

Inclusive Human-Machine Interfaces to Increase Perceived Security in Shared Automated Vehicles



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Submitted by
**Dipl.-Ing. Martina
Schuß**

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**Institute for Pervasive
Computing**

Supervisor and
First Evaluator
**Prof. Dr. Priv.-Doz.
Andreas Riener**

Second Evaluator
**Prof. Dr. Myounghoon
Jeon**

Linz, May 2024

Statutory Declaration

I hereby declare that this thesis is my own unaided work, that I have not used other than the sources indicated, and that all direct and indirect sources are acknowledged as references.

Parts of this thesis have been published as international conference articles or journal papers.

A statement with my contributions to these publications is provided in the next section.

Linz, 10 May 2024

Original Publications

Core Publications

[1] M. Schuß, P. Wintersberger, and A. Riener, “Let’s share a ride into the future: A qualitative study comparing hypothetical implementation scenarios of automated vehicles,” in Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, ser. CHI’21. New York, NY, USA: Association for Computing Machinery, 2021. [Online]. Available: <https://doi.org/10.1145/3411764.3445609>

My contribution I developed the initial idea and the study design for this work in joint discussions with Philipp Wintersberger and Andreas Riener. I prepared and conducted the study, analyzed the qualitative data, was leading the project, and authored most parts of the paper.

Contribution of Others Philipp Wintersberger assisted conducting the study, performed the statistical analysis, and participated in paper writing. Andreas Riener commented and edited the manuscript.

[2] M. Schuß, P. Wintersberger, and A. Riener. Security issues in shared automated mobility systems: A Feminist HCI Perspective. Multimodal Technologies and Interaction. 2021. [Online]. Available: <https://www.mdpi.com/2414-4088/5/8/43>

My contribution I developed the initial idea and the study design for this work in joint discussions with Philipp Wintersberger. I prepared and conducted the study, analyzed the qualitative data, was leading the project, and authored the paper.

Contribution of Others Philipp Wintersberger and Andreas Riener commented and edited the manuscript.

[3] M. Schuß, C. Manger, A. Löcken, and A. Riener, “You’ll never ride alone: Insights into women’s security needs in shared automated vehicles,” in Proceedings of the 14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI ’22. New York, NY, USA: Association for Computing Machinery, 2022, p. 13–23. [Online]. Available: <https://doi.org/10.1145/3543174.3546848>

My contribution The idea and study design evolved from discussions with Andreas Riener. I prepared and conducted all workshops, analyzed the data, and authored most parts of the paper.

Contribution of Others Carina Manger assisted in preparing and conducting one of the workshops. Andreas Riener, Carina Manger, and Andreas Löcken contributed to paper editing.

[4] L.A. Flohr, M. Schuß, D. P. Wallach, A. Krüger and A. Riener, “Designing for passengers’ information needs on fellow travelers: A comparison of day and night rides in shared automated vehicles,” Applied Ergonomics, vol. 116, p. 104198, 2024. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0003687023002363>

My contribution I developed the idea and methodology for this study in joint discussions with Lukas A. Flohr. Lukas A. Flohr and I implemented the set up for the study and I conducted the study with assistance of Tatjana Röhr. The results were analyzed and interpreted by me and Lukas A. Flohr and we co-authored the paper.

Contribution of Others Andreas Riener, Dieter P.Wallach, Antonio Krüger contributed to paper editing and provided feedback to the study design.

[5] M. Schuß, A. Rollwagen, and A. Riener, “Understanding operator influence in automated urban shuttle buses and recommendations for future development,” Multimodal Technologies and Interaction, vol. 6, no. 12, 2022. [Online]. Available: <https://www.mdpi.com/2414-4088/6/12/109>

My contribution I developed the idea for the studies of this paper in joint discussions with Andreas Riener and Alice Rollwagen. I supervised the preparation of the studies and conducted them in assistance with Alice Rollwagen. I analyzed a major part of the data and authored the paper.

Contribution of Others Alice Rollwagen assisted in conducting the study and co-authored the paper. Andreas Riener provided feedback on the project and the publication.

[6] M. Schuß, C. Himmels, and A. Riener, “Development of a Perceived Security Scale for Shared Automated Vehicles (PSSAV) and its Validation in Colombia and Germany,” in Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI ’23. New York, NY, USA: Association for Computing Machinery, 2023, pp. 52–62. [Online]. Available: <https://doi.org/10.1145/3580585.3607177>

My contribution I developed the idea for this experiment in joint discussions with Andreas Riener. I implemented the scenarios in virtual reality and the questionnaire and was leading the project. I co-authored the paper together with Chantal Himmels.

Contribution of Others Chantal Himmels provided the methodological approach for this work and conducted the evaluation of the results. Andreas Riener provided feedback on the project and the publication.

Further Publications

These publications are not directly part of this thesis, however, important contributions during the process of my doctoral studies. Partially, argumentations of these publications are adopted in this doctoral thesis.

[7] J. M. Beuthel, M.-M. Schaper, M. Schuß, E. Márquez Segura, C. Núñez-Pacheco, and A. Riener, “Exploring and materialising bodily experiences of security through lenses of feminist hci practices,” in Adjunct Proceedings of the 2022 Nordic Human-Computer Interaction Conference, ser. NordiCHI ’22. New York, NY, USA: Association for Computing Machinery, 2022. [Online]. Available: <https://doi.org/10.1145/3547522.3547696>

[8] A. Rollwagen, M. Schuß, and A. Riener, “Enhancing accessibility for diverse user groups in automated shuttle buses: Implications from a user enactment study,” in Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 77–82. [Online]. Available: <https://doi.org/10.1145/3581961.3609876>

- [9] J. Dong, C. Nadri, I. Alvarez, C. Diels, M. Lee, J. Li, P. H. Liao, C. Manger, S. Sadeghian, M. Schuß, B. N. Walker, F. Walker, Y. Wang, and M. Jeon, “Play your anger”: A report on the empathic in-vehicle interface workshop,” in Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 168–173. [Online]. Available: <https://doi.org/10.1145/3581961.3609865>
- [10] K. Stojmenova Pečečnik, S. C. Lee, S. Hong, M. Schuß, H. Şahin Ippoliti, A. R. Patel, A. Löcken, D. Dey, A. Riener, A. G. Mirnig, and M. Jeon, “How to ensure diversity and inclusion at conferences? a workshop for general chairs, program committee members, reviewers and authors: A workshop for general chairs, program committee members, reviewers and authors,” in Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 241–244. [Online]. Available: <https://doi.org/10.1145/3581961.3609838>
- [11] M. Schuß and A. Riener, “‘Give me the keys, I’ll drive!’: Results from an exploratory interview study to assess public’s desires and concerns on automated valet parking,” in 12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ser. AutomotiveUI ’20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 16–18. [Online]. Available: <https://doi.org/10.1145/3409251.3411712>

Bachelor and Master Theses

During my doctoral research, I have had the honor and pleasure of mentoring and advising some talented students on their final theses. At the time of submission, five bachelor’s and two master’s theses were completed. Below, those are listed chronologically, along with references to chapters to which some have contributed.

- Veronika Hartl. 2022. Gamification im kulturellen Kontext: Konzeption einer digitalen, gamifizierten Lernhilfe für Kinder mit Migrationshintergrund. Technische Hochschule Ingolstadt.
- Luca Pizzoni. 2022. Conceptualization of a Digital Companion for Shared Automated Vehicles: A Cross-Cultural Approach Comparing Korea and Germany. Technische Hochschule Ingolstadt. Contributes to Chapter 7

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- Tajana Röhr. 2022. Digital Companion: A Concept for Enhancing the Perceived Security in Shared Automated Vehicles (SAVs). Technische Hochschule Ingolstadt. Contributes to Chapter 8
 - Nils Rönneberg. 2023. Design of a persuasive conversational agent to promote sustainable mobility behaviour. Technische Hochschule Ingolstadt.
 - Sarah Sommerschuh. 2023. Digital concept for communicating safety in public spaces. Technische Hochschule Ingolstadt
 - Charlotte Bauer. 2023. Conceptualization and evaluation of an improved User Experience for Shared Automated Vehicles based on the analysis of immersive and interactive art exhibitions. Technische Hochschule Ingolstadt.
 - Katharina Vogl. 2023. Design and Evaluation of a Private Digital Companion for Women's Perception of Safety in Shared Automated Vehicles. Technische Hochschule Ingolstadt.

Contributions from Bachelor's Theses

In Chapters 7 and 8, portions of bachelor's theses were incorporated as they are relevant for the research in this thesis. The contributions for the chapters are as follows:

Chapter 7 is based on the bachelor's thesis entitled "Conceptualization of a Digital Companion for Shared Automated Vehicles: A Cross-Cultural Approach Comparing Korea and Germany" published under [12] and authored by Luca Pizzoni:

My contribution I conceptualized the initial idea, formulated the research questions, and outlined the study designs for this work in joint discussions with Luca Pizzoni. I supervised this work and instigated the analysis of related work by providing critical insights and initiating the exploration of relevant literature. I conducted the study in Colombia and refined the study setup within the Unity environment and undertook the design and implementation of the Colombian variant of the digital companion. I analyzed the final quantitative data from Colombia, Germany, and South Korea and visualized it. I authored Chapter 7, presenting comprehensive discussions on the results and their implications

Contribution of Others Luca Pizzoni designed the Korean and German versions of the digital companion and the robot companion. He implemented the scenarios in Unity, conducted the qualitative and quantitative studies in Germany and South Korea, and analyzed the data from the workshops.

Signature Luca Pizzoni



Chapter 8 is based on a bachelor's thesis entitled "Digital Companion: A Concept for Enhancing the Perceived Security in Shared Automated Vehicles (SAVs)" published under [13] and authored by Tatjana Röhr:

My contribution I conceptualized the initial idea, formulated the research questions, and outlined the study designs for this work in joint discussions with Tatjana Röhr. I supervised this work and investigated the analysis of related work by providing critical insights and initiating the exploration of relevant literature. I analyzed the quantitative data and visualized it. I authored Chapter 8, presenting comprehensive discussions on the results and their implications.

Contribution of Others Tatjana Röhr conducted the qualitative pre-studies and analyzed the results. She implemented the scenarios in Unity, designed the two versions of the digital companions, and conducted the experiment.

Signature Tatjana Röhr

A handwritten signature in black ink, appearing to read 'Tatjana Röhr', with a stylized flourish at the end.

Abstract

Shared automated vehicles (SAVs; SAE level 5) are expected to be beneficial for environment and society, while facing substantial challenges regarding acceptance, human factors, and user experience, with perceived security as the foremost concern. In addressing these hurdles, it is crucial to engage users from the early stages of research by applying the human-centered design (HCD) process to improve perceived security in and consequently the adoption of SAVs. Currently, research and development excludes certain demographics resulting in a data bias and emphasizing the necessity of inclusive research involving diverse groups. This thesis argues for employing suitable methodologies to engage with a broad spectrum of individuals during research processes while focusing on the demographics age, gender, and cultural background. We adopt feminist HCI and HCD to explore the potential of human-machine interfaces (HMIs) to mitigate perceived security in SAVs using straightforward methods. We conceptualize and implement HMI concepts and evaluate them using a mixed-methods approach—combining simulated study settings implemented in virtual reality (VR) or using video-based prototyping with questionnaires and interviews—assessing the advantages of in-vehicle HMIs for SAVs for increasing perceived security. Our findings contribute to the field of HCI research in the area of SAVs with concrete design and interaction solutions. We introduce digital companions for SAVs, discuss solutions and their potential negative side-effects through a feminist HCI lens, and present a validated scale to effectively measure perceived security within SAVs. The results serve as a guidance for researchers and practitioners to develop inclusive and appropriate interfaces for SAVs.

Kurzfassung

Gemeinsam genutzte automatisierte Fahrzeuge (SAVs; SAE Level 5) bieten vielversprechende Vorteile für Umwelt und Gesellschaft, stoßen jedoch auf erhebliche Hindernisse hinsichtlich Akzeptanz, menschlicher Faktoren und dem Nutzungserlebnis, wobei die wahrgenommene Sicherheit als besonders herausfordernd gilt. Die Integration der Nutzerinnen und Nutzer in frühe Forschungs- und Entwicklungsphasen spielt eine entscheidende Rolle, um die Sicherheit in und folglich die Verbreitung und Nutzung von automatisierten Fahrzeugen zu steigern. In Anbetracht der bestehenden Datenverzerrung in der Forschung und Entwicklung, die bestimmte demografische Gruppen ausschließt, wird die Notwendigkeit betont, verschiedene Gruppen umfassend in den Forschungsprozess einzubeziehen, insbesondere in Bezug auf Alter, Geschlecht und kulturellen Hintergrund. Dieser Ansatz unterstützt die Anwendung geeigneter Methoden, um eine breite Palette von Personengruppen zu berücksichtigen. In dieser Arbeit setzen wir ‘feminist HCI’ und den menschenzentrierten Gestaltungsprozess (HCD) ein, um die Möglichkeiten von Mensch-Maschine-Schnittstellen (HMIs) für die wahrgenommene Sicherheit in SAVs zu erforschen. Mithilfe empirischer Studien werden HMI-Konzepte konzeptioniert und evaluiert, um die Vorteile von fahrzeuginternen HMIs für SAVs zu bewerten. Unsere Ergebnisse tragen mit konkreten Design- und Interaktionslösungen zum Forschungsbereich der HMIs für SAVs bei. Wir stellen digitale Begleitungen für SAVs vor, diskutieren Lösungen und ihre potenziellen negativen Nebeneffekte durch eine feministische Perspektive und präsentieren einen validierten Fragebogen zur Messung der wahrgenommenen Sicherheit in SAVs. Diese Ergebnisse dienen als Leitfaden für Forschende sowie Menschen aus der Praxis, um integrative und angemessene HMI-Schnittstellen für SAVs zu entwickeln.

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I would like to express my deepest gratitude to my supervisor, Andreas Riener, whose unwavering support, guidance, and insightful feedback have been instrumental throughout the journey of this doctoral thesis. Your mentorship has been invaluable, and I am truly thankful that you gave me the chance and freedom to pursue this topic of the heart. Thank you Ingrid Stahl, for believing I could do this and for connecting me with Andreas.

I extend my thanks to the members of my doctoral committee for their constructive comments and suggestions that have significantly enriched the quality of this thesis: Prof. Dr. Myounghoon Jeon for being my second examiner— I admire you and your work—, Prof. Dr. Gabriele Kotsis for serving as the internal examiner, and Prof. Dr. Josef Küng for chairing the examination board.

My sincere thanks go to my colleagues and fellow researchers who have contributed to fruitful discussions, shared insights, and provided a supportive academic community. The collaborative spirit within the department has been an enriching aspect of my doctoral experience. To my colleagues and co-authors Alice Rollwagen— I enjoyed working with you and seeing you grow—, Carina Manger— our laughs and coffees were my little refuges during this time—, Franziska Hegner, Chantal Himmels—you rock!—, Patricia Appel—for inspiring conversations—, Andreas Löcken, Philipp Wintersberger, Claus Pfeilschifter, Clemens Schartmüller, Andreas Riegler, Bengt Escher, Henrike Böck, and all other members of CARISSMA and the Human Computer Interaction Group of THI Ingolstadt: thank you all for your support and friendship. Further, I thank various researchers who inspired me so much along my way: Marije Nouwjen for having these research coffees of ours and for your mental support, Waltraud Ernst for your wonderful support in Gender Studies topics and feminism, Lukas Flohr—I enjoyed working with you so much—, Mascha Beuthel and Marie-Monique Scharper for a great collaboration and mutual inspiration, and Claudia Núñez-Pacheco and Elena Márquez Segura. I also would like to thank my colleagues and friends I met during my research in Colombia, Argentina, and South Korea: Jeraldine Mora Herrera and your lovely family, Jimena Dmuchowsky, Francisco Valdez, Andrea Melle, Mercedes Lara, and Ye Eun Song— sharing an office with you was a pleasure.

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I am dedicating this thesis to the strong and remarkable people from my family who have shaped my life. I am deeply grateful to my mum Anni who, with incredible bravery and only one suitcase in one hand a four-year old daughter in the other, fled from a totalitarian regime in Czechoslovakia, in pursuit of freedom. You taught me being an independent woman and the importance of receiving the best education possible. My beloved grandparents Anna and Zdeněk, true free spirits, who, made the courageous decision to flee before the Prague Spring in 1968. In times of uncertainty, they not only found refuge for themselves but generously opened their hearts to provide a home for my mother and me when we, too, needed it. Despite loving their new home Germany, they remained Czechs at heart, imparting to me the importance of cherishing our mother language and preserving our rich cultural traditions.

My grandmother Anna for her unwavering strength, warmth, and a home. In her uniquely spirited way, she used to say that catching her without wearing red lipstick warranted a call to the gravedigger. Her grace not only added a touch of levity into my life but also made me embrace it with flair and a dash of individuality. You had nothing and showed me that an impeccable style is not defined by wealth but rather by embracing one's true self and cultivating a genuine sense of authenticity. My grandfather Zdeněk who filled my life with laughter, Czech polka, and wisdom. You have been like a father to me and in my memory you will always be wearing your blue swimsuit, a rock in the waves with your face towards the sun.

My grandmother Marta, the Nazis took away your first love and your unborn child but you carried on, built a new family—our family—and embraced life anew; your courage has been a guiding light, inspiring me to face challenges with determination and grace. The sacrifices and enduring spirit of the women in my family have not only been a source of motivation but a testament to the

power of strong women in shaping the world.

To my dad Jiří, the socialist regime in Czechoslovakia forced us into a painful separation. I truly believe that we did our best to build a relationship as father and daughter despite being hundreds of kilometers apart from each other. The vintage, orange lamp you gifted me was giving me light during the late hours I was working on this thesis reminding me how proud you would be seeing me finishing this journey.

To my grandfather Emil, a survivor of the Holocaust and inmate of the concentration camp in Dachau for five years, for his indomitable spirit in the face of unimaginable terror. Your pain and suffering are not forgotten. Your survival and subsequent strength are a proof to the human spirit's ability to triumph over darkness but also a reminder that this must never ever happen again. *Nie wieder.*

My aunt Marta and my half-brother Robert. I enjoy our walks around and swims in "Přehrada" when I visit my birthplace Jablonec in Czech Republic. Having someone to turn to and share experiences with makes my annual visits so special.

This thesis is also dedicated to my beloved children, Mila and Lasse, the shining lights in the midst of our family's tumultuous history. Despite the shadows of terror, pain, and loss that have touched our family, you stand as stars of hope, freedom, and peace. As you embark on your individual journeys in the future, I wish for you the same passion and love that fueled my own paths. I will always be here for you.

A very special thanks goes to my amazing husband Frédéric aka Freddie. This whole journey would not have been doable without you. Thank you for always keeping a cool head, for believing that I could— and had to!— do this, for keeping everything going at home while I was away, and for being the first to throw a party for each and every tiny success during this process. I love you.

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1 Introduction

For decades, the concept of automated vehicles (AVs) has captured the imagination and curiosity of people across the globe. These vehicles are equipped with automation technology capable of navigating and operating without human intervention and promise to enhance safety, efficiency, and accessibility in transportation. This idea has deep roots, dating back almost a century [14]. While it may seem like a recent technological development, the dream of self-driving vehicles has been a persistent theme in various forms, long before it became a tangible reality. The iconic picture from Time Magazine in the 1950s that envisions a future with automated cars is a compelling snapshot of an era marked by bold technological optimism (see Figure 1.1).

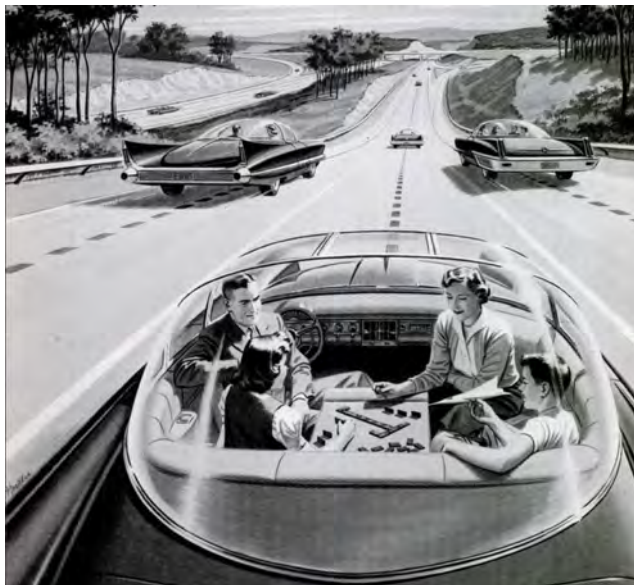


Figure 1.1: Life magazine 1956 <https://www.flyingcarsandfoodpills.com/electricity-may-be-the-driver> (slightly modified). Original source: Americas Independent Electric Light and Power Companies, Advertising, In: LIFE Magazine Vol. 40, N° 5, 30. January 1956, p. 8.

1 Introduction

The image captures the spirit of a time when science fiction and innovation converged in visions of an automated and streamlined future and is accompanied with this text:

“ELECTRICITY MAY BE THE DRIVER. One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road. Travel will be more relaxing and enjoyable. Highways will be made safe — by electricity! No traffic jams ... no collisions .. no driver fatigue.”

In the post-World War II period, especially during the 1950s, there was a prevailing fascination with automation and a belief that technology could solve many of society’s problems. The image likely portrays the dream of a utopian world where automated vehicles promised to free individuals from the hassle of driving, offering more leisure time and safer transportation. At the same time, it symbolizes the era’s drive for progress and the unwavering belief in the power of technology to transform our lives. This historical image serves as a testament to the enduring human desire for a future where AVs play a central role in our everyday lives.

This dream has always seemed to remain roughly two decades away [15]. Recent advancements, however, suggest that we may be on the cusp of a transformative moment in automotive history. AVs are increasingly making their way onto test tracks and public roads across the globe [16, 17, 18]. It is necessary to recognize, that the allure of AVs is not only about convenience and efficiency but also about the promise of a future where utopias and dystopias coexist in complex harmony. As these vehicles emerge, they bring with them both, the promise of utopian scenarios and the perils of dystopian outcomes.

Utopian visions depict AVs as the solution to traffic congestion, accidents, and pollution. They offer the dream of effortless, safe, and environmentally friendly transportation. In these visions, AVs are seamlessly integrated into the urban fabric, allowing for smoother traffic flow, reduced accidents, and decreased emissions. They herald a future where passengers can work, relax, and enjoy their journeys while the vehicles take care of the driving. Some even envision shared AV fleets as the answer to reduced car ownership and the reclamation of urban space once dedicated to parking lots [19].

