or safety of individuals in the event of a personal data breach?
- No

DR2. Will you combine, compare, or match personal data obtained from multiple sources, in a way that exceeds the reasonable expectations of the people whose data it is?
- No

DR3. Will you use any personal data of children or vulnerable individuals for marketing, profiling, automated decision-making, or to offer online services to them?
- No

DR4. Will you profile individuals on a large scale?
- No

DR5. Will you systematically monitor individuals in a publicly accessible area on a large scale (or use the data of such monitoring)?
- No

DR6. Will you use special category personal data, criminal offense personal data, or other sensitive personal data on a large scale?
- No

DR7. Will you determine an individual's access to a product, service, opportunity, or benefit based on an automated decision or special category personal data?
- No

DR8. Will you systematically and extensively monitor or profile individuals, with significant effects on them?
- No

DR9. Will you use innovative technology to process sensitive personal data?
- No

Data minimization

DM1. Will you collect only personal data that is strictly necessary for the research?
- Yes

DM4. Will you anonymize the data wherever possible?
- Yes

DM5. Will you pseudonymize the data if you are not able to anonymize it, replacing personal details with an identifier, and keeping the key separate from the data set?
- Not applicable

Using collaborators or contractors that process personal data securely

DC1. Will any organization external to Utrecht University be involved in processing personal data (e.g. for transcription, data analysis, data storage)?
- No

International personal data transfers

DI1. Will any personal data be transferred to another country (including to research collaborators in a joint project)?
- No

Fair use of personal data to recruit participants

DF1. Is personal data used to recruit participants?
- No

Participants' data rights and privacy information

DP1. Will participants be provided with privacy information? (Recommended is to use as part of the information sheet: For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information at www.uu.nl/en/organisation/privacy.)
- Yes

DP2. Will participants be aware of what their data is used for?
- Yes

DP3. Can participants request that their personal data be deleted?
- Yes

DP4. Can participants request that their personal data be rectified (in case it is incorrect)?
- Yes

DP5. Can participants request access to their personal data?
- Yes

DP6. Can participants request that personal data processing is restricted?
- Yes

DP7. Will participants be subjected to automated decision-making based on their personal data with an impact on them beyond the research study to which they consented?

- No

DP8. Will participants be aware of how long their data is being kept for, who it is being shared with, and any safeguards that apply in case of international sharing?

- Yes

DP9. If data is provided by a third party, are people whose data is in the data set provided with (1) the privacy information and (2) what categories of data you will use?

- Not applicable

Using data that you have not gathered directly from participants

DE1. Will you use any personal data that you have not gathered directly from participants (such as data from an existing data set, data gathered for you by a third party, data scraped from the internet)?

- No

Secure data storage

DS1. Will any data be stored (temporarily or permanently) anywhere other than on password-protected University authorized computers or servers?

- No

DS4. Excluding (1) any international data transfers mentioned above and (2) any sharing of data with collaborators and contractors, will any personal data be stored, collected, or accessed from outside the EU?

- No

Section 3. Research that may cause harm

Research may cause harm to participants, researchers, the university, or society. This includes when technology has dual-use, and you investigate an innocent use, but your results could be used by others in a harmful way. If you are unsure regarding possible harm to the university or society, please discuss your concerns with the Research Support Office.

H1. Does your project give rise to a realistic risk to the national security of any country?

- No

H2. Does your project give rise to a realistic risk of aiding human rights abuses in any country?

- No

H3. Does your project (and its data) give rise to a realistic risk of damaging the University's reputation? (E.g., bad press coverage, public protest.)

- No

H4. Does your project (and in particular its data) give rise to an increased risk of attack (cyber- or otherwise) against the University? (E.g., from pressure groups.)

- No

H5. Is the data likely to contain material that is indecent, offensive, defamatory, threatening, discriminatory, or extremist?

- No

H6. Does your project give rise to a realistic risk of harm to the researchers?
- No

H7. Is there a realistic risk of any participant experiencing physical or psychological harm or discomfort?
- Yes

H8. Is there a realistic risk of any participant experiencing a detriment to their interests as a result of participation?
- No

H9. Is there a realistic risk of other types of negative externalities?
- No

Ethics Warning. As you replied yes to one (or more) of H1-H9, a fuller ethical review is required.
Please provide more detail here on the potential harm, and how you will minimize risk and impact:
In my study Im gonna have focus groups concerning perceived personal safety during transportation. Although, during the focus groups people are not going to be directly asked about previous experiences, or feelings. The way that this will be done is by providing scenarios to the participants, presenting a fictional character that for example is going home from work. They will be asked about how is character would feel about their personal safety, no personal questions asked.