However, this utopian vision is counterbalanced by dystopian fears. Reports from the United States reveal that AVs have blocked streets, locked down entire campuses, enforced restricted operational times, and imposed peculiar safety regulations [20]. The bustling streets of San Francisco have been a testing ground for the automated vehicle industry, with the so-called “robo taxis” becoming an increasingly common sight on the city’s roads [21]. For a while, these

vehicles have been cruising around the city without a human backup driver, showcasing the promise of a driverless future. Nonetheless, a recent traffic accident has raised concerns and prompted a reevaluation of this approach [21]: a robo taxi from Cruise [22], a company for automated vehicles, was involved in an incident where it drew a pedestrian into its path [23]. While the pedestrian was unharmed, this incident raised questions about the readiness of AVs to navigate complex urban environments without human supervision. In response to this incident and with an abundance of caution, authorities and regulators have mandated that robo taxis in San Francisco are no longer allowed to operate without a human backup driver. This decision comes as a pivotal moment in the development and regulation of AVs, underscoring the importance of ensuring the safety of both passengers and pedestrians. These incidents raise concerns about the impact of AVs on urban infrastructure and the potential for increased traffic chaos due to the unpredictable behavior of both the vehicles and their passengers.

Ethical challenges also loom large in the realm of AVs. These vehicles are being programmed to make split-second decisions that can have life-and-death consequences. These decisions raise profound moral dilemmas, such as whether an AV should prioritize the safety of its occupants over pedestrians or other road users. The infamous “trolley problem” [24] is one such ethical dilemma, where the AV must decide whether to save its occupants at the expense of others. These dilemmas bring into question the very foundations of programming and liability in AV technology and public acceptance will be among the most important hurdles that have to be overcome for a successful proliferation and adoption of AVs [25].

Lyons et al. [26] conducted co-creation workshops in the UK and depicted a dystopic future for London’s transportation landscape. While central areas resist car dependence, AVs surge in inner and outer regions. They become a symbol of coolness for the youth, replacing child escort trips and aiding non-drivers. The cars are predominantly privately owned and operated, creating disparities between the ‘haves’ and ‘have nots’. Although enhancing safety, streets prioritize AVs, causing public transport decline, exacerbating social disparities and challenging sustainable mobility efforts amidst resurging car dependence. This vision underscores the intricate challenges of an AV-dominated future, impacting society and urban development.

But how might we tackle these challenges in the field of human-computer interaction (HCI)? Incorporating user feedback and insights from early engagement sessions with users allows researchers, developers, and designers to develop intuitive and user-friendly interfaces for AVs that enhance usability and acceptance among diverse user groups and ensures that AV technology contributes to a more equitable and sustainable future of transportation. Thereby, it is crucial to deal with questions on how to provide information for the user to overcome

psychological and cognitive challenges such as trust [27], control, transparency, security, and privacy challenges [28].

In this work, the focus extends beyond technological considerations. Instead, it takes into consideration the evolving needs of future passengers. The dilemmas and challenges previously mentioned not only shape technological advancements but also profoundly influence the perceptions and experiences of users. By understanding their needs, including issues of gender bias and security issues, we aim to conceptualize and implement improvements that align with user expectations to increase the overall experience of transportation. For this, we follow the user-centered design process [29] and combine it with the Feminist HCI approach [30]. The subsequent sections provide a positioning statement to contextualize this work, a comprehensive introduction to shared mobility, public transportation, and vehicle automation, and the methodology and outline of this thesis.

1.1 Positioning Statement

This doctoral thesis is driven by the overarching goal of fostering equity in technology, particularly in shared automated vehicles (SAVs), and by placing the users and their needs at the center of this highly empirical work. Thus, instead of delving into automated vehicles and their technology, a high focus is put on people's perceptions of these vehicles and the research approach is influenced by feminist theories. According to feminist standpoint theory, knowledge cannot be seen without the context in which and by whom it is produced [31]. In the following, I will situate myself and the context in which I work.

Throughout the course of this work, I endeavored to integrate principles from both computer science and feminism, utilizing methods and theories from each discipline. My research is driven by a personal and academic passion for the field, and I am guided by the conviction that technology can be harnessed to empower individuals and create spaces for meaningful self-expression. My unique perspective as a white woman who, as a child, arrived in Germany as a refugee from former Czechoslovakia has profoundly influenced my academic trajectory. It has given me the privilege to access the rich educational opportunities available in this diverse and welcoming country. However, my journey also involved confronting and overcoming discriminations associated with my status as a refugee and child from a working-class household. This additional layer of personal experience has fostered in me a deep sense of gratitude, responsibility, and a heightened awareness of the disparities people may face due to their demographic characteristics. I am acutely aware of the opportunities that education has given me, and I am committed to using my knowledge and

skills to contribute positively to society, particularly in the realm of technology development and HCI.

I proudly identify as a feminist and I particularly align with intersectional feminism and have been continually enriched by the writings and activism of numerous authors, including Chimamanda Ngozi Adichie, Gloria Anzaldúa, Ruha Benjamin, Judith Butler, Simone deBeauvoir, Lucía Etxebarria, Bernardine Evaristo, Donna Haraway, Toni Morrison, Minna Salami, and many more. Throughout this dissertation, feminism has played an influential role both implicitly and explicitly. However, my journey did not commence with the explicit goal of writing a feminist dissertation. Instead, my perspective gradually became more pronounced throughout the various design processes, reflections, and the process of writing this dissertation. Feminist HCI, with its focus on inclusivity, empowerment, and the recognition of diverse voices, has resonated with me on a personal level. I believe that technology should not only be a tool but a medium through which individuals can express their authentic selves, free from societal constraints and biases. As such, feminism is used as an example of critical thinking within a discipline, as a tool, method of analysis, as a basis for the construction of respectful positions, and as a basis for interdisciplinarity. At this point I want to emphasize that in this work, feminism is not centered around the perspective of women, but instead is expanded by intersectionality, meaning that in addition to gender we take into account other characteristics that might lead to discrimination, such as cultural background and age.

It is no coincidence that I centered my focus on SAVs operating as a form of public transportation. My rationale stems from the understanding that SAVs represent a significant advancement in transportation technology, aiming to be accessible to a wider demographic due to their increased affordability in comparison to privately owned vehicles. Moreover, I view mobility as a fundamental human right, essential for individuals to access opportunities, services, and social connections. By prioritizing SAVs within the realm of public transportation, I aim to contribute to the realization of this right for all members of society. Additionally, SAVs hold promise in addressing pressing environmental concerns, such as reducing emissions and alleviating traffic congestion, thus promoting sustainable urban mobility. SAVs have the potential to enhance inclusivity and accessibility in transportation, catering to individuals with diverse mobility needs, including the elderly, persons with disabilities, and those residing in underserved communities. By exploring HMIs for SAVs, my research seeks to advocate for equitable, efficient, and sustainable mobility solutions for all.

1.2 Shared Mobility and Shared Automated Mobility

As we delve into the realm of shared mobility and explore its various dimensions, the following paragraphs will give an overview of public transportation and shared mobility and the nuances of automated vehicles, examine potential scenarios, and explore the transformative potentials of SAVs.

1.2.1 Public Transportation and Shared Mobility

The Oxford dictionary defines public transportation as: “Buses, trains, and other forms of transport that are available to the public, charge set fares, and run on fixed routes” [32]. In fact, public transportation has a long and fascinating history that spans several centuries. From the earliest forms of transportation in ancient civilizations to the modern-day subway systems and buses, public transportation has played a vital role in the development of urban centers and has revolutionized the way people travel and commute.

Today, public transportation plays a vital role in the daily lives of trillions of people around the world. From buses and trains to subways and light rail systems, public transportation provides an affordable, and environmentally friendly way for people to travel to work, school, and other destinations. In many cities, suburbs, and rural areas public transportation is also an important driver of economic development, as it provides easy access to job opportunities and other resources. Shared mobility can be seen as an umbrella term different services such as bike, car-, ride-sharing and mobility-on-demand-services (MOD) [33]. Shared mobility services have provided new options for urban transportation that were not previously available as they provide convenient, on-demand access to transportation, enabling users to book rides or access vehicles quickly through mobile apps. In the following sections, we provide a short overview on the most established shared mobility concepts: car-sharing and ride-sharing.

Car-sharing is a system where a fleet of small road vehicles are owned by an operator and can be accessed by users of the platform. This gives users the same level of freedom that comes with using a private car without the duties of owning a car [34]. Abouelela et al. [35] differentiate between three different operational models: round-trip, one-way, and free-floating. The round-trip model is where users acquire the vehicle from a fixed station and return the car to the same station. The one-way system is where the user picks up the car from one station and returns it to any branded location within the company. The free-floating model is where vehicles are scattered around the city, and

the user can start his journey by using the car closest to his location. The transaction is finalized when the vehicle is returned within a geographically confined area.

Ride-sharing or car-pooling is a mode of transportation where users with matching or partially matching itineraries and schedules share a vehicle and the emanated cost of the trip [35]. This includes car-pooling and van-pooling, which are differing subcategories categorized by the size of the vehicles used. According to the Federal Highway Administration, van-pooling is described as a group of seven to fifteen passengers traveling together; if the number of passengers is less than seven, it is considered car-pooling [35]. There are many different names for the same transportation mode, such as On-Demand Ride Services, Transportation Network Companies (TNCs), ride-sourcing, ride-hailing, e-ride-hailing, and ride-booking [35]. The basic model of these services is that passengers use a mobile app to connect to the nearest available driver and is driven from their current point to another point. Well-known examples of these services providers are Uber [36] and MOIA [37]. Alternative transit services (ATS) are services that provide transportation sideways to public transit and encompass a variety of modes such as microtransit or shuttle buses, etc. ATS are generally more expensive to the provider than public transportation, as they haul less travelers per trip. ATS typically try to address the shortcomings in public transportation coverage, in terms of either space or time [33]. A common form of ATS are shuttles —vans or small buses —that are chauffeured by professional drivers and cover the first and final miles of a person’s journey when using public transportation— typically between their starting point or residence and the transit station or final destination— providing first and last mile services. As routing and tracking technologies are becoming more and more advanced, microtransit is gaining importance as another form of ATS [35]. Microtransit refers to on-demand, flexible transportation services typically provided by small vehicles like vans or minibusses, often operated by ride-hailing companies or transit agencies. It offers personalized, adaptable routes and schedules based on passenger requests, providing a more tailored and convenient transportation option compared to traditional fixed-route services. These buses, or shuttles can be owned publicly or privately and either operate on flexible or fixed routes, on-demand or with fixed schedules. The largest potential to offer flexible, sustainable, and affordable mobility to passengers have shared mobility concepts when they get combined with intelligent vehicle automation.

1.2.2 Vehicle Automation

Historically, the introduction of technological advancements has spawned multiple future possibilities, generating considerable enthusiasm in their early stages.

For instance, during the “Atomic Age” in the mid-20th century, scientists and designers envisioned nuclear-powered automobiles, airplanes, and even household appliances [38, 39]. Similarly, the development of AV technology is met with akin enthusiasm. Beyond concepts like platooning [40] and shared mobility in first/last-mile solutions [41], futuristic visions encompass ideas such as dynamic lane reversal (lanes adapting direction based on demand/traffic volume) [42], managed intersections (vehicles crossing intersections simultaneously and at high speed) [43], or even homes and businesses [44] driving in automated mode. All these concepts aim to contribute to a more sustainable and livable world.

In order to categorize the extent of automation in motor vehicles, the Society of Automotive Engineers (SAE) [45] introduced a taxonomy and definitions for terms related to driving automation. Since its initial release in 2014, the SAE J3016 Recommended Practice: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, commonly known as the SAE Levels of Driving Automation, has served as the most widely referenced resource within the industry concerning driving automation. The J3016 underwent iterative development in collaboration with the International Organization for Standardization (ISO) to improve its clarity in terminology and is designed to cater to an international audience. The document, establishes a classification system for the six levels of driving automation, ranging from Level 0 (no driving automation) to Level 5 (full driving automation). In accordance with the SAE taxonomy, throughout this doctoral thesis we will use the term ‘automated vehicle’ instead of using the more widely and publicly used term ‘autonomous’. By this we will be referring to automation levels 4 and 5.

As the level of automation increases, an active driver gradually transitions into a passive passenger (1.2). This shift has the potential to revolutionize road traffic dynamics [46] and, consequently, the overall user experience. Activities that were previously considered secondary or tertiary may take precedence, and new pursuits like reading, working, relaxing, socializing, and even sleeping—commonly referred to as non-driving-related tasks (NDRTs)—can come to the forefront. However, this shift also implies that passengers need to place their trust in the system and give away control. While this transition holds significance in reshaping transportation paradigms, it is not the primary focus of this thesis, as we concentrate on SAVs where the users are passengers regardless. Nonetheless, this paradigm shift presents its own set of challenges, such as the absence of a bus driver and the need to ensure passenger security and comfort amidst the automation. Additionally, ensuring effective communication and interaction within the vehicle’s environment emerge as prominent challenges in this context

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.			You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”.		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

Figure 1.2: SAE J3016™ Levels of Driving Automation™ taken from [45] (adapted).

1.2.3 Shared Automated Vehicles

SAVs represent a novel and pioneering concept within the automotive sector, aimed at promoting effective and eco-friendly transportation. Unlike conventional AVs, the shared version is not privately owned. Instead, SAVs are accessible to the general public, and their adoption holds the potential to reduce the volume of private vehicles on the road, thereby alleviating traffic congestion and curbing pollutant emissions [47].

In an optimistic scenario for SAVs depicted by Papa and Ferreira [19], they are envisioned to lead to reduced travel demand, improved road efficiency, and better road safety. The adoption of SAVs results in a reduced number of private vehicles, contributing to a more sustainable and pedestrian-friendly urban environment. These vehicles enhance the value of travel time, reduce stress, and increase safety, especially benefiting individuals with health conditions and disabilities. Furthermore, SAVs substantially diminish the need for parking spaces, as they remain in constant motion, ideally proceeding to their next destination right after passenger drop-off or pick-up [48]. This opens up possibilities for utopias where parking areas are used for alternative uses, such as green spaces or housing developments. SAVs belong to the existing public transportation infrastructures, bridging the gap referred to as the “first and last mile” [49]— the distance between the origin or destination and the nearest station. This makes it easier to switch between various modes of transportation and facilitates access to public transit for specific demographics, including rural residents, the elderly, individuals with disabilities, and those without driver’s licenses or personal vehicles, enhancing their independence and overall quality of life [49]. Moreover, SAVs offer a cost-effective solution for individuals who may find it financially challenging to own a personal vehicle. Rather than incurring acquisition expenses and associated costs, passengers only pay for the distance traveled. This flexibility empowers users to request an SAV at their convenience, ensuring a stress-free and efficient travel experience [19].

In comparison to private car ownership, public transit, particularly when automated and shared, has the highest vehicle occupancy and the capacity to efficiently transport large volumes of people [50]. This makes it a sustainable solution for efficiently moving people in increasingly crowded urban areas. Shared automated public transport, particularly in the form of advanced public transit systems, represents a progressive and effective response to the challenges posed by urbanization, traffic congestion, social impacts, and health considerations in our growing cities. It leverages technology to create efficient and sustainable transportation solutions. As such, SAVs hold the potential to revolutionize and enhance sustainable and efficient mobility. This research is dedicated to the exploration of SAVs with the firmly held belief that the insights gathered from this work will yield multifaceted advantages for diverse modes of public, automated transportation.

1.3 Problem Statement and Data Biases in Technologies

In an era characterized by the relentless advancement of technology, our society has witnessed an unprecedented transformation in the way we live, work, and interact. Technological innovations have permeated nearly every facet of our lives, from the way we access information to the means by which we communicate, navigate, and make critical decisions [51]. However, amid this digital revolution, a disquieting reality has emerged — the presence of biases inherent in our technologies [52, 53, 54].

These biases, which have found their way into the algorithms, data sets, and design processes of various technological systems, have profound implications for the individuals and communities that interact with them. They have raised concerns not only about fairness and equity but also about the potential perpetuation of discrimination, exclusion, and injustice [51]. For example, algorithms often rely on historical crime data, which reflects existing biases in law enforcement practices. As a result, they can lead to over-policing in certain neighborhoods, exacerbating racial disparities in law enforcement [52]. When trained on historical hiring data, systems may reflect existing biases in hiring decisions reproducing and even amplifying discriminatory practices, making it more difficult for women and people of color (POC) to access job opportunities, which occurred at Amazon [55]. Biases in technology, in their various forms, have become a potent force that has the capacity to influence and even exacerbate existing social differences and this phenomenon is intricately linked to the concept of structural discrimination [56]. In other words, technology can amplify existing societal disparities and biases, and it can reinforce inequalities or perpetuate discrimination, depending on the data, algorithms, and intentions

behind its creation. Thus, it is crucial to recognize that technology, rather than being inherently neutral, can either exacerbate or mitigate societal issues, depending on how it is designed, implemented, and used [52].

In essence, the relationship between technology and society is a symbiotic one. Technology is a product of human ingenuity, reflecting the aspirations and limitations of its creators. Simultaneously, it acts as a powerful agent of change, impacting the way we perceive and navigate the world around us. Acknowledging this intricate interplay is essential for both technologists and society at large. It underscores the responsibility to design and utilize technology in ways that align with our collective values and aspirations, fostering a more equitable and inclusive future for all.

This structural discrimination encompasses the systemic inequalities ingrained in society, often rooted in historical, cultural, and power dynamics. These inequalities manifest themselves in the data and algorithms that underpin technology, resulting in a disproportionate impact on marginalized communities. Specifically, these marginalized communities include POC, Lesbian, Gay, Bisexual, Transgender, Queer/Questioning, and other (LGBTQ+), individuals with disabilities, and other historically disadvantaged groups, such as women, children, senior citizens [56, 51]. In fact, there is evidence that technologies carry a bias towards White, heterosexual, tech-savvy, and well-educated men [52, 57]—a group representing a minority in relation to the world population.

It is crucial to consider these biases in the development of SAVs, as they are promising to specifically serve underrepresented user groups. Traditionally, the automotive industry has a strong orientation towards men [58] and AVs are no exception [59]. A poignant illustration of this unfolds in the realm of voice recognition systems, where the performance for women and POC lags behind that for white men [60]. Instead of rectifying this issue by enhancing the diversity of training samples, a perplexing solution is proposed: to train women to conform their speech to the system’s existing parameters, rather than altering the system to accommodate diverse voices [60]. This seemingly trivial yet profoundly disconcerting example lays bare inherent power imbalances. Despite a notable rise in the number of women who engage with technology as autonomous users, their unique needs often remain overlooked. Gender differences are frequently omitted in research, engineering, and design [61] of technologies. This oversight perpetuates biases in software, automated systems, AI, and other technologies [52, 62], inadvertently excluding diverse groups of people from the full benefits of technological advancements.

This exclusion is argued to be in conflict with the fundamental values of the European Union (EU), including its overarching sustainable development goals (SDG) [63], as it prioritizes men over women, potentially exposing the latter to physical harm. The situation at hand vividly underscores the disparities

experienced on multiple levels: while certain user groups are expected to adapt to the technology, no such expectation is levied upon other, more powerful, and privileged user groups. This stark contrast reveals that the issue is not being treated with the gravity it deserves. By forming approximately 50% of the global population [64], women are an important user group which is why this dissertation puts a high focus on women and gender in general. The term “gender” is defined as a multifaceted concept encompassing symbolic and structural dimensions [65]. Symbolic gender denotes identities or attributes assigned to objects, constructed environments, or aspects of nature [66], while structural gender pertains to the customary practices of dividing labor within society [67]. Throughout this thesis, we aim to delineate a distinct boundary between gender and sex— typically referring to biological characteristics such as reproductive anatomy, chromosomes, and hormones that categorize individuals as male, female, or intersex— emphasizing the differentiation between these constructs in our exploration and analysis [65]. In other words, while sex is primarily biological, gender encompasses a broader spectrum of identity, expression, and societal roles. While acknowledging the fluid nature of individual gender [65], we highlight society’s tendency to construct these gender dimensions in ways that reinforce binary distinctions (male/female, men/women). Therefore, our use of terms like “masculine” or “feminine” is mindful of the limited scope they offer for gender expression. These layered interpretations of gender intertwine and impact individuals’ interactions with technology as they navigate these multifaceted relationships. Furthermore, we recognize that underrepresentation is a multifaceted challenge that extends beyond gender alone. As such, we will take on the lens of intersectionality, a concept introduced by Kimberlé Crenshaw [68] that acknowledges how individuals can experience multiple forms of discrimination or privilege simultaneously, often based on their various social identities. Discriminatory factors can be diverse, such as gender, age, ableism, race, class, education level etc. and many of them might be relevant for the design and implementation of SAVs. Addressing all these factors comprehensively is not possible within this thesis. Therefore, we narrow our research focus on gender, age, and cultural background, recognizing them as significant contributors to inequities in SAV adoption and utilization. In Chapter 2.3, we will examine the importance of gender, age, and cultural background within the context of (S)AVs, the research gap around these factors, and how they intersect and influence user experiences, perceptions, and acceptance of AV technology.

1.4 Methodology and Thesis Outline

The field of HCI emerged from human factors, originally concerned with creating interfaces to facilitate human-machine interaction, primarily focusing on optimizing machine performance [69]. During its evolution in the early 1980s, HCI shifted its emphasis towards achieving a more harmonious cognitive connection between humans and computers. This shift marked a rapid growth in HCI, prioritizing user-friendliness and usability [69]. In fact, the second wave of HCI is identified as advocating for a shift in perspective from viewing people as mere users to recognizing them as active participants [70]. This wave placed greater emphasis on the design process rather than the end product. The current third wave of HCI, as proposed by Susanne Bødker [71], expands its scope to encompass a wide range of interactions, diverse usage contexts of technologies, and delves into aspects such as user experience, emotions, and reflexivity. As such, HCI developed into a diverse research field with a variety of knowledge domains contributing to shape and propel it introducing distinct perspectives on research methodologies, such as psychological, ethical, sociological perspectives, and others [72, 73].

Our work is grounded on the principles of the human-centered design (HCD) process, as outlined in ISO 9241-210 [29], a fundamental methodology that serves as the foundation for the research. The HCD approach is characterized by its emphasis on placing users at the heart of the design and development process and includes several distinct stages. These stages encompass understanding user needs, requirements, and aspirations, followed by iterative design, prototyping, evaluation, and ultimately the implementation of user-centric solutions.

To address the multifaceted challenges of unconsidered user groups as outlined in 1.3, we have adopted the theoretical framework of Shaowen Bardzell's Feminist HCI [30, 74]. This approach expands the scope of traditional HCI methodologies by centering on the diverse experiences and aligns with standpoint epistemology [75], suggesting that research should initiate from the perspective of discriminated, unprivileged, and less-favored groups to gain valuable insights, thereby encouraging inclusivity, diversity, and amplification of under-represented communities. Feminist HCI has recently gained attention within the HCI community [76, 77] and adheres to a set of qualities that guide the research and design processes. These qualities encompass pluralism, which involves including a variety of points of views, participation, which emphasizes the use of participatory processes, advocacy, which challenges researchers to scrutinize and verify their own viewpoints, and self-disclosure, particularly in research areas that involve sensitive topics [30]. Additionally, the Feminist HCI approach underscores the importance of considering context and the body (embodiment) and adopting holistic viewpoints (ecology) [30].