Section 4. Conflicts of interest

C1. Is there any potential conflict of interest (e.g. between research funder and researchers or participants and researchers) that may potentially affect the research outcome or the dissemination of research findings?
- No

C2. Is there a direct hierarchical relationship between researchers and participants?
- No

Section 5. Your information.

This last section collects data about you and your project so that we can register that you completed the Ethics and Privacy Quick Scan, sent you (and your supervisor/course coordinator) a summary of what you filled out, and follow up where a fuller ethics review and/or privacy assessment is needed. For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information. Please see the guidance on the ICS Ethics and Privacy website on what happens on submission.

Z0. Which is your main department?
- Information and Computing Science

Z1. Your full name:
Eleni Mouzaki

Z2. Your email address:
e.mouzaki@students.uu.nl

Z3. In what context will you conduct this research?
- As a student for my master thesis, supervised by::
  Judith Masthoff

Z5. Master programme for which you are doing the thesis
- Human-Computer Interaction

Z6. Email of the course coordinator or supervisor (so that we can inform them that you filled this out and provide them with a summary):
m.t.r.vredenborg@uu.nl

Z7. Email of the moderator (as provided by the coordinator of your thesis project):
graduation.hci@uu.nl

Z8. Title of the research project/study for which you filled out this Quick Scan:
"You Can Go Your Own Way" : Tailoring Traveler's Personal Safety during Door-to-Door Transportation

Z9. Summary of what you intend to investigate and how you will investigate this (200 words max):
I am going to invegstigate the reasons behind why people perceived personal safety is low while door-to-door transportation and tty to prevent such feelings. First a scale will be crated to actually measure perceived safety and then this scale will be used to measure peoples perceived personal safety while presented to state-of-the-art technologies and designs of the researhers. The results are going to be compaired, at see the results!

Z10. In case you encountered warnings in the survey, does supervisor already have ethical approval for a research line that fully covers your project?
- Not applicable

Scoring

- Privacy: 0
- Ethics: 1

B. Information Sheets and Consent Forms

B.1 Information Sheet for Focus Groups

Information sheet

Please, read the information below to learn more about how the study will be carried out, data collection, your rights, and study approval.

1. Introduction
You are being invited to participate in a research study aimed at enhancing perceived personal safety during door-to-door public transportation. Please note that the focus groups will take place at the Buys Ballotgebouw building, room 4.45 at Utrecht University (Princetonplein 5, 3584 CC Utrecht).

2. What is the background and purpose of this study?
Recent research has shown the importance of the perception of personal safety in public transportation. This study, titled **"You Can Go Your Own Way" : Tailoring Travelers' Personal Safety during Door-to-Door Transportation"** seeks to understand the underlying factors influencing passengers' perceptions of safety. Eventually, we aim to create a scale that can measure perceived personal safety in public transport and design a technology that caters the diverse user needs. This research does not have any external commercial funding parties.

3. Who will carry out the study?
This study is conducted by **Eleni Mouzaki** as part of my master's thesis in Human Computer Interaction under the supervision of **J.F.M. Masthoff** and **M.T.R. Vredenborg**.

4. How will the study be carried out?

The study involves conducting **focus group**s, where perceived personal safety is discussed, through fictional scenarios of characters. The participants are asked to share their thoughts about the character's possible feelings in those situations and will be asked to provide reasoning. Throughout the study, beverages and snacks will be available to the participants to ensure a nice atmosphere.

5. What will we do with your data?

If you consent to this, an **audio recording** will be made. This recording will be stored on a secure university server. The recording will be transcribed so that participants' input is captured into text. The recording will be securely deleted after transcription (within 3 months of the study). The transcribed text will be **anonymized** so that you will not be identifiable. The transcript will become part of my thesis and will also be stored in a data repository for use by other researchers and research users. My thesis, any publications based on this research, and the data repository will not include your name or any other individual information by which you could be identified.

6. What are your rights?

Participation in this study is entirely **voluntary**. We can only collect your data for our study if you consent to this. If you decide to participate, you may **withdraw** anytime, including during the study. However, if you decide to withdraw, we will not be required to undo the processing of your data that has taken place up until that time. The personal data we have obtained from you up until the time when you withdraw your consent will be erased (where personal data is any data that can be linked to you, so this excludes any already anonymized data). By agreeing to participate, you acknowledge that you have read this consent form, had the opportunity to ask questions, and your questions have been satisfactorily answered.

7. Approval of this study

This study has been allowed to proceed by the Research Institute of Information and Computing Sciences on the basis of an Ethics and Privacy Quick Scan. If you have a complaint about the way this study is carried out, please send an email to: ics-ethics@uu.nl. If you have any complaints or questions about the processing of personal data, please send an email to the Faculty of Sciences Privacy Officer: privacy-beta@uu.nl. The Privacy Officer will also be able to assist you in exercising the rights you have under the GDPR. For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information at www.uu.nl/en/organisation/privacy.