In line with the principles of Feminist HCI [30], which aim to cultivate inclusive and equitable technology design, our research embraces an emic epistemology that prioritizes the perspectives of individuals [78]. Following an interactive research approach, we delve “inside the bowl” to immerse ourselves in the context and gain a deep understanding of the subject matter. This approach mirrors the early stages of the HCD process and embodies an inductive approach. However, in the latter phases of our research, we introduce an experimental methodology [79] to augment our approach. This methodology facilitates the evaluation of implemented prototypes through objective measurements, adopting an “outside-looking-in” perspective and employing an etic, deductive approach [78, 80]. We consider these approaches as complementary as our goal is to infuse feminist principles into the field of computer science while adhering to established research methodologies. In other words, we want to bring feminist perspectives into the field of computer science without abandoning the rigorous and well-established ways of conducting research. Throughout our work, we consistently strive to include participants from different age groups and cultural backgrounds, and maintain a gender-balanced sample. This commitment underscores our dedication to inclusivity and equity in the realm of technology and HCI.

The contribution of this dissertation is to develop innovative HMIs for SAVs based on related work, by applying approaches for inclusive design, and evaluate them with an applied mixed-methods research approach. The result is a rich catalogue of scientific insights into the suitability of specific features, as well as on the theories and recommended practices that were used to design them by including diverse user groups.

This doctoral research was conducted in cooperation with the Human-Computer Interaction Group at Technische Hochschule Ingolstadt and partly within the “SUE — Self-Driving Urban E-Shuttle” project. Large parts of the work that is presented in this dissertation were done in collaboration with colleagues, other researchers, and students. Therefore, the scientific plural “we” is used predominantly in this document. For statements only referring to my personal experiences and perspectives, I will use the first-person singular.

In the subsequent section, we offer an overview of the structure of this thesis. Chapter 2 is dedicated to establishing the theoretical framework and presenting relevant previous work in the domain of SAVs and Feminist HCI. We identify challenges related to the acceptance of SAVs, and provide a detailed description of the Feminist HCI approach, as well as the demographic groups that will be included into our research. The chapter serves as the foundational groundwork for the empirical research detailed in Chapters 3 to 9. These have partly been published: Chapter 3 [1, 2], Chapter 4 [3], Chapter 5 [4], Chapter 6 [5], and Chapter 9 [6]. The papers forming the basis for Chapters 7 and 8 are currently under review. Chapters 1 and 2 encompass elements of the introductions

and related work sections found in the publications. To prevent redundancy, Chapters 3 through 9 concentrate on the user studies that were conducted.

2 Related Work

This chapter provides an overview of the theoretical background and relevant related work. As this doctoral thesis focuses on shared automated vehicles (SAVs), we start with potentials and perceptions of SAVs (2.1). Subsequently, we gather a deep understanding of factors that influence user adoption of SAVs (2.2). Here we will dive into acceptance challenges, psychological needs, and perceived security in public transportation as a potential reason for adoption hurdles of SAVs, and finish with an outlook on interface designs in AVs. Building on this background, we will then concentrate on the theoretical and practical heart of this doctoral work: the urge to include diverse user groups into research of AVs (2.3) and its particular focus on gender, age, and cultural background. Subsequently, we introduce the theoretical basis for our work with the human-centered design (HCD) process and the Feminist HCI framework (2.4), and present the research questions (2.5) resulting from the outlined research gaps. Finally, we summarize the chapter (2.6) as a foundation for the subsequent empirical research presented in Chapters 3 to 9.

2.1 Potentials and Perceptions of Shared Automated Vehicles

The rapid progress of automated driving technologies promises to revolutionize public transportation by creating automated mobility-on-demand (AMoD, [81]) systems and it is predicted that already by 2030 the need for a private car in cities will decrease significantly [82]. In this context, automated mobility solutions at large scale will be game-changing. This system will differ from classic public transport as fixed timetables and routes that are still common today are becoming less important and mobility services are increasingly being provided “on-demand” and adapted to customer requirements [83]. Passengers will be able to book rides according to their personal needs via digital platforms. AMoD solutions of the future are expected to create personal freedom and long-lasting positive effect on the quality of life of people in urban and rural areas [84]. Generally, new transport concepts such as multi-modal transport—referring to multiple modes of transportation such as combining trains, buses, bikes, or walking, to complete a single journey or trip—, first/last mile solutions,

2 Related Work

or mobility on demand could yield in a fundamental change in customers' mobility behavior [85] and existing differences between public and private mobility could become blurred or disappear completely in the distant future.

In SAVs, passengers are transported by AVs — i.e., cars with SAE level 4 or 5 capabilities [86]. These vehicles will be guided by intelligent traffic management systems enabling efficient route planning and smart ride-sharing. Still, it is unclear whether private vehicles or shared options will dominate in the future. Some claim that mass public transportation such as rails will be extincted by the introduction of AVs [87], others argue that the highest environmental and societal benefits will be achieved by AVs supplementing public transportation instead of replacing it [50, 88]. The (potentially) most beneficial scenarios unfold when shared mobility prevails over private vehicle ownership [19, 86] and researchers argue that the most important factor influencing traffic, pollution, as well as urban space occupied by cars [89] is the occupancy rate [50], which currently is just above one person per vehicle [90]. To arrive at its full potential, it is imperative that passengers not only share vehicles but also share rides [50].

Automated ride-sharing has many similarities with today's forms of public transportation. However, its demand-orientated service approach offers both high(er) efficiency and comfort for passengers. SAVs will lead to fewer cars in the streets [88] and – as simulations suggest [91] – lower air pollution [92], making SAVs an attractive alternative to private vehicles [93]. Supplementing conventional public transport with automated services brings comes with a couple of advantages. In addition to the noticeable reduction in running-dependent costs (by saving on driving personnel), automated shuttle buses are particularly suitable to act as feeder services to mass transportation vehicles. Buses are one of the most economically effective alternatives for implementing new public transport in cities as they require minor investments in infrastructure and are used in existing and functioning road networks. The size of an automated shuttle bus alone opens up new possibilities that cannot be realized by conventional buses. For example, driving into a narrow town center is much more difficult with a large bus than with an automated shuttle bus. Equally advantageous is the fact that an automated shuttle bus requires no breaks as the system does not experience fatigue, unlike a human driver. [83].

Several pilot projects already operate on today's roads. Pioneers in the international market for AVs are companies such as the San Francisco-based Waymo [16] and Nuro [94] offering driverless delivery, Cruise [22, 95] with the first fully automated cab service in California, and the French company Navya [96] with its shuttle for passenger transportation for a wide variety of uses, such as businesses, amusement parks, or the city. Also worth mentioning is the Chinese tech giant Baidu, which established self-driving buses and cabs in China's cities Wuhan and Chongqing [97, 98]. The Transdev project is one of Latin America's

pilots and aims to introduce automated shuttle buses in Chile [99]. In Germany ioki has put the first automated service on the road in cooperation with vehicle manufacturer EasyMile, TÜV Süd and the market town of Bad Birnbach [83]. Until 2022, the Association of German Transport Companies (in German: Verband Deutscher Verkehrsunternehmen, VDV) [100] has recorded 44 cities with 61 automated shuttle bus projects in Germany. These include, for example, the ongoing SMO project (Shuttle-Modellregion Oberbayern) [101] with the Navya Arma vehicle type in Kronach, the active KelRide [102] funding project with the EasyMile EZ10 vehicle type in Kelheim, or the Bad Birnbach Shuttle (Line 7015) [103] also with the EasyMile EZ10, which has already been running since April 2017. Other shuttle bus projects are the EVA shuttle [104] in Karlsruhe, which was in operation from 2020 to August 2021, or the CUBe (Continental Urban Mobility Experience) [105], which circulated on the Frankfurt university campus for students and stopped test operation in 2018. These automated shuttle buses serve short fixed routes, usually in the old town, and, during their pilot phase, are free of charge for the passengers.

Despite companies as Waymo and Cruise being ‘state-of-the-art’ in metropolises such as San Francisco or Phoenix, the state of the technology is not as advanced yet. The concept sold to the public usually is an SAE level 5 [45] shuttle bus driving in fully automated mode and with no human operator on board. However, in Germany, this is not a reality yet. The fully automated shuttle buses on the road are vehicles for six to nine passengers that travel at a maximum speed of app. nine mph (15 km/h) and follow a pre-defined route. The technology detects obstacles independently through many sensors that react reliably in case of any impediment [106]. Furthermore, all vehicles have a human operator who must take on various roles during the journey. This includes intervention in vehicle control if the technology is overwhelmed.

The discrepancy between the concept sold to the public and the current state of technology can influence users’ perceptions of SAVs’ capabilities and their willingness to accept and adopt them. Misaligned expectations may lead to skepticism, reluctance to use SAVs, or even resistance to future developments in automated transportation. This mismatch between expectation and reality highlights the importance of transparency, clear communication, and managing user expectations in the deployment and adoption of emerging technologies like SAVs. Addressing these discrepancies is crucial for building trust, fostering acceptance, and ensuring the successful integration of SAVs into transportation systems and society.

2.2 Factors for the Adoption of Automated Vehicles

As we delve into the exploration of crucial factors for a widespread adoption of AVs, the subsequent chapters will navigate through a series of essential components. These sections will intricately examine the social acceptance and psychological needs influencing their integration, evaluate the perceived security concerns and their significance within the realm of SAVs, and examine the existing landscape of public transportation and its implications for the adoption of these vehicles. Finally, we will explore the realm of interface design tailored for shared automated mobility.

2.2.1 Social Acceptance

Regardless of the numerous advantages that automation of shuttle buses would bring (Chapter 2.1), a rapid implementation of this technology is impossible. Road traffic must slowly be adapted to AVs, and society must be convinced of its benefits. Therefore, the users' wishes, problems, and needs must be identified, and as a result, the factors that support the use of AVs from their point of view must be considered. If these are not taken into account, the new technology may not be used by society, despite flawless implementation and functioning. In this way, factors that guarantee the successful use of AVs can also be seen as reasons for the impediment of a sound system integration.

Social acceptance is an important factor influencing how quickly and in what way automated driving technologies and services spread. According to Davis [107] and Eden et al. [108], social acceptance is even one of the critical factors for the success of a technical system. According to the technology acceptance model (TAM) by Davis [107] the social acceptance of technology products can be defined as the intention of a user to use a specific system depending on their internal attitudes. Furthermore, social acceptance can additionally be subdivided into acceptability and acceptance. While acceptance defines the attitude, behavior, and reaction towards an interactive system after experiencing it, acceptability describes users' expected attitude before interacting with a product [109, 110]. A new technology that lacks acceptability and acceptance will not be successful [83].

Several prior works have investigated user acceptance of AVs, frequently using online surveys [111, 112]. Nordhoff et al. [113] propose a conceptual model for user acceptance of level 4 AVs and adopt a holistic view of user acceptance by adding a large number of factors that may determine acceptance. In their investigation of surveys on the acceptance of AVs, Becker et al. [114] point out

that apart from age and gender also the income influences the level of acceptance, and Rödel et al. [115] found that user acceptance and user experience (UX) of different levels of AVs are influenced by age, gender as well as participants' pre-experience with Advanced Driver Assistance Systems (ADAS). User acceptance of automated shuttles has also been evaluated in real environments. Wintersberger et al. [25] showed that potential users perceive this technology similarly to human-driven taxi services, and participants of an interview study by Nordhoff et al. [116] expressed positive attitudes towards AVs as part of public transportation systems.

2.2.2 Psychological Needs

Existing research underlines that psychological needs are regarded as important [117] and that these should be considered when designing products and interactions [118], as well as when investigating acceptability [85]. According to Shariff et al. [119] the biggest obstacles concerning a successful dissemination of AVs are not technological but psychological ones and people are still hesitant toward automated systems and giving up their control. Lundquist [120] establishes a triad of trust, control, and safety needs to ensure positive user experiences during AV rides. They propose to provide clear communication and transparent system feedback to increase these needs and suggest using visual and auditory feedback about the next stop of automated shuttles [120]. As such, the use of monitoring technologies and information sharing has the potential to increase security perception. At the same time, however, it needs to be taken into account that travel information can be a private matter [121]. Acceptance factors identified by related work [25, 122, 123, 120, 124] can generally be allocated to overall demographic factors, system reliability and performance issues, security concerns, users' expectations and trust, and privacy concerns vs. information demands. In this manner, privacy is defined as safeguarding sensitive and private information from unauthorized access, misuse, or disclosure, whether intentionally or unintentionally [125]. In the context of sharing mobility, the tradeoff between personal privacy and security can be exemplified by today's (non-automated) ride-sharing services. When using ride-sharing platforms like Uber [36] or Lyft [126], passengers often need to provide their personal information, such as their name, phone number, and location, to the driver for pickup and drop-off. This exchange of information is crucial for ensuring a secure and efficient ride-sharing experience, as it allows drivers to locate passengers accurately and facilitates communication during the trip. However, sharing personal data raises privacy concerns and can be potentially harmful due to the risk of discrimination [127]. Thus, finding a balance between maintaining passengers' privacy and ensuring the security and convenience of ride-sharing services presents an ongoing challenge in the sharing mobility domain.

A positive attitude toward AVs can be fostered by allowing people to try them out in a safe, real-world environment [128], as is already the case in pilot projects with human operators as a fallback (2.1). It has been shown that acceptability issues also depend on the role of the individual and their relation to the automated shuttle bus [129]. For example, citizens could relate to the automated shuttle bus as a passenger or an external road user (e.g., driver, cyclist, pedestrian). Here, citizens have different requirements for the use of public space or safety expectations for the shuttle bus, depending on their role. Thus, a passenger's safety of the vehicle's occupants is the priority, as well as trust in the technology. Other road users primarily need clear communication with the AV to keep uncertainty to a minimum. The issue of acceptance can not only lead to different requirements depending on the role; it can also lead to different demands in the same role (e.g., passenger) due to socio-demographic characteristics such as gender or age [129]. For example, the willingness to use an AV is slightly higher among men and young people than among women and older people [130]). One reason for this could be the increased fear of losing control while driving, which is more pronounced in women than in men, according to a study by Wicki and Bernauer [131]. Furthermore, subjective well-being in AVs is significantly lower among older people than among younger people [129]. This is also reflected in the requirements, as older people hope that the introduction of new mobility systems will make transportation more stress-free and orderly but would not necessarily use it themselves.

Recent studies examined people's willingness to switch from private to shared mobility modes in the future of mobility with demographics such as gender [128] and age [132] as predictors for the adoption of SAVs and young men being the group with the highest openness towards this technology. In comparison to public transportation today, SAVs offer more security as routes can be booked flexibly, but still, some of the most critical barriers to accepting SAVs are related to security concerns because rides will have to be shared with strangers [124, 133, 134, 135]. Security, therefore, plays a critical role in determining whether users will accept SAVs and could potentially hinder their widespread adoption. In other words, if users perceive SAVs as insecure or unsafe, they may be hesitant or unwilling to use them.

2.2.3 Hurdles for the Adoption of Shared Automated Vehicles

In the following subchapters, we will take a comprehensive exploration of the concept of perceived security, elucidating its significance and implications for SAVs.

Perceived Security

Drawing from Maslow's hierarchy of needs, safety and security are identified as fundamental human needs [136], a notion substantiated by recent research [137]. Understanding the core structure and formative mechanisms of psychological security is pivotal. This sense of security, subjectively perceived, encompasses a cognitive facet (risk perception) and an affective dimension (threat perception) [138]. Similar to various psychological processes, the evaluation and interpretation of security are susceptible to individual and collective differences, entwined with prior knowledge and experiential backgrounds [139]. The genesis of psychological security manifests as a highly dynamic process, continually shaped and adapted. It is crucial to recognize that the subjective sense of security is not a static, enduring construct; rather, it fluctuates due to numerous personal and situational factors [139].

Factors like age [140] and gender [141] emerge as common influencers, with older adults and women exhibiting heightened fear of crime. Contemporary research and statistics emphasize that women encounter elevated levels of "gendered" crime within public spaces [142, 143]. Despite possessing physical capabilities, women often perceive themselves as more vulnerable than men, influenced by gender stereotypes regarding their physical traits [144]. According to the Physical Vulnerability Theory, individuals lacking physical abilities tend to harbor greater fear of crime, unable to defend themselves effectively during a criminal encounter [145, 146]. This aspect becomes noticeably prominent for "visible vulnerabilities" [147]. Notably, older adults, often facing frailty and limited mobility due to declining physical conditions and reliance on walking aids or assistive devices, align closely with this theory. In contrast, the Social Network Theory pivots on information exchanges among individuals and groups [145, 148]. Communities fostering high rates of social interaction theoretically respond collectively and efficiently to crime and the fear it instigates. These theories encompass social [145, 148] and demographic [146, 148] elements. Other theories focusing on fear of crime and perceived security center on contextual factors. The Defensible Space Theory [149], for instance, posits that individuals perceiving ownership and responsibility for a place consider it more secure. Enhanced natural surveillance, facilitated by numerous individuals taking care

of an area, augments perceived security in public spaces and diminishes crime rates [149]. Factors like inadequate lighting, unfamiliarity, or locales with reputations of insecurity [150, 151] can escalate perceived insecurity. Linked to natural surveillance by large groups, the Theory of Virtual Community [152] underscores the promotion of psychological security through the presence of familiar and unfamiliar individuals, facilitating visual connections that foster a sense of security. In other words, perceived security is evidently shaped by demographics, yet interventions exist. In this thesis, we aim to explore how User Interfaces (UIs) concepts within SAVs can positively influence perceived security. Understanding these influences and implementing effective design strategies could mitigate perceived security concerns, facilitating greater acceptance of SAVs in diverse demographics.

Perceptions of Public Transportation and Shared Automated Vehicles

Public transportation is a notably safer mode of transportation in comparison to private cars as it has significantly lower—around one-tenth— injury and death rates [153]. Living in a community centered around public transportation reduces per capita crash casualty rates by about 80% when compared to automobile-centric communities [153]. Strengthening the public transportation infrastructure can improve surveillance and economic prospects for vulnerable populations, subsequently reducing crime risks [153]. Despite being a secure option— at least in most Western countries— public perceptions still regard public transportation as perilous [153]. Individuals often evaluate new transportation options, such as SAVs, based on their experiences with existing modes of transportation, including public transit. If public transportation is perceived favorably (e.g., as reliable, convenient, cost-effective, and secure), individuals may be more open to accepting SAVs as a viable alternative. Understanding these dynamics is essential for effectively introducing and promoting SAVs as part of a comprehensive and integrated transportation system.

Regarding SAVs, passenger reception appears positive, yet concerns about security and emergency handling persist [108, 128, 154]. Research by Clayton et al. [155] delves into the willingness to share an AV with other passengers, revealing uncertainty about sharing and a strong preference for privately owned vehicles. Pakusch et al.’s online survey [156] underscores the reluctance to shift from private rides to shared ones, predicting the dominance of private AVs in the future of automated driving. When applied to SAVs, Lavieri and Bhat’s findings [157] show a willingness among people to pay extra for trips in SAVs when only the vehicle, not the entire trip, is shared. Privacy and security concerns, particularly reluctance to share rides with strangers, impact commuting trips less than recreational rides [157].

Amidst global public spaces and public transportation, research consistently highlights the substantial security concerns faced by women [53, 158, 88, 142, 159]. Women employ diverse strategies to alleviate these fears, altering their travel patterns by avoiding night-time public transportation, circumventing specific stations, or adjusting their attire [160]. In extreme cases, some opt out of travel entirely, constricting their engagement in public and professional spheres [53, 142]. These strategies starkly delineate the encumbrances on women's mobility, underscoring the imperative for SAVs to challenge these limitations and offer solutions prioritizing psychological security. Women's and men's mobility patterns differ in several ways: women walk more, use public transportation more [142], and trip-chain more [142, 161], which means they usually take several short trips around their neighbourhood, whereas men's mobility patterns show fewer and longer trips. To understand the distinctions between how women and men travel, it has to be considered that their mobility patterns result from prevalent gender patterns in our society. Women all over the world cover for 75% of unpaid work [162] defined as care work, housework, childcare or elderly care, shopping, other tasks around house and family, as well as honorary positions, with the latter accounting for the tiniest part. As a result, they usually take several short trips around their neighbourhood to combine their abundant duties [142, 161]. For example, women drop off children at daycare or school on their way to work, or do grocery shopping and other errands on their way home. Compared to men, their space of movement is more centered around the neighborhood whereas men frequently take fewer and longer trips in terms of time and distance. It is also women who travel accompanied by children or elderly more often than men and it is them who carry more luggage with them. Their responsibilities within the unpaid care work many times drives women to opt for part-time jobs, which, in combination with the gender pay gap, results in having less economical power than men [162]. As a consequence, women have less money at their disposal for mobility. It has been demonstrated that even in Western countries, which supposedly are more gender equal, it is the man that primarily has access to the household's car given that only one car is available [53]. Potentially, it is a combination of both facts that leads females to use public transportation more [142]. It is women who make up two thirds of public transportation users [163]. In this context, we would like to point to [164], who conducted an exploratory user study on parents' decisions about allowing their child to ride in an AV unaccompanied. We hypothesize that children being able to drive without their parents could take a considerable amount of responsibility off women who are the ones that usually take their kids from A to B.

Although women typically are not early adopters of ride-hailing solutions [165], their willingness to engage in sustainable mobility modes is researched and they are more open toward the shared version of AVs [166] emphasizing more on environmental protection and saving fuel consumption than men. A study in Chicago revealed Uberpool being considerably faster than public transporta-

tion for short trips around the neighbourhood [167]— the trips mainly women undertake. Hence, SAVs might be perfect especially for women— of course assuming their specific preferences and needs being considered during the design process. This underscores the significance of addressing women’s perceived security within shared automated mobility. Studies by [168] indicate that appropriately addressing anxiety-related effects can dismantle barriers, accentuating the need to focus on women’s security concerns to bolster their acceptance of these technologies. Thus, it is crucial to consider the security requisites of diverse groups to fully unlock the potential of SAVs and guarantee inclusivity in forthcoming mobility solutions, which is what this work is aiming for.

2.2.4 Interface Design for Shared Automated Mobility

Since in SAE level 5 drivers are not needed anymore, passengers will solely interact with the AVs and some sort of booking systems. Two considerations have to be addressed when developing such systems. First, passengers need to rely on digital user interfaces (UIs) that provide them with trustful information in real-time, as well as with efficient controls for their travel needs. Second, in SAVs, passengers will share rides with strangers during both day and night times. Since there is no human authority (e.g., a bus driver) present anymore in AVs, users’ acceptance is likely to be influenced by the presence of co-passengers [124]. Information about fellow travelers prior to and during the ride seems to have the potential to affect user acceptance positively [169]. Two main areas can be identified in analyzing user needs for automated shuttle buses. Firstly, the interior area, including the entire design inside the shuttle bus, the tasks of the (human) operator, and the user’s needs during the ride from the passengers’ point of view. Secondly, the exterior of the automated shuttle bus includes the design and the information visualization in the exterior, the communication with other road users, and the user needs of the passengers before and after the ride (e.g., the bus stops). The interior design primarily focuses on the needs, misunderstandings, safety, and acceptance of the passengers, while the exterior design focus lies on on other road users who interact and communicate with the automated shuttle bus in road traffic. There may also be overlaps between the two areas; for example, certain forms of information visualization in the entrance and exit areas may provide a smooth transition between the interior and exterior spaces. Accordingly, research in both areas is necessary for a successful feeling of acceptance and a positive societal experience regarding innovative technology. While exterior design considerations are crucial for interaction with other road users, our decision to prioritize interior design reflects our commitment to ensuring the perceived security and user experience of passengers who directly interact with the technology. By focusing on interior design, we aim to contribute to a more comprehensive understanding of

perceptions within the vehicle, thereby facilitating the successful adoption and integration of innovative technology into society.