8. More information?

If you have any questions or concerns about this research, please contact Eleni Mouzaki at e.mouzaki@students.uu.nl

B.2 Consent Form for Focus Groups

- I confirm that I am **18** years of age or over.
- I confirm that the research project **"You Can Go Your Own Way: Tailoring Perceived Personal Safety During Door-to-Door Transportation"** has been explained to me. I have had the opportunity to ask questions about the project and have had these answered satisfactorily. I had enough time to consider whether to participate.
- I consent to the material I contribute being used to generate insights for the research project.
- I consent to audio recordings being used in this study as explained in the information sheet.
- I understand that I can request to stop recordings at any time. I understand that if I give permission, the audio recordings will be held confidentially so that only **Eleni Mouzaki** has access to the recording. The recordings will be password protected for up to 3 months after which period they will be securely destroyed. In accordance with the General Data Protection Regulation (GDPR) I can have access to my recordings and can request them to be deleted at any time during this period.
- I understand that in addition to the recordings, personal data will be collected from me and that this information will be held confidentially so that only **Eleni Mouzaki** has access to this data and are able to trace the information back to me personally. The information will be password protected for up to 3 months after which period if will be deleted. In accordance with the General Data Protection Regulation (GDPR) I can have access to my information and can request my data to be deleted at any time during this period.

- I understand that my participation in this research is voluntary and that I may withdraw from the study at any time without providing a reason, and that if I withdraw any personal data already collected from me will be erased.
- I understand that my participation is not a requirement for my course, and that participating or not will not impact me.
- I consent to allow the fully anonymized data to be used in future publications and other scholarly means of disseminating the findings from the research project.
- I understand that the data acquired will be securely stored by researchers, but that appropriately anonymized data may in the future be made available to others for research purposes.
- I understand that the University may publish appropriately anonymized data in appropriate data repositories for verification purposes and to make it accessible to researchers and other research users.
- I understand that I can request any personal data collected from me to be deleted.

○ I confirm that I have read and understood the above statements, and agree to participate in the study

○ I do not consent, I do not wish to participate

B.3 Information Sheet and Consent Form for Initial Survey

*Informed Consent

Please, read the information below to learn more about how the study will be carried out, data collection, your rights, and study approval.

You are being invited to participate in a research study titled **"You Can Go Your Own Way": Tailoring Travelers' Personal Safety during Door-to-Door Transportation"**, which at this stage aims to evaluate a set of questions designed to measure how technology fosters perceived personal safety. I seek to understand the underlying factors influencing passengers' perceptions of safety. Eventually, I aim to create a scale that can measure how technology fosters perceived personal safety in public transport.

The study will be conducted using an **online questionnaire.** You will be presented with a short video about a personal safety application and you will be asked to answer questions about the video.

Participation in this study is entirely **voluntary**. We can only collect your data for our study if you consent to this. If you decide to participate, you may **withdraw** anytime, including during the study. The personal data we have obtained from you up until the time when you withdraw your consent will be erased (where personal data is any data that can be linked to you, so this excludes any already anonymized data). Your aggregated anonymized data will be used in future publications and other scholarly means of disseminating the findings from the research project, including data repositories to make it accessible to researchers. Any publications based on this research, and the data repository will not include your name or any other individual information by which you could be identified. In accordance with the Utrecht University policy, anonymized research data are to be retained for a minimum of ten years. This research does not have any external commercial funding parties.

This study has been allowed to proceed by the Research Institute of Information and Computing Sciences on the basis of an Ethics and Privacy Quick Scan. If you have a complaint about the way this study is carried out, please send an email to: ics-ethics@uu.nl. If you have any complaints or questions about the processing of personal data, please send an email to the Faculty of Sciences Privacy Officer: privacy-beta@uu.nl.The Privacy Officer will also be able to assist you in exercising the rights you have under the GDPR. For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information at www.uu.nl/en/organisation/privacy.

This study is conducted by Eleni Mouzaki as part of my master's thesis in Human Computer Interaction under the supervision of J.F.M. Masthoff and M.T.R. Vredenborg. If you have any questions or concerns about this research, please contact **Eleni Mouzaki** at **e.mouzaki@students.uu.nl**

By agreeing to participate, you declare that you are at least 18 years old and you acknowledge that you have read this consent form, had the opportunity to ask questions, and your questions have been satisfactorily answered.

◯ I confirm that I have read and understood the above statements, and agree to participate in the study

◯ I do not consent, I do not wish to participate

B.4 Information Sheet and Consent Form for Final Survey

*Informed Consent

Please, read the information below to learn more about how the study will be carried out, data collection, your rights, and study approval.