SAV UIs can range, e.g., from passenger information displays in vehicles and planning and booking applications on mobile devices to terminals at mobility hubs. They will provide the sole basis for the communication of passengers and the intelligent systems as no human operators (e.g., drivers) will be involved anymore. In terms of interaction modalities, already familiar technologies like touchscreens, information displays and control buttons seem to be preferred by potential SAV users [170]. The preference for established modalities, such as visual and auditory, and interior locations, such as the front area, is reflected by the systematic literature review on the in-vehicle design space by Jansen et al. [171]. They provide a comprehensive overview of input and output modalities and information locations and highlight the relevance of multi-modal in-vehicle interactions.

In our work, our primary focus centers on designing UIs that aptly address the acceptance needs of passengers while instilling a sense of perceived security. With the transition to AVs eliminating the necessity for drivers, passengers' interactions will primarily involve these intelligent systems and the vehicles themselves. Our emphasis lies in ensuring these digital UIs deliver reliable real-time information and offer efficient controls for passengers' travel requirements and we aim to create user-centric interfaces that prioritize both acceptance and a sense of security in the realm of shared automated mobility.

2.3 User Diversity for Shared Automated Vehicles

Mobility is simply moving from A to B. At the same time it is commonly associated with freedom and progress, and it can be measured and mapped to improve transportation technologies. However, the experience of mobility differs for each individual, influenced by factors such as ethnicity, social class, age, destination, purpose, timing, and subjective perception [172].

In this work, we aim to explore the intricate interplay of gender, age, and cultural background within the realm of SAVs as a form of public transportation and perceived security. Acknowledging the multifaceted nature of underrepresentation as described in Chapter 1.3, we extend our focus beyond singular aspects like gender alone and use intersectionality as a blueprint for recognizing the intricate web of societal dynamics that individuals navigate based on their diverse social identities [68]. However, it is important to recognize that while we aim to address these specific dimensions, we have to limit our research to

handle complexity and, thus, are not able to encompass all influencing factors. By taking a deep look on gender, age, and cultural background, we aim to unravel individuals' experiences and needs in SAVs and derive HMI solutions to meet these needs.

2.3.1 Gender and Age

The potential advantages of SAVs, particularly for demographic groups such as women, the elderly, and individuals with constrained mobility resources, have already been outlined in 2.2.3. Given the demographic shift towards an aging society, with women constituting the majority of the aging population [159], serious consideration of women in automotive research and development sphere is imperative.

Related to that it is important to mention that several efforts have been made to design systems and products especially for women not always leading to the desired effects [62, 173]. For instance, the 1955 Dodge La Femme was an iconic and unconventional car, specifically marketed towards women [174]. It was an attempt by the automotive industry to appeal to women as buyers by offering unique design elements and accessories—allegedly—tailored to women's tastes and needs. This vehicle was painted in a two-tone pink and white exterior, featuring pink and white vinyl upholstery with rosebud-patterned inserts [175]. To further cater to its target audience, the car came with a range of accessories including a matching umbrella, raincoat, and even a pink purse fitted into a compartment on the back of the front seats promoted in the respective advertisement (Figure 2.1). Despite the innovative concept and initial enthusiasm, the La Femme did not resonate well with the target audience and was discontinued after only two model years [175]. The La Femme's sales flop suggests that women's automotive preferences extended beyond color and accessories, revealing that Dodge had missed addressing more substantive needs and desires in their marketing approach.

The Pink Taxis in Cairo aimed to provide a more secure transportation option for women in a predominantly male-dominated public transport system [176]. However, the endeavor faced several challenges leading to its eventual failure [177]. Despite the effort to create a secure space for female passengers, the service struggled due to limited availability, societal stigmas, and insufficient infrastructure to sustain its operations [177]. Additionally, cultural norms and economic constraints hindered its widespread acceptance, resulting in the Pink Taxi project facing considerable obstacles and ultimately not meeting the intended demand or impact initially envisioned. Both the Dodge La Femme and the Pink Taxi initiative in Cairo underscored a common oversight: the failure to adequately address the genuine and diverse needs of women in transportation,



Figure 2.1: 1955 Dodge 'La Femme': advertisement (top), interior with purse and pink and white upholstery [174].

emphasizing that understanding these needs transcends simplistic marketing strategies or color choices.

While some work in the automotive community has explored the inclusion of elderly individuals within the research context [178], such efforts remain exceptional. Notably, research centered on AVs and accounting for gender primarily emanates from the social sciences [53, 158, 179] rather than computer science. We aim to close this research gap and place particular emphasis on gender and age as focal points in our research activities.

2.3.2 Culture Set in Focus: Colombia, Germany, and South Korea

In the scope of this doctoral thesis, we prioritize the inclusion of diverse cultures to steer clear of a Western-centric perspective, aiming to minimize biases. The selection of specific cultures is a result of various considerations and factors. Primarily, our aim was as to ensure a diverse representation of perspectives by intentionally choosing cultures that offered a broad range of viewpoints. We employed Hofstede's cultural dimensions framework to identify cultures that exhibit significant differences. Second, our selection was guided by the varying security levels present within the public transportation systems of the chosen cultures as experiences in public transportation are most likely to influence people's attitudes towards SAVs as a form of public transportation. Additionally, we factored in the degree of representation in the research of automated vehicles, recognizing the disparities between these cultures and the prevalent research landscape, particularly in contrast to the German and broader European context, from which our institutional background stems.

Hofstede's Cultural Dimensions

There are different approaches to define the term culture [180, 181]. In general culture represents common values of a group [182]. It is a system of beliefs, attitudes and values that are reflected in behavior. These values distinguish one group of people from others [180]. Values, expectations, behavior, perceptions, communication, interaction, and cognitive processing patterns of a person are influenced by their culture [180, 183, 184]. One of the most cited and used framework in the field of cross-cultural research are Hofstede's cultural dimensions, which is based on extensive empirical research [181, 182, 185]. To describe culture, Hofstede uses the analogy software of the mind [185] that is programmed and distinguishes one group of people from another. It influences the way we think, behave, and feel. While these patterns are learned in early childhood and overwriting these programs is more difficult than its initial learning, it is also our life experiences that influence culture and our "mental programs" are adapted throughout life [185].

Based on his empirical research, Hofstede has developed six cultural dimensions and his model is widely used to describe the preferences and behavior of people of a certain culture [186]. In the following list we paraphrase Hofstede's cultural dimensions [187]:

- **Power Distance:** Power distance describes the acceptance of the distribution of power within a culture. Cultures with high power distance accept strong hierarchies - within organizations, leaders make decisions. These decisions are not contradicted. Cultures with a low power distance are characterized by flat hierarchies; people tend to meet at eye level. Asian cultures, such as South Korea, Japan, and China have high power distances, as well as Latin American countries. Simultaneously, these countries tend to be more collectivist valuing harmonious togetherness. In contrast to this, most Germanic countries show lower power distances and are inclined towards being more individualistic.
- **Individualism versus collectivism:** Describes the strength of relationships between people in a culture. In individualistic cultures, the bond is comparatively loose—the individual is the focus here. In contrast, collectivist cultures prioritize the collective over the individual, emphasizing loyalty, care, and harmony. South Korea exemplifies this with its tight social structure, where loyalty is highly valued, and individuals can rely on fellow group members, such as relatives, for support. Similarly, Colombians, known for their collectivist tendencies, prioritize belonging to a close-knit group and aligning with its views. On the other hand, Germany stands out as an individualistic society, characterized by a more relaxed social structure. Here, self-realization is highly esteemed, and people are primarily responsible for themselves and their immediate families.
- **Masculinity versus femininity:** Describes the extent to which a culture accepts the division of classic gender roles. In masculine cultures, the roles are clearly distributed, whereas in feminine cultures, the roles can be easily switched. In addition, masculine cultures are characterized by status, power and prestige, while feminine cultures are characterized by caring and empathy. South Korea is characterized as feminine, prioritizing values such as equality, cooperation, modesty, solidarity, and quality of life. Germany and Colombia are considered masculine societies as they are highly competitive and success oriented.
- **Uncertainty avoidance:** Describes the extent to which a society is willing to take risks and embrace renewal and innovation. Cultures with a high level of uncertainty avoidance prefer to rely on tried-and-tested patterns; they try to reduce uncertainties to a minimum through rules and specifications. All three countries, Colombia, Germany, and South Korea are among the uncertainty avoidant countries.

- **Long term orientation versus short-term orientation:** Describes whether a culture tends to plan and think in the long term or whether it is characterized more by spontaneity and short-term thinking and action. Both Korea and Germany are long-term oriented countries with a high focus on the future. In contrast, Colombia has a low long-term orientation score with a great respect for traditions. They have a small propensity to save for the future and concentrate on achieving quick results instead.
- **Indulgence versus restraint:** Describes how much a culture accepts the self-realization of each person. Thus, in a culture with a high value, marginalized groups or people who do not conform to ‘the average’ are also accepted as freedom is considered an important value. In cultures with a low value, this is not the case. Instead, strict regulations apply. Both Koreans and Germans exhibit restrained tendencies, governed by strict social norms that regulate the gratification of desires. There is a prevailing sense of pessimism and a belief that indulgence is somewhat inappropriate. In contrast, Colombians display a high level of indulgence, characterized by a positive outlook and a tendency toward optimism.

Cultural differences directly influence communication behavior, information processing, interaction, and dialog design [188]. Therefore, it is crucial understanding them when designing in cross-cultural contexts. Previous research in the context of automation shows that power distance and the acceptance of automation are positively related to each other. Automation is considered similarly to authorities by people from high power distance countries and therefore their purpose is less questioned [189]. Pilots with low power distances are more condemned towards flight deck automation than pilots with high power distances and this effect is even intensified in connection with uncertainty avoidance [190]. Furthermore, enthusiasm for automation has been found to be larger across nations than across airlines, underlining once more the role that culture plays in the context of automatization, making it highly relevant for this work.

Perceived Security in Public Transportation in Colombia, Germany, and South Korea

Despite Hofstede’s framework, the comparative analysis of cultures was informed by the diverse security measures and perceptions within their respective public transportation infrastructures. We aimed to scrutinize and juxtapose these security paradigms against the evolving landscape of automated vehicle research. Furthermore, given our affiliation with a German/European institution, the comparative analysis bore particular relevance, enabling an exploration of the distinctive cultural nuances, both in terms of security perceptions

and the representation within the research of automated vehicles, in contrast to the context with which we are more familiar. This selection aimed to illuminate unique perspectives and potential solutions from disparate cultural contexts, enriching the depth and breadth of this doctoral thesis.

In Colombia and South Korea, the levels of security within their respective public transportation systems stand in stark contrast. Colombia faces notable challenges with security in its public transportation, grappling with prevalent issues such as gender-based violence, harassment, and heightened crime rates [142, 35, 191]. During the last decades, the level of urbanization in Latin America increased from 25% to 61.2% [192]. Currently, Latin America and the Caribbean region hold the top position in the world in terms of urbanization, with 80% of the populace residing in cities according to UN Habitat's report in 2012 [193]. Research on mobility, access, and social inequality in Latin America [194, 195] discloses that the mobility systems reinforce inequality, and, if opportunities for travel were fair and accessible, urban mobility could reduce the effects of inequality in other aspects of urban life [196].

Colombia was among one of the first two countries to protect the right to the city through national laws since 2014 (law no. 388/1997). Still, the transport sector in developing countries is problematic, with people's mobility depending mainly on public transport. However, many times the supply of public transportation is insufficient to meet the demand with a poor service quality and high levels of personal insecurity [35]. This pushes people to use private motorized modes instead which, in turn, results in higher levels of traffic, air pollution and energy consumption [35]. Public transportation users in Latin America face various mobility challenges with personal safety and gender-based violence being the most important ones [35, 142, 191]. Several studies underline that public transportation users in Latin America feel unsafe while using transit services [191], where sexual harassment, pick-pocketing, and aggressive behavior in overcrowded buses, and gender-based violence is a growing problem for both users and operators. Daily mobility experiences can lead to social isolation and particularly women's fear and their travel to and from employment shows that self-imposed measures limit women's mobility and contribute to their under representation in certain settings [197].

In contrast, South Korea's public transportation system stands out for its high perceived sense of security within the cultural context, representing a notably different scenario characterized by elevated perceptions of safety and security among commuters [198]. Notably, in 2004, the Korean government initiated the u-City project, aiming to employ specialized sensors and networking technologies to deliver intelligent applications across healthcare, transportation, education, and water management [199]. The u-City vision centered on inter-connecting various facets of urban life— offices, residences, schools, medical facilities, social infrastructure, and the environment— through communication

networks. This initiative aimed to harness essential data for crafting innovative applications that enhance daily living experiences. South Korea's lower crime rates have contributed to this perceived security within its transportation system and the country counts among the 20 safest countries for women traveling on their own [200]. Hence, our choice to include these diverse countries into our research was purposeful: South Korea embodies a context where public transportation is widely perceived as secure [200], Germany stands as a model with strong security protocols but a visible disparity between real and perceived safety [138], and Colombia acts as a representation of areas grappling with (perceived) insecurity within their public transportation networks [142].

As the primary platform for automotive user interface research and other vehicular technologies, the ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI) attracts professionals, academics, researchers, and industry representatives worldwide who are passionate about innovation, research, and application in automotive user interface topics. However, an analysis of the conference's main program over the past five years reveals that over 87% of all full papers originated from only five countries, primarily focusing on Germany and the USA [201]. Recognizing our desire to contribute to the conference's research community while also diversifying its representation, South Korea and Colombia emerged as important and promising candidates for inclusion.

2.4 Human-Centered Design and Feminist HCI

To comply with the user-centric landscape of this thesis we apply the human-centered design (HCD) approach. While valuable, HCD may not alone suffice in mitigating biases present in technological development. To comprehensively address these biases, we require the critical lens of Feminist HCI. Through this lens, we can delve deeper into understanding and rectifying inherent biases, paving the way for a more inclusive and equitable technological landscape. Taken together, these methodologies are straightforward tools to transcend biases which aligns closely with our motivation and set the foundation for the subsequent detailed explanations in the following sections.

2.4.1 Human-Centered Design

Human-centered design (HCD) [29] is a systematic approach to developing interactive systems that centers on users, their needs, and requirements, integrating human factors/ergonomics and usability knowledge to ensure systems

are not just usable but also beneficial. The process involves iterative cycles of analysis, design, and evaluation to ensure that the resulting system supports user tasks and goals while providing a positive user experience. It aims to bolster effectiveness, efficiency, and user satisfaction, while countering potential adverse impacts on human well-being, safety, and performance [29].

The HCD integrates principles from cognitive psychology, ergonomics, and HCI to create user interfaces that are intuitive, efficient, and satisfying to use. The process is outlined in ISO 9241-210 [29] and revolves around four iterative design activities following an initial planning phase:

- Understanding and specifying the context of use: This involves conducting thorough research to identify and understand the needs, preferences, and requirements of the system's intended users. Methods such as user interviews, surveys, and task analysis are commonly used to gather relevant data.
- Specifying user requirements: Once the context of use has been understood, designers specify the user requirements for the system. This involves translating the insights gained from the research into concrete requirements that the system must meet to effectively support users' tasks and goals.
- Producing design solutions: With user requirements in hand, designers generate design solutions that address the identified needs and requirements of the users. This stage involves brainstorming, sketching, prototyping, and iterating on design ideas to create solutions that effectively meet user needs and goals. Design solutions may range from low-fidelity concepts to high-fidelity prototypes, depending on the stage of the design process.
- Evaluating the design solutions: Once design solutions have been developed, designers evaluate them to assess the effectiveness, efficiency, and user satisfaction for the intended users. This stage may involve usability testing, expert evaluations, and user feedback sessions to identify strengths, weaknesses, and areas for improvement in the designs.

The design process is iterative, with multiple cycles of design, evaluation, and refinement [29]. This iterative approach allows designers to incrementally improve the system based on user feedback, leading to a final product that effectively meets user needs and goals. Typical methods used during the HCD process are user interviews, surveys, contextual inquiries, persona development, storyboarding, prototyping, and usability testing [69]. These are drawn from various disciplines, including HCI, psychology, social sciences, and design, and have been adapted and refined over time to suit the specific needs of HCD

[202]. The combination of qualitative and quantitative methods enables triangulation, where findings from different methods are compared and validated against each other. Researchers gain holistic insights into user needs, behaviors, and experiences on the one hand, and enhances the reliability, validity, and applicability of research findings, on the other hand.

HCD places the user at the core of the development process and emphasizes the importance of involving users from the early stages and consistently checking how a design aligns with their needs. Given the importance of user acceptance, the current security issues and unmet needs highlighted throughout the discussions in Chapter 2.2, HCD emerges as a particularly straightforward approach for this thesis. Its focus on understanding users, their requirements, and iteratively improving designs to meet their expectations resonates well with the challenges presented, making it a valuable framework for addressing the multifaceted dynamics of perceived security and unmet needs in public transportation and SAVs.

2.4.2 Feminist HCI

As established in the introductory Chapter 1.3 and in Chapter 2.3, the technologies in general tend to favor a specific demographic group— typically, White, heterosexual, tech-savvy, and well-educated men [52, 57]. This bias stands in contrast to our aim of including a diverse range of individuals and their requirements within the shared automated mobility system, leading us to explore which methodologies, frameworks, and approaches offer suitability, and what epistemological approach beyond HCD we could apply to challenge these prevailing biases. As a supplement for the HCD process we explored feminism.

In the field of HCI, Shaowen Bardzell [74] proposes the Feminist HCI framework as an approach to confront the existing data bias/research. The framework is inspired by feminist standpoint theory which allows new approaches of user research by proposing to start from the discriminated, unprivileged, and less-favored groups. Standpoint theory is the idea that people see the world differently based on where they come from and what their life experiences are [74]. This means that women might have a different perspective on things than men, and that people who have less power might see things differently than people who have more power. The radical and standpoint perspectives emphasize the importance of considering values that are traditionally associated with women, particularly with regard to the objectives and priorities supported by technologies, and the hidden norms that shape both individuals and society. Standpoint theory asserts that women and men are fundamentally different and that “femininities” need to be revalued, with systems and cultures adapting to female requirements [31]. This theory emphasizes the importance of valuing

women's experiences and suggests that all attempts to acquire knowledge are influenced by the social context in which they occur [75]. It posits that the perspective from the lives of less powerful individuals can provide a more objective view than the perspective from the lives of more powerful individuals, and that inquiry should start from the lives of women and others who are marginalized [75]. It further argues that all standpoints are partial, and that a person can have many standpoints at a time, shaped by the social groups to which they belong. The use of standpoint-epistemology acknowledges that personal life-experiences are a source of knowledge-production, and recognizes that the life-experiences of the protagonists in a field of study contribute to the systematized knowledge [75].

In the mid-1980s, Science and Technology Studies (STS) emerged, incorporating technology as a subject and concept within science studies programs [203, 204, 205]. STS aims to reveal and record the reciprocal influence of social, political, and cultural factors on scientific research, technological innovation, and design [206]. Within this framework, gender has become a significant aspect of what is commonly known as the social shaping/construction of technology [205]. Bardzell [74] uses STS to emphasize how technologies shape society and vice versa. Thereby, the gender plays an indispensable role as “ideas about women and men shape science and technology, evident in the decades-long practice of more men than women studying computer science, designing, implementing, administering network infrastructure, purchasing and using Internet and digital devices” [74, p. 3]. While she acknowledges that HCI partly is already inspired by feminism, she points out how women's underrepresentation in these fields led to a so-called digital divide and, once more, emphasizes to take gender into account during research, design, and evaluation of interactive systems. With her framework she proposes feminist theories to inspire and guide the field of HCI in its theories, methodologies, user research, and evaluation [74]. For this purpose she introduces five qualities—that will be described in detail in the following paragraphs—to build feminist interaction design principles. While acknowledging that these qualities are 1) not necessarily unique to feminist theories, and 2) these are already to be found especially in the third wave HCI [71], which broadens its focus to diverse interactions, varied technology contexts, and includes user experience, emotions, and reflexivity, shaping a multifaceted research field with diverse methodological perspectives, it is their *constellation* [74] that is particularly peculiar to feminist interaction. In the following list we paraphrase Bardzell's set of qualities [74]:

- **Pluralism:** Pluralism, as argued in the framework, requires including a variety of viewpoints into research because “human” as in human-centered design is too diverse too “complex and diverse to bear a universal solution” [74, p. 5]. It places pluralism above universalism, which attempts to find one solution that fits everyone and this is not possible given the vastness of human experience. Pluralist design is about encouraging a different

sensibility to design, one that focuses on cultural differences (2.3.2) and encourages a constructive engagement with diversity. Furthermore, it embraces the ones that are usually left out in research and development of technological solutions for two reasons: 1) to be more inclusive and 2) to benefit from them and their viewpoints to stimulate new design solutions. Bardzell criticizes that Western standpoints are considered as the norm in technology advancements and even cross-cultural design do not take into consideration the different experiences and outlooks of people from different cultures. This leads to imposing Western norms and practices without justification which in turn infringes the standards of feminism and science, because these are not based on scientifically sound justifications for themselves.

- **Participation:** Participation refers to valuing participatory processes that lead to the creation and evaluation of design prototypes [74] which in turn stimulates pluralism. Participatory design (PD) methods are rooted in Scandinavia in the late 1960's and early 1970's [207, 208] and involve different stakeholders into the design process in an inclusive and collaborative way. It applies methods that oppose traditional research methods, such as co-creation workshops, prototyping sessions, democratic dialogues, and even games [209]. Especially Scandinavian participatory design approaches seem straightforward for including and fostering feminist values in research as they 1) are deeply committed to democracy, 2) aim to foster discussions of values and design and imagined futures (which is particularly interesting for our research project, as it confronts with high levels of automation), and 3) regards conflict and contradictions as stimuli for design and development [210]. Their peculiarity does not lie in the specific methods but rather in the mentioned commitments. In field of HCI research, PD methods are widely used [211] and are recently promoted in research and development in the transportation area to include underrepresented user groups, such as women [159]. In automated driving research PD methods are also used [212, 213, 214]. In her manifesto, Bardzell [74] promotes to overcome the distance between researcher and participant- other than in traditional, controlled experimental and laboratory settings where a distance between them is not only maintained but even required. She grounds this standpoint on the epistemological position that *knowers are not substitutable for one another* [74] and proposes empathic user research to *avoid the scientific distance that cuts the bonds of humanity between researcher and subject, pre-empting a major resource for design (empathy, love, care)* [74, 215]. Thereby, she does not aim to replace traditional usability studies but rather supplement them in order to gain insights that would not have been achieved otherwise. Methodologically, we ground our research on this urge by combining classical experiments and quantitative methods with qualitative, exploratory, and

co-creative techniques through the lense of feminist epistemologies and with the claim of including as diverse groups of participants as possible.

- **Advocacy:** Advocacy ensures feminist designs to not only promote political emancipation but additionally challenges researchers to verify their own viewpoints by taking ethics into account and question how to achieve an improved society [74] without imposing their own biases. Here, again it becomes clear how the proposed qualities relate to each other and do not exist in isolation as own standpoints, e.g. taking the Western perspectives in technological standards and uses for granted, has been already addressed in the description of pluralism. As reseachers we are widely influenced by our own Western European, privileged, well-educated, and White background and context. Thus, the quality of advocacy has been particularly challenging and at the same time rewarding as in our every-day work we had to always reflect upon our own stereotypes, and norms. In our work we furthermore consider advocacy as giving our participants the opportunity to speak for themselves and to be part of the design and development process.
- **Self-Disclosure:** The extent to which software renders visible the ways it affects us as subjects is what Bardzell defines as the quality of self-disclosure [74]. This quality calls users' attention to what the software is trying to make of them. It both creates a space between users and interactions and also provides chances for users to explain themselves to the software. Furthermore, it requires the researcher to self-disclose themselves so their work and results can be seen in the context in which they have been produced.
- **Embodiment:** In the context of HCI, embodiment refers to a shift in focus from the interface or designer towards users' physical bodies, motivations, and primal instincts [74]. This involves exploring how users, both women and men, experience and engage with technology in varied contexts such as emotion, fun, spirituality, food, sexuality, embodied interactions, and whole-body interactions. It emphasizes understanding the diverse ways individuals interact with technology through their physical experiences and behaviors, considering the nuanced perspectives and experiences of different genders. Bardzell's Feminist HCI [74] theory urges to take embodiment into account during the design process. Hereby, the development on the quality of embodiment, needs to push embodiment in the direction of gender commonalities and differences, gender identity, human sexuality, pleasure and desire, and emotion [74]. As Bardzell argues much has been done recently to overcome the purely disembodied view on the user. Through embodied awareness activities, the participants included in this PhD project should become a secure space to express their

experiences, give them a voice and explore possible concepts to enhance perceived security and empower individuals when moving with SAVs.

- **Ecology:** Ecology supports a more holistic viewpoint considering how a technology also shapes the environment in which it is used. Bardzell sees a rising interest in the concept of ecology from the standpoint of systems theory and in the environmental sense with the increase of sustainable interaction design. She argues that, however, these ecological perspectives need to take into consideration gender, race, social status, and other characteristics of potential discrimination, such as cultural background (e.g. by including developing countries, Section 2.3.2).

The framework aims to contribute on two levels: 1) critique-based contributions to analyze design processes in order to bring negative consequences to light, and 2) generative contributions that apply feminist approaches in decision-making and design processes [74]. These contributions support the analysis of user needs and requirements and open up design opportunities. The manifest has recently been widely discussed [77, 216] and Chivukula's and Gray's [76] literature review on papers citing the manifest revealed that the papers mostly pointed to her framework while not applying it extensively or explicitly. In our work, we aim to close the gap by addressing the two contributions of Feminist HCI mentioned in the previous paragraph and to comply with Bardzell's manifest that rejects universal designs. In summary, our research has been guided by Feminist HCI as an overarching principle. Each study has been carefully designed to incorporate diverse perspectives, including participants from various age groups, balanced gender samples, etc. Moreover, we have adhered to the HCD process, ensuring iterative refinement and evaluation of solutions. Figure X provides an overview of the studies and chapters, indicating their alignment with different phases of the HCD process, thus illustrating the integration of theoretical foundations with practical research methodologies.

2.5 Research Questions

As computer scientists, we find ourselves at the forefront of innovation, tasked with developing cutting-edge technologies that have the power to shape the future of society. With great power comes great responsibility, and it is incumbent upon us to carefully consider the potential outcomes of our work.

In this role, we serve as architects of the future, with the ability to either pave the way for utopias or dystopias.

The rapid advancement of technology, particularly in the fields of AVs and HCI,

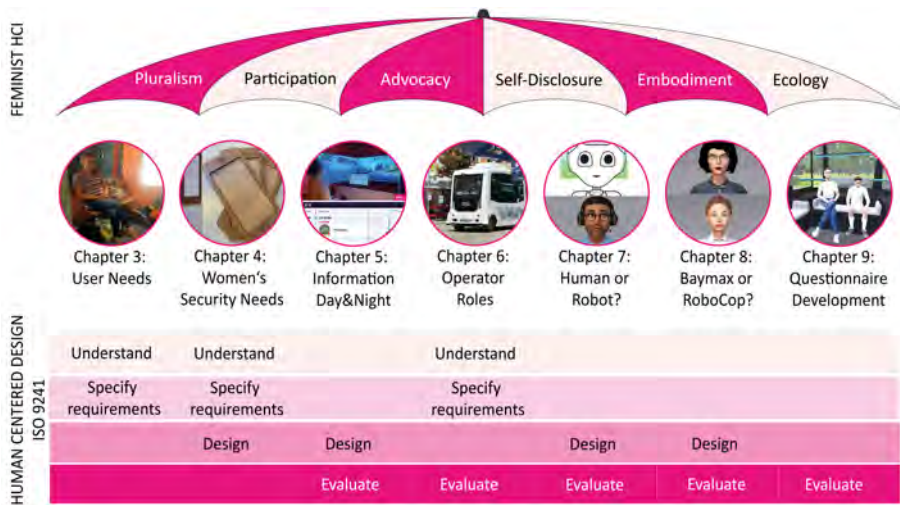


Figure 2.2: Integration of Feminist HCI Principles and Human-Centered Design Stages Across Research Studies.

where this thesis is situated in, has ushered in a new era of possibilities and challenges. As we set off for this transformative journey, we must remain vigilant in our pursuit of technologies that genuinely contribute to the betterment of society. It is not enough for our creations to be innovative; they must also be beneficial, ethical, and equitable.

By placing a strong focus on users and incorporating the Feminist HCI approach [74], it embraces a holistic perspective on technology and its societal impact. The thesis recognizes that technology does not exist in isolation but is intricately entwined with the human experience [62]. Therefore, understanding and addressing the unique needs, concerns, and aspirations of users is essential in shaping technology that aligns with the aspirations of a better society.

As we navigate the development of AVs and related technologies, we must remain vigilant in identifying and mitigating biases that can perpetuate inequities. We contend that the scientific community shares the responsibility of working toward a sustainable future. The most promising outcomes are likely to be achieved when shared mobility and reduced private vehicle ownership dominate the future reality [19, 86]. Thus, this thesis places particular emphasis on SAVs, recognizing that their promise of shared mobility holds the potential to be more beneficial for society and the environment. By doing so, we not only fulfill our duty as creators but also leave a lasting legacy of progress, equity, and social betterment. Achieving this requires critical decisions on various levels, including legislation and scientific project funding. Consumers, however, play a pivotal role in determining which mobility concept—the private or

the shared— gains prominence. Therefore, it is essential to thoroughly identify their concerns and requirements, including those from underrepresented groups such as women, senior citizens, people from the Global South, and other groups [52, 53, 158]. The range of individuals overlooked in technology development is extensive, encompassing various groups beyond our thesis’s scope to comprehensively address. Hence, we concentrate our attention on the intersections of specific facets: age, gender, and cultural background. While acknowledging the broader spectrum of marginalized groups, we prioritize these aspects within the context of our research to offer more in-depth insights and analysis. This process centers on the needs and experiences of users, forming the core of our methodology. As a starting point for this thesis we derived the first two research questions:

RQ1. How do the needs and preferences of individuals representing diverse gender, age, and cultural profiles influence the requirements of shared automated vehicles, and how can these vehicles be tailored and adapted to ensure broader acceptance?

In order for AVs to fulfill their potential in both private and public transportation, they must confront a range of technical and psychological challenges [28, 123, 217]. The extent of their adoption and success hinges significantly on the acceptance of this technology by future users. These challenges, which have the potential to impede their acceptance (2.2.1), must be effectively addressed, beginning in the early stages of new system development. For the creation of the aforementioned utopia, it is necessary that people switch from private transportation modes to shared mobility [19, 50], as it offers a more sustainable, efficient, and environmentally friendly alternative to private vehicle ownership. Given that the presence of a human driver will no longer be necessary within AVs, future users will engage exclusively with AI systems through digital interfaces. Therefore, the nature of interaction and communication between humans and AVs, and the related user experience (UX), stand as pivotal determinants of the technology’s success.

Consequently, we derived the second research question for this dissertation:

RQ2. How can Human-Machine Interfaces (HMIs) be optimized and designed within shared automated vehicles to effectively increase users’ perceived security, fostering greater trust and acceptance of this technology among diverse user groups?

2.6 Summary

This chapter provided the theoretical and methodological basis for the works conducted within this doctoral research. Beginning with an exploration of the potentials and perceptions of SAVs, we then delved into the factors influencing user adoption, including acceptance challenges, psychological needs, and perceived security in public transportation. Moreover, we discussed the importance of considering diverse user groups, with a particular focus on gender, age, and cultural background, in AV research. Building upon this foundation, we introduced the human-centered design (HCD) process and the Feminist HCI framework as theoretical frameworks guiding our research. Furthermore, we presented the research questions that emerged from the identified research gaps. As a synthesis of this chapter, we have laid the groundwork for the subsequent empirical research detailed in Chapters 3 to 9, which will further explore the intricacies of user experiences and perceptions in the context of SAVs.

Given the thesis's objective to develop, prototype, and evaluate HMI concepts that effectively address acceptance barriers and challenges, the chapter introduced the HCD process. This approach prioritizes placing the user at the core of the design process, involving them at every stage. However, recognizing the importance of incorporating diverse user groups, the chapter concludes by introducing the Feminist HCI approach as a complementary framework to enhance the HCD process. With this, we have the tools to address the motivation of this thesis and to answer our research questions.

3 Private or Shared? Comparing Hypothetical Implementation Scenarios of Automated Vehicles

In the dynamic realm of transportation, where shared automated vehicles (SAVs) are expected to reshape the way we move [50], the imperative of involving users from the early stages of development cannot be overstated. Unlike traditional transportation projects, where top-down decision-making prevails [218, 219], the development of SAVs demands a more user-centric approach. These innovative vehicles hold the promise of enhancing mobility, reducing congestion, and mitigating environmental impacts, but realizing these benefits hinges on a fundamental shift in how we approach their development.

Historically, stakeholder participation has been championed as the ideal approach in spatial planning theory since the 1980s [210, 220]. Yet, in practice, decision-making processes often fall short of inclusivity [30]. Planning major mobility projects is an intricate, contentious, and time-consuming endeavor, marked by a multitude of stakeholder interests and power dynamics [219].

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- [1] **M. Schuß**, P. Wintersberger, and A. Riener, "Let's share a ride into the future: A qualitative study comparing hypothetical implementation scenarios of automated vehicles," in Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, ser. CHI'21. New York, NY, USA: Association for Computing Machinery, 2021. <https://doi.org/10.1145/3411764.3445609>
 - [2] **M. Schuß**, P. Wintersberger, and A. Riener. Security issues in shared automated mobility systems: A Feminist HCI Perspective. Multimodal Technologies and Interaction. 2021. <https://www.mdpi.com/2414-4088/5/8/43>
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3 Private or Shared? Comparing Hypothetical Implementation Scenarios of Automated Vehicles

This is where the importance of early user involvement in SAV development becomes evident. To understand the significance of incorporating user perspectives from the outset of SAV development, we can draw parallels with an analysis of stakeholder participation in the planning of mobility solutions. In this context, decision-making processes have been marred by democratic deficits stemming from unfavorable institutional arrangements, legislative constraints, and a mere semblance of inclusivity [218]. The transparency and accessibility of these processes remain contingent upon the preferences of primary decision-makers, typically concentrated within national institutions. Furthermore, these cases exhibit legitimacy gaps and susceptibility to powerful stakeholder influence, highlighting the pervasive impact of power dynamics [218].

In essence, the lessons learned from examining (transportation) user participation in mobility planning underscore the critical need for early user involvement in SAV development and at the same time resonate with the feminist approach used for this work [30, 77, 221]. The success of SAVs in revolutionizing transportation hinges on embracing user input and preferences, as it not only enhances the efficiency of decision-making processes but also ensures the acceptance and integration of these transformative technologies into our daily lives.

In this chapter, we engage with users right from the beginning of SAV development. Acknowledging the paramount importance of integrating their perspectives early into the design process, we aimed to learn their needs and concerns of users as future passengers. The future cannot be predicted for certain and at the moment highly and fully AVs are not expected on public roads in the near future. Therefore, and due to the hypothetical character that mobility implementations of AVs currently have, the framework of acceptance [110], which is defined as the attitude, behaviour and reaction towards an interactive system after having experienced it, is too early when comparing future implementation scenarios of AVs. Instead, and as a first step, we opted to explore the acceptability, which refers to the anticipated attitude that users have before having interacted with a product [109, 110].

For this, we conducted a series of workshops, user enactments, and in-depth interviews, gaining invaluable insights into the expectations, preferences, and concerns of SAV users. This comprehensive approach ensures that the SAVs we design are not merely innovations of technology but empathetic companions that resonate with the diverse lifestyles and requirements of our users.

The technology of AVs would allow several implementation scenarios, such as private vehicles (PAVs) with or without driving controls (steering wheel/pedals, etc.), but also forms of shared mobility, either in a private setting or as part of public transportation systems [86]. Although these variants will exist in the

future side-by-side, one form of mobility will likely dominate – just as private, gas-powered vehicles dominate the markets today.

How transportation systems in the future will look like depends on various aspects (consumer demand, political/societal situation, economy, etc.), but there will be winners and losers in this transformation process. Relevant stakeholders include human users from diverse target groups, companies involved in the transportation sector, but ultimately also the environment itself. Recent studies suggest that the implementation of AVs will not necessarily change humans' mobility behavior and ownership models, and that a major risk of the technology is ultimately threatening public transportation rather than private vehicles [222], and the result may even increase the issues associated with reliance on cars, highlighting its environmental, health, and social drawbacks [19].

We argue that it is also the responsibility of the scientific community to strive towards a livable future and, without doubts, the potentially most positive effects can be achieved when shared mobility and low private vehicle ownership will dominate future reality [19, 86]. Although this involves important decisions on different levels, including legislation, scientific project funding, etc.; consumers play an important role as those will finally favor the one or other mobility concept. Thus, it is important to identify their doubts and requirements in detail, thereby including target groups that have not been considered in the past to the necessary extent, such as women and minorities like migrants [52, 53, 158]. In this work we compared potential future implementation scenarios of automated vehicles in a user study, which combined qualitative methods (interviews, enactment, UX cards) to identify relevant requirements to make shared automated vehicles (SAVs) successful. We included migrants in our sample to address the need of a pluralistic viewpoint, rather than hypothesizing about potential differences. Consequently, we pose the following research question:

RQ3.1. Which future automated vehicle scenarios are preferred by potential users, and what are the underlying reasons for their decision?

To investigate this research question we conducted a qualitative user study involving a diverse group of participants, ensuring gender balance and including three migrants. We asked them to envision their ideal mode of transportation for a future 20 years or more from now, assuming that automated driving technology has become completely reliable. To facilitate this, we presented various hypothetical scenarios for the implementation of Automated Vehicles (AVs) based on relevant literature [86]. These scenarios encompassed different options, including both private AVs (PAVs) and shared AVs (SAVs) and their potential effects on various pertinent factors, including traffic volume reduction, privacy, ownership models, and costs.

3 Private or Shared? Comparing Hypothetical Implementation Scenarios of Automated Vehicles

We supplemented the scenario description with existing product images from the web that were redrawn by us (Figure 3.1):

- **Private Fully Automated Vehicles (FAV):** In this scenario the vehicle drives exclusively in automated mode and vehicles are mostly privately owned (high costs). The driver has no option to control the vehicle, but plenty of space for non-driving related activities like sleeping, working, etc. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams. This mobility scenario is the most expensive one but it offers a lot of privacy and comfort. Such a form of future AVs is frequently outlined by car manufacturers (for example the Volvo 360c concept car¹).
- **Private Highly Automated Vehicles (HAV):** In this scenario it can be chosen whether to drive manually or in automated mode and the vehicles are mostly privately owned (high costs). Due to the possibility to intervene any time (for reasons such as the “fun of driving” [122]), intelligent traffic control systems can only partly manage traffic in order to reduce traffic jams due to the persisting possibility to drive in manual mode. On account of driving controls, the space is less customizable as the first scenario, while the other advantages/disadvantages are identical.
- **Shared Automated Vehicles (SAV):** In this scenario the vehicle drives exclusively in automated mode and the vehicles are owned by mobility providers (medium costs, payment on-demand or subscription based). Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams. The vehicles can be booked for a single person or a group for any desired distance either in advance, or on-demand. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams.
- **Shared Automated Transit (ST):** In this scenario the vehicle drives exclusively in automated mode and the vehicles are owned by mobility providers. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams. These SAVs are an extension of the PT and cover the first/last mile of an entire route. This mobility scenario is the cheapest one but has to be shared with strangers. In addition, it has the largest effect on space recovery in urban areas as most part of the trips carried out in PT.

¹<https://www.volvocars.com/intl/cars/concepts/360c?redirect=true>

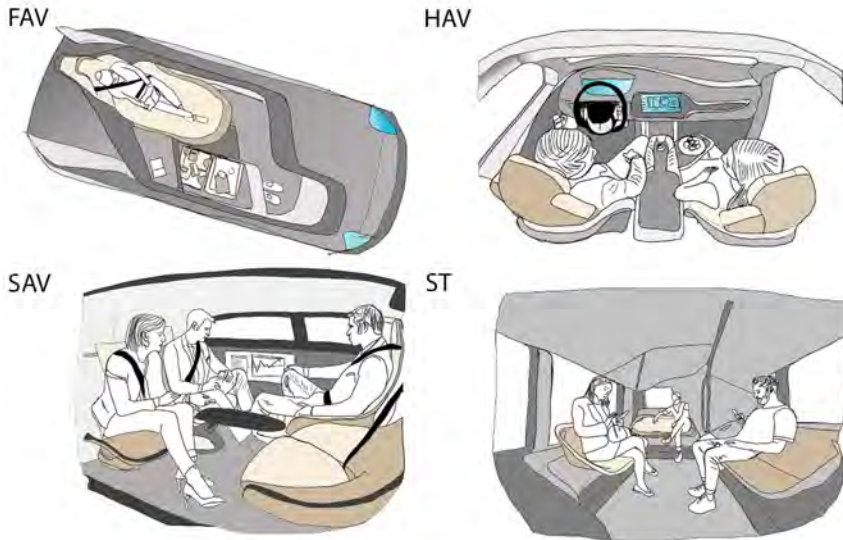


Figure 3.1: Four scenarios of the future of mobility in the context of AVs: (upper left) Private Fully Automated Vehicles (FAV), (upper right) Private Highly Automated Vehicles (HAV), (lower left) Shared Automated Vehicles (SAV), (lower right) Shared Automated Transit (ST).

We incorporated a brief user enactment segment, allowing participants to immerse themselves in these future scenarios. Additionally, we assessed their mobility preferences through interviews and employed UX cards [223] to pinpoint the user needs that influenced their choices.

3.1 Material and Methods

We provided participants with visual representations (see Figure 3.1) and brief narratives (refer to Section 3.1.1 for an abbreviated version) of four potential future scenarios involving Automated Vehicles (AVs). We asked them to rank these scenarios based on their personal preferences. In line with recommendations from Human-Computer Interaction (HCI) researchers, who advocate for the inclusion of embodiment in research [74, 224, 225], and inspired by previous research in the context of Automated Driving (AD)[226, 227, 228], we conducted interviews accompanied by the user enactment method. User enactments allow doing “*fieldwork of the future*” [229], meaning that not yet implemented technologies can be simulated. That way, first insights on how users will experience and interact with the technology can be gained. Subse-

quently, we aimed to analyse how a potential interaction in private and shared travel modes might look like by putting them into relation in an enactment part. The enactment part is in line with Bardzell's Feminist HCI [74] theory, urging to take embodiment into account during the design process to ensure feminist interaction.

Additionally, we aimed to investigate how different mobility solutions influenced the fulfillment of psychological needs [117, 230] argue that applying psychological needs analysis is a valuable approach during the early analysis phase of products or solutions, making it suitable for exploring various potential AV variants. The study guide underwent iterative development, including preliminary test sessions, which led to refinements in the interview guidelines and the order of activities.

3.1.1 Automated Vehicles Scenarios

Four speculative scenarios that were derived from Litman et. al [231] were presented to our study participants.

3.1.2 Participants

In total, 11 participants (6 women, 5 men, 0 diverse, 0 n/a; from 21 to 57 years; $M = 34.4$; $SD = 10.3$; $Mdn = 34$ years) took part in this study. Participants consisted of university staff, students, and people interested in the topic. All participants were recruited through university's mailing-list and word-of-mouth and attended our study voluntarily and without any compensation. In compliance with the feminist HCI manifest [30], we recruited participants from different age levels and from cultural backgrounds to assure for a pluralistic view. Their national background was German, Italian, Hungarian, and Portuguese, and all used public transportation and had a private car to their disposition. The study took place during the COVID-19 pandemic in early summer of 2020.

3.1.3 Procedure and Measurements

Following a briefing session and the completion of the consignment form, we introduced the four AV scenarios to the participants in a randomized sequence. We explicitly informed them that the narratives and sketches represented potential implementation scenarios set in a distant future (20+ years) and em-

phasized that, throughout the entire interview process, they need not concern themselves with technical limitations commonly associated with AVs, such as sensor reliability or algorithmic accuracy.

Participants' initial task was to arrange the scenarios based on their personal preferences. Subsequently, the interview phase commenced, during which participants were encouraged to openly discuss their mobility preferences, thoughts on the four scenarios, and their expectations and apprehensions regarding them. We also prompted them to share insights on the advantages and disadvantages of each scenario and how these would impact various facets of society, including elderly individuals and children, the environment, and the participants themselves within the context of their gender roles.

As our pilot study revealed that enacting all four scenarios proved to be overly time-consuming and occasionally perplexing for our participants, we made the decision to embody one shared AV and one private AV for the subsequent enactment phase (presented in randomized order). This approach allowed participants to exercise their imagination and preferences in certain aspects. For example, they could decide whether the private AV should be fully automated or offer manual driving controls, or if the shared AV should facilitate complete trip coverage or be integrated with public transportation. The sole stipulation for the shared AV scenario was that participants would share the ride with a stranger, played by one of the experimenters. This choice aimed to explore contrasting elements of private and public atmospheres.