You are being invited to participate in a research study, titled **"You Can Go Your Own Way" : Tailoring Travelers' Personal Safety during Door-to-Door Transportation"** aimed at validating a scale designed to measure how technology fosters perceived personal safety in public transportation. This study seeks to confirm the reliability of the questions developed from previous research to understand the underlying factors influencing passengers' perceptions of safety. Eventually, it aims to create a scale that can measure how technology fosters perceived personal safety in public transport.

The study will be conducted using an **online questionnaire.** You will be presented with a short video about a personal safety application and you will be asked to answer questions about the video.

Participation in this study is entirely **voluntary**. We can only collect your data for our study if you consent to this. If you decide to participate, you may **withdraw** anytime, including during the study. However, if you decide to withdraw, we will not be required to undo the processing of your data that has taken place up until that time. The personal data we have obtained from you up until the time when you withdraw your consent will be erased (where personal data is any data that can be linked to you, so this excludes any already anonymized data). Your aggregated anonymized data will be used in future publications and other scholarly means of disseminating the findings from the research project, including data repositories to make it accessible to researchers. Any publications based on this research, and the data repository will not include your name or any other individual information by which you could be identified. In accordance with the Utrecht University policy, anonymized research data are to be retained for a minimum of ten years.

This study has been allowed to proceed by the Research Institute of Information and Computing Sciences on the basis of an Ethics and Privacy Quick Scan. If you have a complaint about the way this study is carried out, please send an email to: ics-ethics@uu.nl. If you have any complaints or questions about the processing of personal data, please send an email to the Faculty of Sciences Privacy Officer: privacy-beta@uu.nl. The Privacy Officer will also be able to assist you in exercising the rights you have under the GDPR. For details of our legal basis for using personal data and the rights you have over your data please see the University's privacy information at www.uu.nl/en/organisation/privacy.

This study is conducted by Eleni Mouzaki as part of my master's thesis in Human Computer Interaction under the supervision of J.F.M. Masthoff and M.T.R. Vredenborg. If you have any questions or concerns about this research, please contact **Eleni Mouzaki** at **e.mouzaki@students.uu.nl**

By agreeing to participate, you declare that you are at least 18 years old and you acknowledge that you have read this consent form, had the opportunity to ask questions, and your questions have been satisfactorily answered.

◯ I confirm that I have read and understood the above statements, and agree to participate in the study

◯ I do not consent, I do not wish to participate

C. Initial Scale Items

#	Statement	Theme
1	Using this technology helps me feel more confident while traveling	Demographics & Identity
2	Using this technology helps me feel less scared while traveling	Demographics & Identity
3	Using this technology helps me feel less vulnerable while traveling	Demographics & Identity
4	Using this technology helps me feel less of a target while traveling	Demographics & Identity
5	Using this technology helps me feel less fear while traveling	Demographics & Identity
6	Using this technology helps me feel more comfortable while traveling	Demographics & Identity
7	Using this technology helps me feel less anxious while traveling	Demographics & Identity
8	Using this technology helps me feel less powerless	Demographics & Identity
9	Using this technology helps me feel at ease	Demographics & Identity
10	Using this technology helps me feel more comfortable in unfamiliar places	Demographics & Identity
11	Using this technology helps me feel less insecure in new settings	Demographics & Identity
12	Using this technology helps me feel less fear after missing the last bus/metro/tram/train etc	Demographics & Identity
13	Using this technology reassures me after missing the last bus/metro/tram/train etc	Demographics & Identity

Continued on next page

Table C.1 Continued from previous page

#	Statement	Theme
14	Using this technology helps me feel less nervous about dealing with my potential limitations while traveling	Demographics & Identity
15	Using this technology helps me balance my perception of risk of violence, without feeling overwhelmed by concerns while traveling	Demographics & Identity
16	Using this technology helps me balance my perception of risk of gender-based violence, without feeling overwhelmed by concerns while traveling	Demographics & Identity
17	Using this technology helps me reduce my fear of standing out while traveling	Demographics & Identity
18	Using this technology helps me ease my concerns about standing out due to my appearance or presentation in areas with different religious or cultural norms	Demographics & Identity
19	Using this technology helps me express my individuality with confidence and less fear of (physical) confrontation while traveling	Demographics & Identity
20	Using this technology helps me reduce my discomfort in diverse social settings where my ethnic or racial identity might be more noticeable while traveling	Demographics & Identity
21	Using this technology helps me feel more empowered, countering my concerns about appearing vulnerable while traveling	Demographics & Identity
22	Using this technology helps me reduce my fear of hate crime when I express my individuality while traveling	Demographics & Identity
23	Using this technology helps me feel less worried about prejudice based on how I express myself	Demographics & Identity

Continued on next page

Table C.1 Continued from previous page

#	Statement	Theme
24	Using this technology helps me feel less scared when traveling in areas where I am considered a minority	Demographics & Identity
25	Using this technology helps me maintain my confidence even in areas where my ethnicity is not well-represented	Demographics & Identity
26	Using this technology helps me feel more prepared when transitioning from public transportation to walking	Immediate Environment
27	Using this technology helps me feel more prepared during transitions between different modes of public transportation	Immediate Environment
28	Using this technology helps me feel less concerned about being alone at a station	Immediate Environment
29	Using this technology helps me feel less afraid while traveling during peak hours after dark on public transport	Immediate Environment
30	Using this technology helps me feel less concerned traveling at night	Immediate Environment
31	Using this technology helps me feel more confident while maintaining an appropriate level of caution when walking alone in a dangerous area	Immediate Environment
32	Using this technology helps me feel less scared while maintaining an appropriate level of caution when walking alone in a bad neighborhood	Immediate Environment
33	Using this technology helps me feel less nervous while staying vigilant when using public transportation or walking in an area with a bad reputation	Immediate Environment
34	Using this technology helps me feel more assured in areas where I have concerns about prejudice	Immediate Environment

Continued on next page

Table C.1 Continued from previous page

#	Statement	Theme
35	Using this technology makes me less scared in areas where I have concerns about prejudice	Immediate Environment
36	Using this technology helps me feel more comfortable taking a new route	Previous Experiences
37	Using this technology helps me feel less fear when I am traveling in an unfamiliar area	Previous Experiences
38	Using this technology helps me feel less scared when using a public transport mode which I have not used before	Previous Experiences
39	Using this technology helps me feel less worried about walking alone at night	Previous Experiences
40	Using this technology helps me minimize the impact of prior bad experiences on me while traveling	Previous Experiences
41	Using this technology helps me feel more comfortable around strange people	Social Interactions & Trust
42	Using this technology helps me soothe my alertness while maintaining an appropriate level of caution when traveling with strangers	Social Interactions & Trust
43	Using this technology helps me soothe my anxiety while maintaining an appropriate level of caution when traveling with intoxicated individuals	Social Interactions & Trust
44	Using this technology helps me feel more comfortable when unwanted interactions with strangers occur	Social Interactions & Trust
45	Using this technology helps me feel more confident when unwanted interactions with strangers occur	Social Interactions & Trust
46	Using this technology helps me maintain a healthy level of alertness when traveling alone	Social Interactions & Trust
47	Using this technology helps me soothe my anxiety when traveling alone	Social Interactions & Trust

Continued on next page

Table C.1 Continued from previous page

#	Statement	Theme
48	Using this technology makes me feel at ease when traveling alone	Social Interactions & Trust
49	Using this technology helps me feel less scared when traveling alone	Social Interactions & Trust
50	Using this technology helps me feel less fear when traveling alone	Social Interactions & Trust
51	Using this technology helps me feel less scared when walking alone	Social Interactions & Trust
52	Using this technology helps me feel less anxious when walking alone	Social Interactions & Trust
53	Using this technology helps me feel less anxious when walking home alone	Social Interactions & Trust
54	Using this technology makes me less anxious when walking through a station alone	Social Interactions & Trust
55	Using this technology helps me maintain a healthy level of alertness when walking through a station alone	Social Interactions & Trust
56	Using this technology helps me maintain a healthy level of alertness when walking alone	Social Interactions & Trust
57	Using this technology makes me feel more safe when traveling when only few people are around	Social Interactions & Trust
58	Using this technology helps me maintain a healthy level of alertness when only a few people are around while I am traveling	Social Interactions & Trust
59	Using this technology helps me feel less afraid when only a few people are around while I am traveling	Social Interactions & Trust
60	Using this technology helps me be confident even when I am not part of a group while traveling	Social Interactions & Trust
61	Using this technology makes me less anxious when my group gets smaller and smaller while traveling	Social Interactions & Trust

Continued on next page

Table C.1 Continued from previous page

#	Statement	Theme
62	Using this technology helps me maintain my confidence when my group gets smaller and smaller while traveling	Social Interactions & Trust
63	Using this technology helps me feel less vulnerable when continuing my journey after separating from my friends	Social Interactions & Trust
64	Using this technology helps me feel less worried about being the last one in public transit	Social Interactions & Trust
65	Using this technology helps me maintain my perception of personal safety sparing me from unnecessary negative thoughts and feelings	General