During this enactment phase, participants were instructed to envision a typical journey that they might undertake in their real-life experiences (see Figure 3.2). They were free to select from a range of props to bring with them, including items like backpacks, bags, diaper bags, laptops, newspapers, books, coffee mugs, a baby doll (symbolizing a child), a stroller, and even a plush toy dog, all in an effort to create as authentic an experience as possible.

Throughout the enactment segment, we encouraged participants to express their thoughts openly and share their expectations on various subjects. We inquired about (a) how they envisioned initiating the ride, encompassing aspects like booking and navigation, (b) their perception of an ideal experience, and (c) their considerations regarding a potentially dystopian experience, along with any potential measures to mitigate dystopian occurrences.

Following this, we delved into an exploration of the psychological needs associated with each enacted scenario, utilizing Hassenzahl's UX cards toolbox [117]. This toolbox comprises eight cards representing fundamental needs within the context of interactive systems, as originally proposed by Sheldon [230]. These needs include autonomy, competence, meaning, physicalness, popularity, relatedness, safety (please note that we use "safety" instead of the original term

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Figure 3.2: Examples of setup for the Shared Transit (ST) during the enactment.

“security” to better align with the safety-critical nature of the driving context), and stimulation.

Participants were presented with these cards and invited to express whether they believed each need was fulfilled, not fulfilled, or not relevant in both enacted scenarios (see Figure 3.3). Subsequently, we engaged in a comprehensive discussion of each need and scenario to uncover the underlying rationale behind their assessments. Each session lasted approximately 90 minutes per participant.



Figure 3.3: Psychological needs sorted by fulfillment, non-fulfilment and non-relevance for the Shared Transit scenario (ST).

3.2 Results

All interviews were audio recorded and the enactment parts were video recorded. The material was transcribed and analyzed using qualitative content analysis [232]. We used inductive coding and refined themes and codes in an iterative process until the final themes and codes were identified. A Borda count analysis (see Table 3.1) of our participant’s ranking of the four scenarios showed that SAV (SAV) and SA Transit (ST) systems were equally well evaluated (33 points), followed by the personal highly AVs (HAV; 28 points), and the fully automated AVs (FAV) as the least preferred solution (20 points). However, a statistical analysis of the orderings (Friedman tests) yielded no statistically significant effect.

Table 3.1: Borda Count Results of the Scenarios

SAV	ST	HAV	FAV
33	33	28	20

In the following we present the main findings of our qualitative material (interview statements, enactment, and need card results). The material was transcribed verbatim analyzed using qualitative content analysis [232, 233]. We used inductive coding and refined the themes and codes in an iterative process until the final themes and codes were identified. The analysis was carried out using MAXQDA [234].

Table 3.2 summarizes the advantages/disadvantages of the individual scenarios investigated and for which situations private and shared modes are suitable from our participants’ point of view.

Table 3.2: Summary of advantages, disadvantages and the suitability of the different mobility implementations.

Private modes are suitable for... ... during the night, ... when under time pressure, ... for particular journeys such as family trips or travels, ... in suburban areas.	Private Fully AVs + High flexibility + High autonomy + Highest privacy + High security + High safety + High hygienic conditions - Low sustainability - Highest costs	Shared AVs + High sustainability + High safety + Low costs - Low flexibility - Low autonomy - Low security - Low privacy & efficiency - Low hygienic conditions	Shared modes are suitable for... ... during the day, ... when not under time pressure, ... for daily routines, such as going to work ... in urban areas.
	Private Highly AVs + Fun of driving + Highest flexibility + Highest autonomy + High privacy + High security + High hygienic conditions - Lowest sustainability - Lowest safety - High costs	Shared Transit + Highest sustainability + Highest safety + Lowest costs - Lowest flexibility - Lowest autonomy - Lowest security - Lowest privacy & efficiency - Lowest hygienic conditions	

3.2.1 Private Automated Vehicles

The expressed advantages of PAVs were frequently personally flavoured. Participants emphasized the flexibility and privacy aspects as the main improvements. Flexibility thereby has different facets. Frequently, it was linked to the freedom of one's mobility in terms of when (permanent availability of the car), from where (i.e., directly from the garage or in front of one's door), where to (being completely free about chosen destinations), and how (navigation or relevant place en route) to go. In this regard, time was the most important resource which can be saved by private vehicle ownership, as it solved first/last mile issues. A mother of two children described it as follows: *"It is the flexibility and the freedom to decide when to drive [...emphasizing she has to balance between child care and work...] when a meeting lasts longer I have security that the car is waiting and my children don't have to wait because I missed a shared vehicle"* [P03, woman]. The privacy aspect, defined as being alone or with family, comes along with a feeling of freedom (*"behaving like one wants to"* [P05, woman]; *"being able to choose whom to take along"* [P08, man]), as well as increased productivity. Participants stated working as a major advantage of AVs and argued that private vehicles reduce disturbance from other passengers as experienced in public transportation. Another important aspect was higher security. Especially the women among our participants depicted private vehicles as secure places (*"I feel secure because I have it for myself. In the evenings I see it as an advantage to be alone"*). During the interviews and enactments with the women a clear linkage between the self-perception as a woman and the importance of the feeling of security regarding their mobility became evident. Participants rated PAVs to be especially suitable for particular journeys, such as family trips, traveling, for situations with time pressure, within rural or suburban areas, as well as during the night (mentioned by women for security reasons).

However, also disadvantages of PAVs have been expressed by study participants. Those frequently had a societal flavor. Mainly environmental impacts such as the higher number of vehicles in general or on the road were emphasized, and especially the low occupancy rate was considered being a *"disaster for the environment and climate"* [P05, woman], which clearly were important to them (*"To me, sustainability is important. The environment is important"* [P02, woman]). Some also worried about social isolation when everyone just uses their own car, and a social gap between people who can afford such *"luxury"* [P06, man] and others who would have to stick to SAVs or PT. Interestingly, it became evident that this luxuriousness was considered as a disadvantage with participants stating that despite the aforementioned personal advantages they considered a private automated car as *"unnecessary"* [P06, man] and *"needless"* [P11, man].

Private Highly Automated Vehicles (HAV)

Many interviewees favoured the highly over the fully automated vehicle with emotional arguments, stating that *"If I choose the version that is worse for the environment, then at least I want to have the fun of driving"* [P02, woman] or *"I need to do something, I want to brake and steer. I would only tolerate the passivity within the shared version."* Driving pleasure and controllability were highlighted as exclusive advantages of this vehicle type. Even some participants who preferred fully automated vehicles told us they like to drive and described it as stimulating, adventurous, and diverse as *"there is no ride like the other"* [P05, woman]. Participants liked being able to accelerate, brake, and steer, as well as having the flexibility to spontaneously change the route. They compared the steering wheel with power and control that is lost in fully automated driving: *"We know [the steering wheel] well and it gives us control. We can drive as we want and where we want. [...] And in a couple of years there will be a bunch of people thinking of the 1980s and the music from the 1980s and think 'aw, how nice' and I think we will miss it. In [manual driving] we have power"* [P03, woman]. Still, participants were aware of the disadvantages of such a situation. It was expressed that traffic systems could not fully exploit their advantages to optimize and reduce traffic, as this would be impaired by manually driven cars, which, on the other hand, would have a negative impact on the environment.

Private Fully Automated Vehicles (FAV)

Statements in favor of vehicles without driving controls, in contrary, were more pragmatic. The ride with an automated vehicle was described to be a ride *"from A to B, not more not less"* [P08, man]. Participants liked being able to spend their time doing other things such as working or reading. Productivity and efficiency were frequently emphasized. Furthermore, mobility for everyone independently of the physical/mental state or age was highlighted as important benefit of this scenario. Children, elderly and disabled people could use automated vehicles, as well as people without a driver's license. Also, being able to drive after restricting medical examinations or under the influence of alcohol were mentioned. Additionally, driving in automated mode was seen as convenient and also comfortable, due to the stressful character of manual driving. Some participants accentuated the increased safety of the automated variant: *"The three completely automated versions are the safest."* [P04, woman] leading to fewer accidents and deaths. The increased safety was connected to the fact that other people were not able to drive. The driving style of other drivers was described as fast, reckless, even dangerous and this *"elimination of the human factor"* [P05, woman] made our participants feel safer with an automated vehicle than with another human *"I feel safer as humans always make errors. I feel safer with the car than with people, people can be tired or crash against some-*

thing by purpose." [P07, woman]. However, some participants criticized the automated systems as *"error-prone"* [P02, woman] and trusted their own ability more: *"I can evaluate dangerous situations differently than an algorithm."* [P04, woman].

3.2.2 Shared Automated Vehicles

Arguments for SAVs were often socially flavoured. The most frequently expressed benefit was their contribution to a more sustainable future, as they lead to a more balanced occupancy rate, fewer cars on the road, and consequently fewer pollution through traffic jams and emissions caused by the production of cars. In this context, it is worth mentioning that our data supports a *mind shift* towards more sustainability and environmental consciousness. In our participants we examined that owning a car is seen as something negative and egoistic whereas using a shared mobility version was equated with *"doing the right thing"* [P08, man]. As we explicitly asked for advantages of the different vehicle types for society, there might be some interviewer bias; however, participants also mentioned how they are perceived by other people such as friends and family (*"My friends would say: What? You don't have a car? Wow, you are so cool. How do you manage?"* [P03, woman]; *"Because it is reasonable. This one [private version] is the luxury version, but acting reasonably is more important to me. For the society, for the environment."* [P02, woman]). Another advantage indicated by study participants addressed the financial benefits emerging when not owning a private vehicle (*"I only have to pay for the distance I traveled that's all"* [P03, woman]). Not having to bother with running costs and maintenance would save even more money and personal resources making mobility in a car available to a broad public not only to the privileged ones that could afford it, thus, making it *"beneficial for everyone"* [P02, woman]. Further, it was articulated that SAVs work best for daily routines such as the way to work, for situations with no time pressure, within urban areas, and during the day.

Unsurprisingly, the disadvantages (often personally flavoured) of SAVs oppose the advantages of private ownership: lower flexibility and availability leading to more time and organizational effort and a decreased efficiency were described as especially cumbersome (*"I cannot just go there and take one. I have to plan and that is exhausting for me, because I have to plan many things anyway, the kids and so on, so this can be very exhausting."* [P03, woman]). In the context of planning participants stated that they would need several information about the vehicle, such as the occupation and space of the vehicle (*"I want to know, if I have enough space with two persons and luggage. So I have to know, if another passenger is inside."* [P04, woman]; *"I have two kids so I need a vehicle with three free seats, I couldn't book [a vehicle] with less."* [P03, woman]). In this

sense, an easy and straightforward booking process was seen as indispensable. Some participants stated complicated booking to be an obstacle for elderly or impaired people. Fast availability of the service was considered as important: *“The most important thing is that it is quickly [available] and in a given time frame. If I am planning half an hour and then it takes 20 minutes longer, then it’s difficult, because then many things don’t work out any more”* [P02, woman].

Additionally, our sample commented on hygienic concerns stressing the current pandemic situation due to COVID-19 and the probability of the cars being *“dirty”* [P03, woman] and *“not conforming to hygienic standards”* [P10, man] because of the high fluctuation of people (*“In times of Corona this matters because people are sick and don’t stick to the rules, so, yes, this is definitely a disadvantage.”* [P01, woman].

Shared Transit (ST)

The most frequently expressed disadvantage of shared transit was linked to the presence of other passengers. Thereby, two main themes existed. First, some participants feared becoming victim of crimes like pick-pocketing, harassment, or even rape and abduction, stating that the risk is comparable to PT. All but one of these statements were expressed by women, while the proposition from men was *“This might be a problem for women I guess. I don’t think about that.”* [P09, man]. Women emphasized security concerns especially during the night *“It depends on the time of the day[...]. Especially in the night I want to know, which car is available and who is inside. And if maybe another, more suitable car [with only women as passengers] will be available in 10 minutes.”* [P04, woman]. When asked how shared mobility should deal with such issues, participants emphasized to include a human fallback – either via camera, voice chat, or in-person. In this context, a button allowing to stop the car for safety (= accident prevention) or security (= prevention of crime) reasons, or to reach out to security personal was highlighted. Regarding privacy concerns about disclosing their address to other passengers, our interviewees were weighing off security and comfort. On the one hand, interviewees wished that the vehicle would pick them up or drop them off *“as close as possible”* [P09, man] or *“in front of the door.”* [P08, man]. On the other hand, they did not want others to know where they got off: *“I don’t want others to know where I live. I want it [SAV] to stop at home but only, if nobody is on board with me. Otherwise, it should stop one or two corners away.”* [P04, woman]. In this context, the system should offer enough flexibility: *“I would like to change the stop during the ride depending on who is inside [the SAV].”* [P08, man].

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In contrast, the second main theme was only expressed by men. Those feared to be disturbed (noise, other passengers hopping on/off) by other passengers in their activities (such as working). Despite the disadvantages emerging from driving with strangers, this leads to advantages, too. In this light a connectedness with others was especially underlined by our participants. They liked encountering strangers and talk to them, listen to their opinions on things because it prevented them of being *“trapped in [their] own bubble”* [P07, woman]. Some interviewees found it stimulating to see what others read or wear and especially enriching for elderly people and children. In this matter, it would be possible to offer help in case of emergencies such as, for example, an elderly person suddenly getting sick.

Shared Automated Vehicles (SAV)

Beside the general advantages and disadvantages of shared mobility, some emphasized the flexibility of this vehicle type as it could be booked when needed, making it more flexible than public transportation. It also was stated offering more security and privacy than shared transit.

3.2.3 User Enactments

During the enactment part our participants played different daily travel routes such as going from home to work, going from work to pick up the kids from school, traveling to see acquaintances and friends, or going from home to an excursion on a weekend. We derived a passenger journey including utopian and dystopian scenes from our qualitative results and clustered the results into the four important phases booking process, pick up and boarding, riding, as well as arrival and disembarking.

Booking Process

During the booking process, the most important factor indicated by our study participants was time. Either a SAV was booked beforehand or on-demand, the information on the departure of the vehicle, the duration of the ride, and its arrival were emphasized. It was considered important to know when the vehicle would arrive to pick them up and when it would drop them off at their destination. In this regard, study participants especially emphasized how important the reliability of the arrival time would be to them and that it would be available within a short period of time.

- Information about Other Passengers** Our participants expected to have information on the vehicle's occupation with other passengers during the booking process. They wished to know whether someone is already inside the vehicle when they got on, whether someone would join the ride and where, and the destination the other person had. On the one hand, our participants reasoned with pragmatic motivations such as checking the vehicle's capacity when planning a ride for the family (*"I have two kids so I need a vehicle with three free seats, I couldn't book [a vehicle] with less."* [P03, woman]), or when traveling with luggage (*"How many people are in the vehicle? Maybe I want to take my bike along or a lot of luggage."* [P01, woman]). On the other hand, the presence of other passengers was also linked to security concerns (*"It is also an issue of security, so you know what you should expect."* [P01, woman]). Some participants feared becoming victims of crimes like pick-pocketing, harassment, or even rape and abduction, stating that the risk is comparable to PT. All but one of these statements were expressed by women, while men's proposition was *"This might be a problem for women I guess. I don't think about that."* [P09, man]. Women emphasized security concerns especially during the night: *"It depends [...] during the day the destination of the person is enough— but in the night I would want to know how many people, their age, their gender. Then it would also be okay to reveal this information about myself."* [P07, woman]. During the enactment our women participants engaged in the situation of traveling alone during the night and elaborated on the system supporting them proactively by offering more suitable compositions of passenger groups for specific situations, such as, for example, vehicles for women only: *"[...] Especially in the night I want to know which car is available and who is inside. And if maybe another, more suitable car [with only women passengers] will be available in 10 minutes. Then I'd rather wait."* [P04, woman].

Pick-Up and Boarding

Participants expected the vehicle to give them constant feedback on the arrival status of the vehicles, which they supposed would pick them up at the curb. Doors should open automatically and an easy access was presumed so one could enter the vehicle even when carrying bulky luggage, being accompanied by children or elderly passengers, or when carrying a stroller or walker. After being seated, people expected the vehicle to start smoothly instead of abruptly. Here, again time was mentioned frequently and a late arrival or no arrival at all were considered as *"impossible"* [P04, woman]. Also, it was emphasized that it should be made sure the booked vehicle with the necessary capacity should arrive. Inside the vehicle participants expected a personalized welcoming message: *"It*

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would be nice if the vehicle would say something like: Good morning Mrs. [participant's name], I wish you a pleasant ride." [P07, woman].

Ride

When en route, participants anticipated to have abundant offerings of distractions such as music, films, or multimedia entertainment that they could either consume by themselves or share with their co-passengers. Even coffee was mentioned as a comforting factor.

- **Route** Unsurprisingly, people are unfamiliar with the fact that SAV and ST systems may not have fixed routes but depend on the individual destinations of the passengers. Certainly, study participants wished to have knowledge of the route already during the booking process and required to be kept up-to-date on it during the ride: *"Hold on a sec, these vehicles don't have a fixed route, it depends on who will be picked up. It would be good to know which stop or street it is heading to next."* [P05, woman]. Likewise, participants wanted to take advantage of the freedom that no given routes provided and expected the system to provide the flexibility of changing routes and stops "on-the-fly" depending on the situation. This was true for cases of (medical) emergencies (*"I want to get off when I get sick, for example"* [P07, woman]), as well as for adjusting the stop to the individual preferences (*"I still want to decide for myself. If I suddenly think that I need flowers and there's a flower shop in front or if my child gets sick or spills something. That I [am able to] intervene."* [P04, woman]).
- **Handling Safety and Security Issues** When asked how shared mobility should deal with safety (=accident prevention) and security (=prevention of crime) [142] issues, participants emphasized to include an interaction with a human fallback. While presupposing cameras such as in today's PT systems, they expressed concerns about the absence of any kind of security-staff: *"On the bus there is at least the bus driver who would stand up for me, but here not. Some sort of surveillance system would be good, a camera and an emergency button. That would give me a feeling of security but I would need to know that it really works."* [P05, woman]. During the enactment, a button allowing to stop the car for safety or security reasons was highlighted. Participants were intuitively "pressing" an emergency knob either right next to them or under their seats in order to reach out for help that – as subsequently explained – they imagined to be some kind of security personal. Correspondingly, participants expected an interaction with a human either asking what the problem was, giving feedback on the situation, or proactively communi-

cating that help was already underway. Multiple interaction modalities, such as a camera, voice chat, or in-person, were proposed in this context all having in common involving a “real” human (*“I want to talk to a person from the company.”* [P07, woman], *“I want to speak to a person – not a system.”* [P08, male]).

- **Cleanliness of the SAVs** Regarding SAVs our participants expressed hygiene concerns. Due to extensive use and high fluctuation of people the vehicles would be dirty and worn-away: *“Usually there is no hygienic standard. People treat things differently when they not own them and that’s why [PT] is so dirty.”* [P10, man]. Hereby, they attributed responsibility to other passengers, as well as the service providers: *“It will probably depend on the company how clean they are. I guess there will be different types and tariffs.”* [P08, man]. Stressing the current pandemic situation due to COVID-19, our sample mentioned even further concerns: *“In times of the Coronavirus, this matters because people are sick and don’t stick to the rules, so, yes, this is definitely a disadvantage.”* [P01, woman]. Again, the SAVs were compared to PT with its disadvantages: *“They should be cleaner than trains.”*, [P11, man].

Arrival and Disembarking

- **Arrival time** During the ride itself our study participants expected the system to deliver constant feedback on the time of arrival. Our sample indicated ambiguity regarding how the system should provide this information. Some participants supposed the information would be displayed on some kind of screen, or via voice, whereas others imagined details were not exposed to all passengers but rather provided to them individually via their smartphone. Especially when traveling with children or luggage, participants desired a notification before the arrival to be able to prepare themselves to get off: *“I have to prepare my kids for getting off at least one minute before, with the backpacks and all. I have to anticipate the [exact] arrival.”* [P03, woman]. In this context it would be helpful for passengers that the system would recognize groups to assure that no group member—especially a kid or elderly passenger—is left behind.
- **Privacy Concerns regarding Stopping Points** Regarding the stopping points of the SAVs, privacy concerns about disclosing their address to other passengers, our interviewees were trading off security and comfort. On the one hand, interviewees wished that the vehicle would pick them up or drop them off in front of their door or *“as close as possible”* [P09, man]. On the other hand, they did not want others to know where they got off. This was highly dependent on the context. For example,

during the day, women would rather get off a few corners away from their home and take the burden to walk the last bit: *"I don't want others to know where I live. I want it [SAV] to stop at home but only, if nobody is on board with me. Otherwise, it should stop one or two corners away."* [P04, woman]. In contrast, in the evenings or nights, which are the times of the day where most security issues were mentioned, women emphasized they would want the vehicle to drive them directly in front of their home to not have to walk the last bit on their own. Furthermore, the exact stopping point also depends on the other passengers sharing the ride. In that regard, if traveling with *"a certain type"* [P07, woman], the system should offer enough flexibility to change the exact location of the stop: *"I would like to change the stop during the ride depending on who is inside [the SAV]."* [P08, man]. Here, our participants elaborated on the fact that even if the system would not display their private address to other passengers, these would know where they lived when they got off: *"Maybe I can anonymize my stop in the settings? But when I get off, he would know anyway."* [P04, woman]. It is particularly worth mentioning that whereas security concerns were mentioned exclusively by the women in our study, privacy concerns regarding the disclosure of one's address were expressed by men and women alike.

3.2.4 Psychological Need Fulfillment

In the final session after the enactment part, we used UX cards to further collect participants' attitude towards PAVs and SAVs. For each of the needs, participants were encouraged to state whether they believe it fulfilled, not fulfilled, or not relevant in the given situation, and provide a justification for their decision. The results (need profiles and selected statements) can be seen in Figure 3.4 and Table 3.3. A statistical analysis (Stuart-Maxwell test) of the differences of non-/fulfillment of user needs in shared and private mobility modes were only significant for autonomy ($SM(df = 2, cat. = 3) = 6.0; p = .025$). Thus, the results are reported descriptively.

Autonomy is completely fulfilled for the private AV scenario and balanced out between fulfilled and not fulfilled for the SAV scenario. The high fulfillment of autonomy for PAVs is related to the high flexibility of this form of mobility. In SAVs our participants see their autonomy as less fulfilled as they consider themselves as highly dependent on the car's availability, route, and have no impact on who else they have to share the vehicle with. Nevertheless, half of our participants still rated their autonomy as fulfilled due to the freedom of choice to book it and when to book it.

Table 3.3: Non-/Fulfillment of psychological needs in the private and shared implementation scenarios and example statements of participants.