D. Analysis Codes

D.1 EFA Python Code

```python
import pandas as pd
import matplotlib.pyplot as plt
from factor_analyzer import FactorAnalyzer
from factor_analyzer.factor_analyzer import calculate_bartlett_sphericity, calculate_kmo
import pingouin as pg

#read the qualtrics file
df = pd.read_csv('qualtrics_all.csv')


### CLEANING THE FILE ###

# convert column names to lower-case for easier handling
df.columns = df.columns.str.lower()


##################################################
# func to rename dublicate column names
def rename_duplicates(df):
    cols = pd.Series(df.columns)
    for dup in cols[cols.duplicated()].unique():
        dup_indices = cols[cols == dup].index.tolist()
        for i in range(len(dup_indices)):
            cols[dup_indices[i]] = f"{dup}_{i+1}"
    df.columns = cols
    return df

# Rename duplicate columns
df = rename_duplicates(df)
##################################################

# deleting the people that failed the attention checks
deleted_ids_video_check = df[df['video check'] != 'Yes']['id'].tolist()
#print("deleted because of video check: ", deleted_ids_video_check)
df = df.drop(df[df['video check'] != 'Yes'].index)
deleted_ids_prev_exp = df[df['prev. exp._5'] != 'Strongly disagree']['id'].tolist()
#print("\ndeleted because of pacific ocean check: ", deleted_ids_prev_exp)
df = df.drop(df[df['prev. exp._5'] != 'Strongly disagree'].index)
deleted_ids_social_int = df[df['social int._7'] != 'Agree']['id'].tolist()
#print("\ndeleted because of 'agree' check: ", deleted_ids_social_int)
df = df.drop(df[df['social int._7'] != 'Agree'].index)

```

```
# Combine all deleted IDs in a single list
all_deleted_ids = deleted_ids_video_check + deleted_ids_prev_exp + deleted_ids_social_int

df = df.drop(columns=['identity items_12_1','identity items_1_2', 'identity items_2_2']) # not directly relevant to pps


df = df.drop(columns=['identity items_1_1','identity items_2_1', 'identity items_3_1', 'identity items_6_1',
                      'identity items_5_1','identity items_7_1','identity items_8_1', 'identity items_9_1']) # too general

# delete non-needed columns
df = df.loc[:, ~df.columns.isin(['startdate', 'enddate', 'status', 'ipaddress', 'recipientlastname', 'recipientfirstname',
       'recipientemail', 'externalreference', 'locationlatitude',
       'locationlongitude','progress', 'duration (in seconds)', 'finished', 'recordeddate',
       'responseid', 'distributionchannel', 'userlanguage',
       'information sheet', 'id', 'video check' , 'prev. exp._5', 'social int._7' ])]


# get rid of likert scale strings and replace with integers 1-2-3-4-5-6-7
replacer = {'Strongly disagree': 1, 'Disagree': 2,'Somewhat disagree': 3,
            'Neither agree nor disagree': 4,
            'Somewhat agree': 5, 'Agree':6,'Strongly agree': 7}
df= df.replace(replacer)

# drop rows with empty items
df = df.dropna()
print("After cleaning the data, the remaining participants are participants: ",len(df))


# write final items in csv file
df.to_csv('df_clean.csv', sep=',', index=False, encoding='utf-8')


#### CHECK FOR STUITABILITY FOR EFA ####

print("\n\nChecking stuitability for EFA with Bartlett's test and KMO test...")

# Bartlett's Test of Sphericity
chi_square_value, p_value = calculate_bartlett_sphericity(df)
print(f"\nBartlett?s test p-value: {p_value}")
if p_value < 0.05:
    print("Bartlett?s test is supportive of performing EFA")