Need	Description [117]	PAVs +/-	Statements	SAVs +/-	Statements (if available)
Autonomy	Feeling like you are the cause of your own actions rather than the feeling that external forces or pressure are the cause of your actions.	+	"We can go when and where we want to. It is the freedom that we have nowadays in a regular car."	+	"I can book it whenever I need it and I don't have to ask anyone whether he has time to drive me."
		-		-	"I don't have any influence on when and where to go because there are other people also."
Competence	Feeling that you are capable and effective in your actions rather than feeling not competent or effective.	+	"Because I can drive manually and show, that I am capable of it."	+	"I dare to use it, I engage in the aspect of sharing it and I am doing what's best for the society."
		-	"No, because I am acting in an egoistic way [when having a private car]."	-	"It drives itself. I don't have to have any competence to sit there."
Meaning	Feeling that you are developing your best potentials and making life meaningful rather than not getting anywhere and experiencing nothing of importance.	+	"It is more [than in SAVs] because I can listen to the music I want, or just dream."	+	"I can focus on the people I am with."
		-	"I have a bad consciousness because I drive in my own car. It is bad for the environment."	-	"I don't know if it can have any meaning to drive from A to B."
Physicalness	Feeling that your body is healthy and well-taken care of rather than feeling out of shape or unhealthy.	+	"I am more relaxed due to the automated mode."	+	"I don't have stress [of driving] and that is good for my body."
		-	"I only sit there. There is no fitness in that."	-	"Would rather be fulfilled when I ride by bike."
Popularity	Feeling that you are liked, respected, and have influence over others rather than feeling like a person whose advice or opinions nobody is interested in.	+	"I am popular, I am such a good driver."	+	"I am popular because I don't own a car and my friends say I am cool"
		-	"No, I would excuse myself for having a car and say, well, I have kids, live in the suburbs and commute 20 miles every day."	-	
Relatedness	Feeling that you have regular intimate contact with people who care about you rather than feeling lonely and uncared for.	+	"I can talk to my kids instead of having to drive [manually]."	+	"I am with other people, I have the chance to talk and relate to others."
		-	"No, it is not fulfilled here because I sit there alone. Everyone in his own car."	-	"I am together with strangers that I don't know."
Safety	Feeling safe and in control of your life rather than feeling uncertain and threatened by your circumstances.	+	"The automated part is safe, the one that takes over when I am not able to."	+	"The system works and there are not accidents."
		-	"Because of the human factor. The part that drives in automated mode is safe but the manual part is not safe."	-	
Stimulation	Feeling that you get plenty of enjoyment and pleasure rather than feeling bored and understimulated by life.	+	"I can have cool conversations when I don't have to concentrate on driving."	+	"You have the chance to get in touch with others and you are not in your own bubble but together with others."
		-	"Maybe it's stimulating in the first 10 minutes but then you get used to it."	-	"After taking it a couple of times it is not exciting anymore."

3 Private or Shared? Comparing Hypothetical Implementation Scenarios of Automated Vehicles

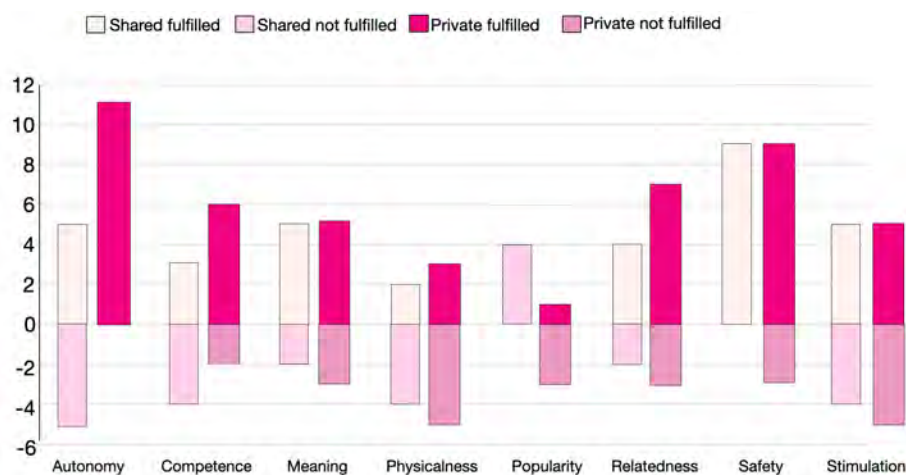


Figure 3.4: Fulfilled and not fulfilled psychological needs.

Competency shows a higher fulfillment for PAVs than for the SAVs. This is connected to the fact that one is able to drive manually which requires certain skills. However, meaning, physicalness, relatedness, safety and stimulation are balanced out between shared and private AVs. Participants related meaning to the time one can spend with family and friends when the vehicle drives in automated mode. Physicalness is low for both scenarios due to the low physical effort that is needed for “*just sitting there*” [P05, woman]. Safety is highly fulfilled for both scenarios and here is related to the high trust in the automated mode that our participants emphasized. Stimulation is balanced out between fulfilled and not fulfilled. In this context, our participants expressed that once one is used to AVs in general, the stimulation will decrease. In contrast to the aforementioned security aspect, no gender differences were found with respect to the need of safety. Overall, no differences between migrants and non-migrants emerged in our results.

Although only a subgroup considered the need for popularity as relevant, those four of eleven participants argued it being fulfilled in SAVs, and not fulfilled in PAVs. This highlights the before mentioned *mind shift*: vehicles seem to gradually lose their image of being a status symbol (only one participant stated a private vehicle would satisfy the need for popularity), while in the future, popularity may mean not to own a vehicle and utilize sustainable transportation.

3.3 Discussion and Implications

Overall, the obtained results indicate people’s willingness to contribute to a more sustainable future by using shared mobility modes. This contradicts previous findings, for example, the works of Pakusch et al. [156], who conducted an online-survey and concluded that private cars will persist as the dominant mobility mode. In our experiment, shared mobility was perceived more positively – both shared variants received the highest score in a Borda count analysis of the ordered concepts, and participants expressed various advantages such as the largest positive impact on the environment, lower costs, or social benefits for everyone. We are well aware that the discrepancy to the findings of [156] could have been partly influenced by social desirability bias (anonymous online survey vs. interviews). However, we believe the result not only emerging from such a bias, as participants frequently emphasized the importance of making an environmental-friendly impression also to fellow friends or family, what indicates a *mind shift* towards more sustainable behavior in general. Another interesting finding regarding desired future AV scenarios is, that fully automated driving was rejected by many participants, what contradicts the expectations of vehicle manufacturers that have presented future concept cars. Although concerns such as the fear of losing control or the fun of driving have been revealed in literature [122] already, we were surprised that participants expressed those also when imagining a much more distant future.

Despite the rankings, participants feared shared vehicles not being able to satisfy their need for autonomy as good as private vehicles. Shared mobility was not considered being flexible with respect to have control over when, from where, where to, and how to go. Participants feared not being able to exploit all benefits when driving with strangers because they might get disturbed or feel insecure. Summarizing, essential concerns towards shared mobility solutions were expressed by our participants, as well. Taking advantage of shared mobility in the future demands to take their anxieties seriously into account. Based on our qualitative insights, we have derived the following design requirements, which we believe to be highly relevant for the design of SAVs.

3.3.1 Maximize Autonomy for Diverse Target Groups

To make SAVs users’ transport modality of choice, it will be necessary to design them as flexible as possible for the needs of the diverse user groups. Systems should provide options for customizing pick up and drop off locations, reservation of multiple seats, a possibility to pick up other passengers en route (for example, picking up children from school on the way home), and navigation details. Such requests should be supported by pre-scheduled, recurring, as

well as on-demand service solutions. Thus, we claim the frequently used term “mobility-on-demand” to be misleading as it neglects highly relevant user needs – such services must not only be available on demand, they must allow precise planning for potentially complex situations.

3.3.2 Maintain Privacy, Efficiency, and Flexibility

Brown et al. [235] found that time becomes less relevant if it can be used efficiently. An often mentioned advantage of AVs is the possibility to engage in non-driving related activities, such as working. However, it was emphasized by study participants that concentrated work that conveys a feeling of efficiency is associated with privacy. In addition, also relatedness (i.e., having a peaceful chat with friends, children, etc.) can be increased through privacy. Thus, the interior designs of SAVs should support as much privacy as possible to support those needs, for example, by providing not only seats but also compartments. However, at the same time people increasingly fear being isolated in the future, and participants also mentioned positive aspects of driving with strangers. Systems should account for both aspects, for example by using social network services to match with other passenger of similar interests. Our participants wanted to be able to rely upon the mobility solution. The vehicle should arrive on time, it has to be the one that passenger ordered, and with the seats he/she ordered to allow for precise planning and a smooth work-life balance. In our view, this demands to rethink the labelling of SAVs, which are often called “on-demand” solutions. In fact, for many participants it is important to schedule and plan upcoming trips in detail already in advance. Thus, SAVs must provide much more flexible booking options than what one would typically understand by “on demand”. Also en route, the vehicles should allow for flexibility: participants wished to be able to change routes and stops, to get off earlier, and to adjust the disclosure of their stopping points to other passengers. From our point of view, such flexibility should be gone through by taking into account the quality of ecology. While such options make perfect sense from the perspective of a single individual, we believe it being difficult to simultaneously act upon such desires when multiple passengers are on board, as such requests would reduce predictability for both, the involved passengers and the service itself. However, passengers’ desire for high flexibility might be addressed more holistically, for example, by including several artifacts, such as adjustment of the seats, temperature, multi-media offerings, or (as described above), by offering personalized adjustments already in the booking process. Especially flexible configuration of the compartment could account for participants’ needs: sometimes, passengers prefer privacy to relax, work, or be with their friends and family, other times they enjoy to relate to strangers. Here, several solutions already have been proposed [135] and we would like to highlight Layer’s Jon [236] solution that has been inspired by airplane cabins and

allows for opening or closing the personal area of each seat by pushing or pulling the “wings” attached to each seat.

3.3.3 Increase the Feeling of Security/Safety

Security concerns were clearly gender-based. The women among our participants expressed anxiety and fear when reflecting on the shared versions of mobility underlining the evenings or nights as the times of the day related to the most negative emotions. A broad spectrum of research in the PT area [142] shows that women’s considerations in this regard is appropriate. In our study, women suggested a human fallback, someone who they could rely upon when riding with strangers, or cameras to prevent crimes (in line with existing studies [170, 237]). However, the analysis of our qualitative material goes beyond: to feel safe, women would like to have options such as being informed about the age/gender and number of other passengers in the vehicle, changing destinations during the trip, driving alone or with other women only (especially at night), or to share location/trip details with relatives, who are informed when they deviate from their planned path. Such options, even though they were mainly expressed by women in our interviews, could of course raise the feeling of security for other target groups, as well.

The booking and reservation of seats in an automated shuttle has been studied by [238], who found that a freedom of seat choice mattered to people. We additionally identified women’s desire to get information about co-passengers before entering the vehicle to feel more secure. However, this need falls into the category of privacy vs. security dilemmas: on the one hand, it is important to have information about co-passengers, on the other hand, our data showed considerable privacy concerns regarding disclosing their private address to others. Thus, it is indispensable to study which information would support passengers’ need for security in their decision of whether to book a vehicle or opt for another one (e.g. a woman choosing a vehicle with only other women as co-passengers during the night or when traveling alone), while also identifying which information people are willing to reveal about themselves in the first place. Here, a balance between an increased security feeling and privacy concerns has to be found. However, we feel this need must also be discussed through the lens of advocacy. Let us imagine the consequences of people deciding for or against a vehicle based on personal characteristics of other passengers – could this lead to a society where race, gender, and class are segregated? Could this lead to a disadvantage for some passengers, for example, when their bodies, clothing, etc. do not comply with certain “norms”? In the worst case, the cost for a slightly higher feeling of security could be a loss of privacy and inclusiveness – consequences we would definitely reject. Ge et al. [127] already revealed a racial discrimination in Uber and Lyft drivers putting African-American pas-

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sengers at disadvantages by cancelling accepted rides after reading their African American-sounding names in the booking app. Taking a feminist point of view on this important issue, we reason that other solutions have to be designed to foster security feelings in SAVs and ST and these solutions under no circumstances should exclude groups with certain physical, psychological, or social characteristics.

We would like to push the discussion even further and reflect upon the possibility of a rating system. Evidence exists that Uber drivers do not rate passengers negatively even though these might have behaved inappropriately because they feared getting a low rating back. Ruha Benjamin [52] discusses how rating systems might impose discrimination in societies while referencing “Nosedive” [239], an episode of the series “Black Mirror” [240]. In the episode the protagonist Lacie lives in a society where every interaction is being rated and people have access to privileges according to their ranks. While losing her high level ranking due to a series of unlucky incidents she finds herself being cut off from mobility: the last available seat in the plane that would fly her to the wedding of a friend is only available for people with higher rankings so she has to queue for a low quality car with no comfort in front of the car rental service. Thus, and within the scope of advocacy we support an anonymous booking system for SAV and ST solutions to make them accessible for everyone, just like PT is today. In this context, another solution which should be reflected upon is the women-only SAV mentioned by the women in our study for certain times of the day or trips. This is again an approach that has been proposed [135] and implemented several times and that has its advantages, as well as its disadvantages: Delatte et al. [177] argue that while ensuring privacy and security, the “Pink Taxi” [176] did not eliminate the problem of sexual harassment because women were assaulted on the streets when disembarking the cabs and furthermore, it favoured gender-segregation. Due to its pink look, women were infantilized instead of being empowered and taken seriously. In their evaluation on women-only transport services in Mexico, Abenoza et al. [241] conclude that whether women-only transportation increases the level of security and trip satisfaction could neither be confirmed nor rejected and that these types of services remain to have an ambiguous character. Again, we would like to regard this through the lens of advocacy and reflect upon this approach while taking a feminist standpoint. While we argue that a women-only version has to be very carefully designed so women feel respected instead of being ridiculed, we would at the same time question whether a women-only vehicle would be the appropriate solution in the first place because, again, it would exclude people due to their physical characteristics, in this case, non-female individuals (and further could lead to conflicting situations with non-binary people). We argue that instead, research is needed on how to enhance women’s security while not leaving other groups of people out.

3.3.4 Cleanliness of the Vehicles

Another important point that we would like to discuss through the lens of ecology are the hygienic concerns expressed by our participants. Here it becomes evident how the general openness to use shared mobility solutions goes hand in hand with a sense of well-being which, in turn, is related to the vehicle's design and state of the interior. Thus, we propose that vehicles should be kept clean and nice and several stakeholders should be considered when designing for such cleanliness: obviously the service providers have to make sure the vehicles are maintained and cleaned regularly, but furthermore the passengers themselves should be engaged. As one of our participant emphasizes: *"It [SAV] doesn't correspond to hygienic standards because it's highly used. People treat their own property differently than things that don't belong to them."*, [P10, man]. Sanguinetti et al. [135] use territoriality in defensible space theory to discuss that identifying with a vehicle would provide the feeling of control and ownership and, thus, would enhance natural surveillance for security reasons. We argue that in the design of SAVs territoriality should be taken into account to nudge passengers to treat the vehicles properly. We agree with [135] who state that clean vehicles would support security. They rely upon the broken windows theory (BWT) [242] to argue that neglected places are more prone to crimes due to the unobserved impression they make. While the BWT has been been disproved [243], we believe that clean and maintained vehicles will furthermore enhance the perceived security of passengers— a circumstance that should be researched before SAVs are fully deployed on our streets.

3.4 Limitations and Future Work

The presented work has some limitations. Our study was conducted in Germany with a small sample, mainly participants employed at a university. Although we intentionally included migrants in our sample, we plan to conduct this study with an even more diverse group of participants, in order to get a broader understanding of public's attitudes and user need fulfillment in different implementation scenarios of AVs. Our study included a small sample (N=11) with a high educational level who was recruited through university mailing lists and word-of-mouth, which might have lead to a self-selection bias and the inclusion of people already interested and motivated to use to use autonomous forms of transportation. Therefore, our results are not generalizable. However, our aim with this study was to explore the potentials of the different scenarios rather than generalizable results and we believe that this has no negative impact on the general insights of our work. Especially regarding the feeling of security of women a cross-cultural approach might provide additional insights. [142] report that women are exposed to sexual harassment

in PT systems especially across Latin America. Thus, there might be cultural differences in the choice of PAV or SAV mobility modes and also in the fulfillment of user needs. Furthermore, all of our participants defined themselves as either man or woman. In order to cover the whole gender aspect of mobility non-binary gender groups should also be included in future studies. We used a qualitative approach to get rich insights in the reasons for people's mobility choices. Thus, our results aimed to develop hypotheses [244] on why people prefer certain mobility implementations of AVs instead of quantitative, general results.

3.5 Conclusion

In this study we have explored people's preferred mobility modes of AVs in an imaginary distant future (20+ years). We wanted to gain rich insights on how people expect the implementation of AVs, as well how their attitude towards different implementation scenarios might influence their mobility choices. Thus, we followed a qualitative approach and combined in-depth interviews with an enactment part and the use of UX cards. Our results indicate that many users might be willing to use shared mobility in the future to contribute to a more livable world both for society and the environment. However, to translate such positive attitudes into actual behavior, SAVs must provide high flexibility to allow users maintaining full control of their mobility behavior. In addition, specific needs of diverse target groups, such as women, must be seriously taken into account. Expressed requirements include precise trip planning for multiple users (including other family members such as children) or changing drop-off locations, both on-demand but also in form of pre-scheduled bookings. Also privacy (for example, not being disturbed while working) and relatedness (getting into contact with other people) have to be balanced to raise acceptance in the future. Finally, various concerns regarding security have been expressed especially by the women among our study participants, extending beyond the ride experience to encompass aspects like the booking process and the layout of pick-up and drop-off points. We applied qualities from the Feminist HCI framework, acknowledging the significance of diverse viewpoints. While stressing that it is crucial to address these concerns to allow for the widespread acceptance of SAVs, we caution that solutions to mitigate these issues should be meticulously designed to prevent unintended repercussions. In our discussion, we raise questions about the balance between security and privacy in the booking process and the potential drawbacks of gender-specific vehicles, prompting a nuanced examination of these complexities for future developments in shared mobility. For this, we argue to include a diverse variety of age groups, cultures, and educational levels in the early design process to make our mobility of the future accessible and desirable for everyone.

4 Unveiling the Journey: Understanding Women’s Needs in Shared Automated Vehicles

Despite the environmental and societal benefits of SAVs, people seem to be reserved towards this technology. The results of Pakusch et al. [156] point toward people preferring private cars in the future. Lavieri et al. [245] uncovered increased travel times associated with pick-up/drop-off of other passengers and having to share a vehicle with strangers as factors for acceptance. Clayton et al. [155] examined the willingness to adopt and share an AV with strangers and found significant uncertainty among participants. Related work points emphasized that security concerns will be the major challenge when sharing AVs [133, 135] which is supported by our own findings as discussed in Chapter 3.2.2. Although women are usually not early adopters of ride-hailing solutions [165], they seem to be open to contributing to more sustainable mobility modes [166]. When comparing people’s willingness to use private and shared automated vehicles, we confirmed that especially women express strong security concerns towards SAVs, arguing that the lack of a driver would exacerbate them compared to today’s public transportation system (see Chapter 3.2.2). This result substantiates the findings of interviews with people who rode an automated shuttle bus [124], as well as quantitative studies that reach similar conclusions [111, 133]. These findings indicate the need to address women’s perceived security in the context of shared automated mobility. As [168] found that anxiety-related effects can be reduced if appropriately addressed, we target women’s security concerns to increase their likelihood of adopting these technologies.

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In this section, we present a qualitative study using co-creation and focus group discussions and derives design implications for the development of SAVs by women of different age groups. We present results from three workshops on SAVs and security in shared automated mobility. We illustrate concrete features for ensuring security in SAVs from the perspectives of young, middle-aged, and older women, and conclude by proposing a research agenda. While other individuals also have feelings of fear of crime, such as immigrants, people of color (POC), people with disabilities, and other groups facing intersectional discrimination [68], we focus here on women in different age groups for the following reasons: 1) women make up half of the world’s population and their adoption of SAVs is important, 2) according to the presented psychological theories, gender and age are among the characteristics that have the highest negative influence on perceived security, which 3) is an issue in today’s PT systems and 4) might prevent them to adopt SAVs precisely for that reason [124]. We consider this focus as one first step towards taking viewpoints into account that many times do not matter in research. Simultaneously, we believe that many different user groups will highly benefit from the gained concepts, as secure mobility modes may affect all of us.

By building upon the results of prior research confirming that perceived security *is* an issue in today’s PT, we want to explore *how* to overcome this issue with appropriate measurements and concepts for SAVs and come up with concrete ideas while focusing especially on the security needs of women from different age groups. Thus, we pose the following research question:

RQ4.1. What are the security issues in SAVs from a women’s perspective and how can they be addressed?

To answer this question we took a participatory approach [210, 220] by combining co-creation techniques and focus group discussions. Accordingly, we wanted to give our participants a voice to express their concerns and empower them by being part of designing our future [74, 246] of mobility according to their security needs.

4.1 Material and Methods

In this study, we took a participatory approach [210, 220] by combining co-creation techniques and focus group discussions. Accordingly, we wanted to give our participants a voice to express their concerns and empower them by being part of designing our future [74, 246] of mobility according to their security needs. We conducted a workshop series to answer our research question. In total, we invited 21 women to participate in our workshops and asked them

about their feeling of security in SAVs and how this feeling could be enhanced through the design of the booking, the ride, and the departure and stopping points. From our results, we derived several concrete design ideas for future shared automated vehicles, as well as an agenda for further research on security in the context of shared mobility solutions.

4.1.1 Participants

We wanted to get qualitative insights on how women from different generations and in different life situations (working, studying, being a mother, being a grandmother, being a pensioner) perceive security in the context of automated shared mobility. In total, we invited 21 women to participate in our workshops and asked them about their feeling of security in SAVs and how this feeling could be enhanced through the design of the booking, the ride and the departure and stopping points. From our results, we derived several concrete design ideas for future shared automated vehicles, as well as an agenda for further research on security in the context of shared mobility solutions. For the first workshop, we recruited 7 women (from 22 to 57 years; $M = 36.3$; $SD = 11.2$; $Mdn = 36$ years): university staff, students, and people interested in the topic. For the second workshop, we recruited 5 senior women (from 68 to 75 years; $M = 71.8$; $SD = 2.6$; $Mdn = 72$ years) through a local community center. In this workshop, we wanted to focus on security needs of senior women (defined as 65 years old and above), as we hypothesized that these might be different in comparison to young and middle-aged women. For the third workshop, we combined younger and older women. As we planned a co-creation session including prototyping, we expected that women of different ages and life stages would fuel each other. The younger group was familiar with prototyping techniques and the senior citizens would bring their life experiences to the table. The younger group consisted of 3 university students (from 23 to 31 years; $M = 26$; $SD = 4.3$; $Mdn = 24$ years) and the older group consisted of 6 senior citizens (from 69 to 82 years; $M = 74$; $SD = 5.2$; $Mdn = 73$ years) who were recruited through a local community center. All three sessions took place during the COVID-19 pandemic, and Workshops 1 and 2 were therefore carried out via the online platform Zoom. Workshop 3 was conducted in person and according to the hygiene regulations valid at that time, and Corona tests were given to our participants for free. All participants received a voucher (app. 30 US dollars) for their participation and their national background was German, Italian, and Finnish. Our participants used public transportation at least occasionally and had a private car at their disposal. We opted for a women-only workshop because we supposed women would not discuss security concerns as openly in the presence of men due to the sensitivity of the subject. Therefore, the researchers that conducted all sessions were women, too.