```

```python
# Kaiser-Meyer-Olkin (KMO) Test
kmo_all, kmo_model = calculate_kmo(df)
print(f"\nKMO Test: {kmo_model}")
# Interpret the KMO value
if kmo_model < 0.5:
    print("KMO value below 0.5 indicates that EFA may not be suitable")
elif 0.5 <= kmo_model < 0.6:
    print("KMO value between 0.5 and 0.6 suggests EFA may not be suitable, but it's borderline")
elif 0.6 <= kmo_model < 0.7:
    print("KMO value between 0.6 and 0.7 is mediocre, but EFA can be considered")
elif 0.7 <= kmo_model < 0.8:
    print("KMO value between 0.7 and 0.8 is good for EFA")
elif 0.8 <= kmo_model < 0.9:
    print("KMO value between 0.8 and 0.9 is great for EFA")
elif kmo_model >= 0.9:
    print("KMO value above 0.9 is *amazing* for EFA")


### DETERMINE THE NUMBER OF FACTORS ###

print("\n\nDetermining the number for factors with Eigenvalues...")

# initial factor analysis to get eigenvalues - no rotation
fa = FactorAnalyzer(rotation=None)
fa.fit(df)
ev, v = fa.get_eigenvalues()
print(f"Eigenvalues: {ev}")

n_factors = sum(ev > 1)
print("According to eigenvalues I need ", n_factors," factors")

# Scree Plot
plt.plot(range(1, len(ev) + 1), ev, marker='o')
plt.xlabel('Factors')
plt.ylabel('Eigenvalue')
plt.title('Scree Plot')
plt.axhline(y=1, color='r', linestyle='--')
plt.savefig('scree_plot.png')
plt.show()
```

```python
# Identify and remove items with communalities less than 0.2
communalities = fa.get_communalities()
communalities_df = pd.DataFrame(communalities, index=df.columns, columns=['Communalities'])
items_to_keep = communalities_df[communalities_df['Communalities'] >= 0.2].index
df_filtered = df[items_to_keep]

# factor analysis with rotation
fa_filtered = FactorAnalyzer(n_factors=n_factors, rotation='oblimin')
fa_filtered.fit(df_filtered)

# Get the factor loadings and new communalities
revised_loadings = fa_filtered.loadings_
revised_loadings_df = pd.DataFrame(revised_loadings, index=df.columns, columns=[f'Factor{i+1}' for i in range(revised_loadings.shape[1])])


### EFA ###
def EFA(n_factors, df, rotation='oblimin'):
    efa = FactorAnalyzer(n_factors=n_factors, rotation=rotation)
    efa.fit(df)

    # Get factor loadings
    loadings = efa.loadings_

    # Interpret the results
    loadings_df = pd.DataFrame(loadings, index=df.columns, columns=[f'Factor{i+1}' for i in range(loadings.shape[1])])

    # Save the loadings to a CSV file
    loadings_df.to_csv('factor_loadings.csv', sep=';', encoding='utf-8')

    # Visualize the loadings
    plt.matshow(loadings, cmap='viridis')
    plt.colorbar()
    plt.xlabel('Factors')
    plt.ylabel('Variables')
    plt.title('Factor Loadings Heatmap')
    #plt.show()
```

```
    # Get eigenvalues and create scree plot
    ev, v = efa.get_eigenvalues()
    plt.plot(range(1, len(ev) + 1), ev, marker='o')
    plt.xlabel('Factors')
    plt.ylabel('Eigenvalue')
    plt.title('Scree Plot')
    plt.axhline(y=1, color='r', linestyle='--')
    #plt.show()

    return efa


# remove items that are considered redundant and (re)conduct EFA

df = df.drop(columns=['identity items_4_1', 'immedi. env._3', 'immedi. env._9', 'prev. exp._1',
                      'prev. exp._3', 'prev. exp._7', 'social int._9', 'q115_5', 'q115_6', 'q115_7',
                      'q115_11', 'q115_12', 'q115_4','q115_8', 'q115_9', 'q115_10', 'immedi. env._4'])
                      # delete cross loadings and items without significant loadings (6)

df = df.drop(columns=['identity items_10_1', 'identity items_11_1'])
                    # delete cross loadings and items without significant loadings<0.4 (5)


df = df.drop(columns=['social int._12','social int._11', 'social int._1', 'identity items_3_2', 'prev. exp._6',
                      'immedi. env._10', 'identity items_4_2', 'identity items_9_2', 'prev. exp._2', 'social int._3',
                      'identity items_5_2', 'immedi. env._1', 'immedi. env._2', 'immedi. env._5',
                      'social int._2', 'social int._6', 'social int._8',
                      'q115_3',
                      'identity items_7_2', 'identity items_12_2',
                      'q115_1']) # delete cross loadings and items without significant loadings<0.44 (4)


# conduct EFA
factors = 4 # initially 6, then 5, now 4
efa = EFA(factors, df, 'oblimin')
```

D.2 CFA Python Code

```python
import numpy as np
import pandas as pd
from factor_analyzer import ConfirmatoryFactorAnalyzer, ModelSpecificationParser
import pingouin as pg

file_path = 'Final_Survey.xlsx'
df = pd.read_excel(file_path, sheet_name='Final_Survey')

# convert column names to lower-case for easier handling
df.columns = df.columns.str.lower()

# delete non-needed columns
df = df.loc[:, ~df.columns.isin(['startdate', 'enddate', 'status', 'ipaddress', 'recipientlastname', 'recipientfirstname',
       'recipientemail', 'externalreference', 'locationlatitude',
       'locationlongitude','progress', 'duration (in seconds)', 'finished', 'recordeddate',
       'responseid', 'distributionchannel', 'userlanguage', 'information sheet', 'age', 'gender', 'gender_4_text' ])]

# get rid of likert scale strings and replace with integers 1-2-3-4-5-6-7
replacer = {'Strongly disagree': 1, 'Disagree': 2,'Somewhat disagree': 3,
            'Neither agree nor disagree': 4,
            'Somewhat agree': 5, 'Agree':6,'Strongly agree': 7}
df= df.replace(replacer)


# Cronbach's Alpha
print("\n\nMeasuring internal consistency with Cronbach's Alpha...\n")
def reliability_if_item_dropped(df, factor_items):
    alpha_values = {}
    for item in factor_items.columns:
        remaining_items = factor_items.drop(columns=[item])
        alpha = pg.cronbach_alpha(data=remaining_items)[0]  # Get the alpha value
        alpha_values[item] = alpha
    return alpha_values

# Define your factors
factor1_items = df[['identity_items_6_2', 'identity_items_8_2', 'identity_items_10_2',
                    'identity_items_11_2', 'identity_items_13']]
alpha_factor1 = pg.cronbach_alpha(data=factor1_items)
print("\na_factor1 = ", alpha_factor1)

factor2_items = df[['social_int._10', 'social_int._13', 'q115_2']]
alpha_factor2 = pg.cronbach_alpha(data=factor2_items)
print("\na_factor2 = ", alpha_factor2)
```

```python
factor3_items = df[['immedi._env._6', 'immedi._env._7', 'immedi._env._8']]
alpha_factor3 = pg.cronbach_alpha(data=factor3_items)
print("\na_factor3 = ", alpha_factor3)

factor4_items = df[['social_int._4', 'social_int._5']]
alpha_factor4 = pg.cronbach_alpha(data=factor4_items)
print("\na_factor4 = ", alpha_factor4)



# Model specification
# This is a dictionary specifying the model structure
model_dict = {
    'Identity': ['identity items_6_2', 'identity items_8_2', 'identity items_10_2', 'identity items_11_2', 'identity items_13'],
    'Traveling Alone': ['social int._10', 'social int._13', 'q115_2'],
    'Perceived High-Risk Content': ['immedi. env._6', 'immedi. env._7', 'immedi. env._8'],
    'Interactions with Strangers': ['social int._4', 'social int._5']
}

# Parse the model specification
model_spec = ModelSpecificationParser.parse_model_specification_from_dict(df, model_dict)

# Fit the Confirmatory Factor Analysis model
cfa = ConfirmatoryFactorAnalyzer(model_spec, disp=False)
cfa.fit(df.values)

# Unstandardized loadings
loadings = cfa.loadings_

# Standard deviations of observed variables
observed_std = df.std().values

# Standard deviations of latent factors (factor variance is typically 1 in standardized CFA)
latent_std = np.ones(loadings.shape[1])

# Standardize loadings
standardized_loadings = loadings * latent_std / observed_std[:, None]

print("\nUnstandardized Loadings:")
print(loadings)

print("\nStandardized Loadings:")
print(standardized_loadings)
```

D.3 RMSEA, CFI, TLI Python Code

```python
import numpy as np
import pandas as pd
from factor_analyzer import ConfirmatoryFactorAnalyzer, ModelSpecificationParser
import semopy


file_path = 'Final_Survey.xlsx'
df = pd.read_excel(file_path, sheet_name='Final_Survey')


# convert column names to lower-case for easier handling
df.columns = df.columns.str.lower()

# delete non-needed columns
df = df.loc[:, ~df.columns.isin(['startdate', 'enddate', 'status', 'ipaddress', 'recipientlastname', 'recipientfirstname',
       'recipientemail', 'externalreference', 'locationlatitude',
       'locationlongitude','progress', 'duration (in seconds)', 'finished', 'recordeddate',
       'responseid', 'distributionchannel', 'userlanguage', 'information sheet', 'age', 'gender', 'gender_4_text' ])]

# get rid of likert scale strings and replace with integers 1-2-3-4-5-6-7
replacer = {'Strongly disagree': 1, 'Disagree': 2,'Somewhat disagree': 3,
            'Neither agree nor disagree': 4,
            'Somewhat agree': 5, 'Agree':6,'Strongly agree': 7}
df= df.replace(replacer)


# Define the model components
model_dict = {
    'Identity': ['identity_items_6_2', 'identity_items_8_2', 'identity_items_10_2', 'identity_items_11_2', 'identity_items_13'],
    'Traveling_Alone': ['social_int._10', 'social_int._13', 'q115_2'],
    'Perceived_High_Risk_Content': ['immedi._env._6', 'immedi._env._7', 'immedi._env._8'],
    'Interactions_with_Strangers': ['social_int._4', 'social_int._5']
}

# Construct the model description string
model_spec = ""

for latent, observeds in model_dict.items():
    model_spec += f"{latent} =~ " + " + ".join(observeds) + "\n"

# Create a Model instance and load the dataset
model = semopy.Model(model_spec)
model.load_dataset(df)

# Fit the model to your data
model.fit()
# Inspect the model to get fit indices
res = semopy.calc_stats(model)
print(res)
```

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