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Figure 4.1: Tools and materials for the workshops (from left to right): 1) Workshop 1: Miro board, 2) Workshop 2: Booklet for participants, 3) Workshop 3: Prototyping material and 4) Collection of ideas on post-its.

4.1.2 Procedure and Measurements

The demographic data of our remote participants were collected in a phone call, and a consent form was sent to the participants by e-mail or mail one week before the actual remote session. The completed forms were returned to us by e-mail or mail. The participants of our in-person workshop completed these forms before the actual workshop session started. The workshops started with a briefing of our participants and a presentation of the idea SAVs. As a warming-up activity in all workshops, participants were asked on their first impressions of the concept of SAVs and whether and under what circumstances they would (not) use them. All three workshops (1,2, and 3) lasted app. 230 minutes in total, with two short breaks in-between. We aimed to foster vivid debates on women’s security concerns and gain rich insights into how the three different phases of the ride should be developed from a women’s perspective. We closed each workshop with a final group discussion on the outcomes of the brainstorming phase, with the researcher asking open-ended questions to get more opinions and details on the derived design recommendations. All workshops covered 1) potential security issues and 2) how security could be implemented. However, the focus of the workshops differed, and we will explain each workshop in detail in the following.

Workshop 1 (younger and middle-aged women, P01-P07)

After the warming-up, the group was divided randomly into three breakout sessions with smaller groups of 2 or 3 participants. Each subgroup was brainstorming on how security could be designed in SAVs and focused on one of the three phases of an SAV ride: 1) booking, 2) during the ride, and 3) departure and stopping points. During the brainstorming, we wanted to lead our participants as little as possible to give room for creative and potentially completely new concepts. As an inspiration and starting point, we offered open-ended questions on what our participants needed to feel secure and how this could be transferred into an SAV in general. We further asked questions on how security

could be provided during each phase of the journey and what features would help during the specific phase.

The resulting ideas were collected on a Miro board. After a given time, the groups met again in a plenary session and presented their outcomes. The other participants discussed the derived concepts, and the researcher asked open-ended questions about why this concept would improve security and what else could be implemented into SAVs. Then the group split up again into breakout-sessions to refine the already existing ideas on the digital whiteboard. This time, each participant was assigned to brainstorm on a different phase of the ride. This procedure was done three times so that each participant brainstormed on each phase of the ride and had the opportunity to discuss with different peers during each session. This workshop focused on collecting concerns and producing potential solutions.

Workshop 2 (elderly women, P08-P12)

All our senior participants received individual technical support one week before the remote workshop took place to make sure they disposed of the technical preconditions to dial themselves into the Zoom session (installing and setting up Zoom, and a test trial for dialing into a prepared meeting). During the focus group discussion, we asked our participants open-ended questions about their current mobility, how it would change with SAVs, and which advantages and disadvantages SAVs would have for them personally. After the first break, the group was divided into breakout-sessions. We separated our participants into two groups consisting of 2 or 3 participants. Fearing that it would be tiring for our participants to have three rounds of breakout-sessions as in Workshop 1, we opted for one breakout-session part in this session. We asked our participants to brainstorm on how security, in general, could be enhanced through the design of SAVs, prompting the same questions represented in Workshop 1. Due to the aforementioned technical restrictions on the participants' side, the data was collected differently in this workshop. Instead of a Miro board, our participants received the printed version of a booklet via mail (see Figure 4.1). The booklet consisted of some information on the workshop and one page for taking personal notes. We designed this booklet to invite participants to write down their ideas. After a given time, the groups met again in a plenary session and presented their outcomes. The other participants commented and discussed the derived concepts, and the researcher asked open-ended questions. This workshop primarily focused on the collection of security concerns, while designing solutions played a subordinate role.

Workshop 3 (younger and elderly women, P13-P21)

After the warming-up, participants were asked to brainstorm on which unpleasant or unsafe situations they had already experienced in public transport and what strategies they used to cope in these situations. For the subsequent prototyping session, participants were split into 3 groups. Each consisted of one student and two senior participants. We introduced the following vignette and asked our participants to imagine a ride in an SAV with one or more people getting in that made them feel uncomfortable. Based on the collected personal strategies to solve safety-critical situations, the groups were asked to paper prototype possible technical concepts to ensure security and comfort. In the last part of the workshop, each group presented and discussed their conceptual ideas, and the researchers asked open-ended questions. This workshop focused on the production of (paper) prototypes and potential solutions.

4.2 Results

During Workshop 1, our participants produced the data themselves on the digital whiteboard and only part of the group discussion sessions was video and audio recorded and transcribed verbatim afterwards. The whole focus group session in Workshop 2 was video and audio recorded. The material was transcribed verbatim and, together with the transcribed material from Workshop 1, analyzed using qualitative content analysis [232, 233]. We used inductive coding and refined the themes and codes in an iterative process until the final themes and codes were identified. The analysis was carried out using MAXQDA [234]. Workshop 3 was not video recorded. Instead, the results were collected on post-its and our participants produced paper prototypes. Additionally, one of the researchers took notes during the plenary discussions. We clustered the results from all three workshops in an iterative way during discussion sessions among the researchers combining statements from the transcribed and analyzed material and the design solutions that our participants produced. Due to the interactive nature of our workshops and group works, a full transcription and thus quantification of the derived codes and themes is not practically feasible. Instead, we are following the good practice of qualitative content analysis [232, 233] and will present the synthesized results. First, we report on findings on the general attitude towards SAVs, and second, we report on security needs during the specific phases of the usage (booking, during the ride, departure, and arrival).

4.2.1 General Opinions on SAVs

Our participants pointed out that SAVs would have similar security issues as today's public transportation systems (sharing rides with strangers) and these could even become worse because of the absence of a driver. At the same time, SAVs could offer more security, for example, through authentication processes and first and last mile services. During all three sessions, it became evident how being mobile is connected to feeling autonomous and free (*"When you are unable to drive yourself then you suddenly realize how dependent you are. Everyone offers their help, but you don't want to bother others."* [P11]). This autonomy is constrained by insecurity not limiting oneself to mobility choices that are at the same time considered as secure is only possible at the expense of security which underlines its importance.

4.2.2 Phase 1: Booking

Participants were presupposing an app for the booking process where they could enter their destination and the system would offer available vehicles. Many ideas to foster a feeling of security were generated for the booking phase of the journey already. As a first step, our participants suggested a thorough profile authentication referring to other services, such as Airbnb. When booking an SAV, our participants differentiated between night and daytime. Thus, we will point to these differences in the following sections, where applicable.

Time

Participants wanted to receive information on the exact arrival time of the car, as they wanted to know how long they would have to wait for the vehicle. This mattered for different reasons: during the day, the time factor especially mattered due to time constraints caused by work, care-work, and other duties that had to be done. During the night, the information on the precise arrival time would avoid prolonged waiting times outside, making the first part of the journey safer. To guarantee this security, the vehicle's arrival has to be absolutely reliable. Push notifications should keep passengers updated in real-time to allow for taking actions in case of delays, such as staying inside until the car arrives. These push-notifications should also work proactively by informing the user that an adequate vehicle would pass by in a couple of minutes and *"it would be possible to hop on"* [P05].

Route

It was important for our participants to have detailed information on the route and the stops the vehicle would make. During the day, knowing this was essential to balance everyday duties. It would allow for trip-chaining [158] by providing the option to interrupt a journey and get off to, for example, go shopping and then continue home using another vehicle on a similar route. At night, the route was particularly important to avoid dubious neighborhoods.

Co-Passengers

Unsurprisingly, the role of co-passengers was dominant in the context of security in SAVs and already applied for the booking phase. Apart from thorough user profile information such as age, name or gender, participants wanted to know the destination of other passengers to know whether they should get off the vehicle before or after them. Other participants insisted that detailed information about others *“would make no sense at all”* and that *“in public transportation, you don’t know who is coming along either”* [P03]. Also, privacy concerns were expressed. In that respect, booking women-only vehicles was discussed during all breakout-sessions and was one of the favorite options for some participants, while completely rejected by others. Another vividly discussed feature was the blocking of co-passengers in the app to prevent offering rides with them in the future. Ticking this option should not be notified to the *“blocked”* out person. Furthermore, the app should have the option to report co-passengers behaving *“strangely”*.

4.2.3 Phase 2: During the Ride

Control

The results of our co-creation sessions underline that a feeling of control increases the feeling of security. Participants wished for a feature to be able to stop the vehicle (hardware or in the app), to *“jump out”* [P01] and even to change vehicles during the ride in case of uncomfortable situations. In this context, situations of medical emergencies or emergencies due to traffic were also of interest, especially for our senior participants.

Feedback from the system

Constant feedback from the system about the vehicle's route was desired for reasons of reliability, security, and control that the vehicle was going as planned. However, when going home, especially when traveling alone or during the night, participants wanted the possibility to hide their address and their exact stop on the information screen or in the app due to privacy and security issues. In addition, the system should send notifications when other vehicles are nearby to allow for changing from one vehicle to another spontaneously, in case that they would feel uncomfortable in the vehicle or with their co-passengers.

Emergency measures and human assistance

As possible solutions for enhancing the feeling of security within SAVs, cameras and emergency buttons were mentioned (see Section 4.2.3). In this context, the supervision of a person was unanimously presupposed, and one participant even pointed out that *“the psyche plays an important role”* and *“maybe we could have a dummy inside the car, and then we think: aw, he’s the driver.”* [P01]. Although we introduced the SAVs of the future as vehicles that drive in a fully automated mode without a human driver, the assistance of a human came up in different contexts. An interphone where a “real” person would answer was required. Additionally, security staff, especially during the night, would be an option for some of our participants to account for different types of emergencies, such as medical emergencies, inappropriate behavior of others, and technical failures. Furthermore, the system should offer the possibility to chat with staff in an unobtrusive way to feel more comfortable during the ride. Emergency buttons should be placed under the seat to be easily accessible. However, our groups discussed that an emergency button is not suitable for many situations. Usually, it would be pushed in cases of “real” emergency. In turn, in ambiguous situations, or when feeling uncomfortable or uneasy, people would be reluctant to press the emergency button. Thus, our participants stated that different solutions should be provided to address these different grades of emergencies.

Co-passengers

When discussing the ride itself, our participants refined the idea of the buddy system that was already proposed during the booking process: *“It is super practical if, for example, at a certain time of the day there are always the same people traveling. I don’t have to know that person necessarily in person, but since we always travel to work at [the same company] then I can add the person*

to my buddy pool" [P07]. Especially when traveling alone or at night, having the company of "riding buddies" or familiar people was considered an advantage.

4.2.4 Phase 3: Departure and Arrival

Virtual stops

Our participants suggested personalized departure and stopping points where – depending on the individual situation – the user should have the choice between being picked-up at home or at official hubs, maintained by the service provider. The system should offer the possibility to change the stopping points during the ride to adjust the exact stop of the car in the app and change it, for example, from one's home to a corner close by, underlining once more the need for control.

Last mile and arrival at home

Compared to public transportation, SAVs offer door-to-door service, which was considered a benefit for security. Nevertheless, from our participant's point of view, this service could go even further. During one breakout-session, it was discussed that when being chauffeured home by friends and family, the driver would wait until the passenger was gone through the door of her house and the participants proposed a companion from the system. They suggested this could be via the app, for example, through a chat function, or through a telephone call while walking the last bit of the way home. Users should give the system a confirmation when arriving at home. This must be very easy, for example, through a notification on the smartphone that the user just has to swipe away in a given time frame, otherwise, the system would check why the user did not send a notification. This would also account for people who live on their own and do not have a social network to rely on.

4.3 Discussion and Implications

We found a general openness to use SAVs among all participants. Especially our senior participants emphasized how important being mobile when getting older and not being that reactive anymore would be. Our participants emphasized that one would get used to driving in automated modes over time. Another topic they brought up was women-only vehicles. As the pros and

Table 4.1: Design Implications

Phase	Requirement	Need(s)	Feature	By
Booking	I want other users to be properly registered so I can be sure not just anyone uses the vehicle.	Security, Control	Profile authentication for 1st time users of service	App
Booking	I don't want to spend too much time waiting on the street.	Control, Information	Vehicle's precise arrival time is constantly communicated	App
Booking	I don't want the vehicle to pass certain/unsafe areas .	Control, Information	Vehicle's route is constantly communicated	App
Booking	I want to know the route, so I can combine different responsibilities on the way.	Control, Information	System informs on the route and stops	App
Booking	I want to know who else is coming along.	Control, Information	System informs about other passengers	App
Booking	I want to block the person that made me feel awkward the other day.	Control	System allows to block specific passengers	App
Booking	I want to have a buddy system to share rides with people I know.	Security, Connectedness	System allows to set up a personal buddy system	App
Riding	I want to know where we are and whether the vehicle will be on time.	Control, Information	Displays with vehicle's arrival time	In-vehicle
Riding	I want to see what the vehicle's next stop is.	Control, Information	Vehicle's stops are communicated	In-vehicle
Riding	I don't want others to see my exact address.	Privacy, Security	Exact address is hidden on the display.	In-vehicle
Riding	I want to feel like I am not alone.	Security, Control	(Digital) companion appears on the display/app.	Companion
Riding	I want an emergency button that is easy to reach.	Security	Emergency buttons under each seat	In-vehicle
Riding	I want to speak to a real person in case of uncomfortable situations.	Security, Control	(Digital) companion appears on the display/app.	Companion
Riding	I want to speak to a real person in case of emergency.	Comfort, Security	(Digital) companion appears on the screen display/app.	Companion
Riding	I want the vehicle to proactively intervene in uncomfortable situations.	Security	(Digital) companion appears on the display/app.	Companion
Riding	I want my trusted people to know where I am.	Security	System send position of the vehicle and arrival time to trusted contacts.	App
Riding	If I get off the vehicle I want another vehicle promptly.	Security	Apps offers available vehicles nearby.	App
Riding	I want to have the option to report passengers that were behaving "strangely" .	Control, Self-efficacy	Possibility to report on uncomfortable passengers.	App
Riding	I want to get off the vehicle if I feel anxious or uncomfortable.	Security, Control	Flexibility to stop the vehicle	In-vehicle
Dep./Arrival	I want the system to check whether I arrived at home safe and sound.	Security	System checks upon successful arrival and notifies trusted contacts.	App
Dep./Arrival	I want to choose where the vehicle stops: in front of my house or at the corner.	Control	Virtual stops instead of fixed stops	Infrastructure
Dep./Arrival	I don't want to be alone during the last mile.	Security	System offers last mile support	Companion

cons of women-only vehicles have already been discussed by [2], we will focus on the interaction part of the system in this paper and will not go into more detail regarding this concept. All proposed features are listed in Table 4.1 with the respective phase of the ride, the addressed need, and how it could be implemented. In the following, we discuss the importance of control (see Section 4.3.1) and a suggestion of the three most promising features (see Sections 4.3.2, 4.3.3, and 4.3.4). These turned out to be not particularly women-specific and these concepts target security in general. As already stated in the introduction, diverse groups of people may be affected by security issues in public transportation systems and they could all potentially benefit from the concepts that were derived during our workshops, making the contribution of our results even more important.

4 Unveiling the Journey: Understanding Women's Needs in Shared Automated Vehicles

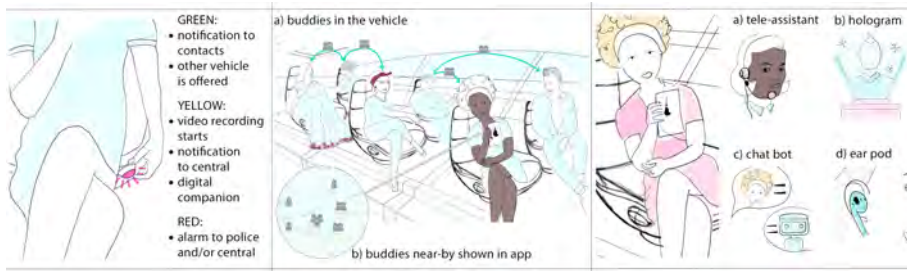


Figure 4.2: Main design implications (from left to right): 1) emergency button, 2) buddy system, 3) digital companion. ©Martina Schuß.

4.3.1 Need for Control

Control plays an important role on different levels. Participants explained they would want to have the ability to intervene at several points during the trip, such as stopping the vehicle, changing vehicles, blocking out passengers, deciding whether to accept a vehicle depending on its occupancy, etc. Indeed, [247] argue that passengers of SAVs prefer to be seated facing forward to have a feeling of control. Virtual bus stops that allow passengers to get off on individual demand have also been discovered by [248]. Compared to private automated vehicles, people experience less control and autonomy in SAVs (Chapter 3.2.4), underlining once more its importance. Control over a situation is even important for relaxing and enjoying the ride [120]. We extend these results as we can confirm what has been already known for public transportation [138]: control has a positive effect on psychological security and a lack of control significantly impact stress reactions [249]. Google's Waymo comes with a button to make the vehicle pull over at the closest safe place to stop [16] and we argue that besides constant information from the system about the route, the arrival time, the next stops, and the system status control should be stimulated through flexible adjustments of the seating. In addition to comfortable seating, its position, and themed designs [250], passengers should be able to adjust temperature, lighting [135], even scents [251], as these influence the senses and emotions and thus could help to reduce insecurity in addition to convey control.

4.3.2 Redesigning the Emergency Button

Our results illustrate the urge to rethink and redesign the emergency button. First, the emergency button should be easily accessible. As [143] already evaluated, an emergency button on the smartphone does not address the complex situations of insecurity. Thus, we propose that the vehicle should offer an emergency button, so passengers are not dependent on having their (charged)

smartphones at hand. Unlike emergency buttons in today’s public transportation systems, the buttons should be placed nearby, e.g., under the seats, and allow for the complex nuances of “emergencies”. This would make triggering the alarm more unobtrusive than today’s emergency buttons. We propose a three-stage emergency system (red, yellow, green) that adapts to the complex conditions of security, and addresses the inhibitions that people have if pressing the emergency button that they would usually do in case of attacks, or sexual harassment: the *green* phase is pushed in case of slightly uncomfortable situations and notifies trusted contacts about the passenger’s location and the passenger is offered an alternative vehicle nearby, so that the person can get off the vehicle. This would provide enough self-efficacy to leave uncomfortable situations, which influences perceived security positively [138]. The *yellow* phase is pushed in case of uncomfortable situations and unease and starts the video recording of the vehicle’s interior and sets off an alarm to a central. Simultaneously, it could be displayed to all passengers that someone set off the alarm to discourage potential escalations of a situation. The *red* phase is pushed in case of emergencies or situations that clearly are harmful, such as attacks. The police and/or the SAV central are notified immediately. It still has to be investigated how passengers can set off these different phases, e.g., whether all three should be placed under the seat, with different textures, for example, a soft button for the green phase and spikes for the red phase, or green and yellow can be activated differently (via app or display in the vehicle).

4.3.3 Buddy System

While our results show that security can already be provided during the booking process by implementing the relevant functions in the app, this is quite different and not sufficient during the trip itself. Here the app covers part of the functions needed, but at different points the desired participation of “real humans” or companions became evident. Based upon our findings, we propose two concepts that address people’s strategy of being accompanied by someone (via telephone or in real life) and how they could be implemented in SAVs: the buddy system and the digital companion. Fellow passengers often create insecurity but they can also provide security. Our participants suggested the possibility of having a pool of people to share rides with. This idea addresses the Social Network Theory and Theory of Virtual Community introduced in Section 2.2.3, where psychological security is promoted by a visual connection to familiar people and/or strangers. While cameras and maybe even real humans from the system have the dystopian flavor of (external) surveillance and come along with privacy issues, the buddy system, as suggested by our participants, has a utopian flavor of people caring for and about each other. From an economic perspective – if implemented meaningfully – it could save service providers staffing costs by using the community spirit. Mirnig et al.

[154] investigated the participant's behavior and willingness to assist in solving problems. They found that the passenger's role shifts from the passive passenger to the active participant because of the situation that there is no driver on board. A buddy system could be set up individually and based upon different characteristics, such as people traveling the same direction every day, people living in my neighborhood, people going out every Thursday night and looking for a buddy to travel back home, people that do not know each other, but that felt comfortable with each other during a ride, etc. The system should display available or present buddies during the booking process and during the ride (see Figure 4.2).

4.3.4 (Digital) Companion

In emergencies, our participants emphasized the need to contact with a person from the system. At least during the transition phase and during the adoption of SAVs, the system should have staff on board, as Riener et al. found that a human operator fosters trust and security in automated shuttle busses [248]. During the workshops, several groups discussed virtual operators or “digital companions” that would appear on the screen in the vehicles during the ride. We argue that this idea has great potential from an economic point of view, as it does not require personnel on board. The operator could supervise several vehicles at the same time while still providing a feeling of security. If implemented independently of the vehicle, the (digital) companion could also help in the last mile. We draw the results from our participants further and state that the companion could be 1) a human tele-assistant from the service provider, 2) an avatar or hologram, 3) a chat (bot) communicating with passengers through the app or a screen integrated into the seats, or 4) someone from the service provider talking to passengers via earplugs (see Figure 4.2). Which modality is most appropriate requires further research, as does the question of whether and under what circumstances avatars, holograms, or other “non-human” solutions would be accepted.

4.4 Limitations and Future Work

We conducted qualitative user studies with a relatively small sample size in Germany. Thus, our results are not generalizable, and our study should be replicated with more diverse groups of people. Furthermore, we would like to acknowledge that although we focused on women as one of the largest under-represented groups in AD research, our findings should be complemented with the perspective of men from different contexts. Finally, we used a participa-

tory design approach, and although we took a holistic view on rides in SAVs, more research on security in different contexts is needed. Researchers working in the shared automated mobility domain may further explore different concepts for security in the context of automated driving as there is a number of open issues to clarify prior to a broad dissemination of automated vehicles and shuttle buses, such as information needs of passengers and ways to replace the driver as an important security (and cost) factor. Our workshops and subsequent compiling and clustering of the results have several implications for future shared automated mobility solutions. Based on the presented opportunities and challenges, we define the following overarching action points for HCI researchers:

1. The possibilities of **ranking systems and blocking out co-passengers** seem to be a good starting point for an increased sense of security. These potential features have to be evaluated from the user's and society's perspective and from an ethical point of view. They may be biased by stereotypical prejudices and exclude people from SAVs.
2. **Information during the booking process** has to be researched thoroughly. How much information is already necessary during the reservation of SAVs? How should co-passengers and their respective information be displayed during the booking process in the system/app? How should privacy issues be handled in this context?
3. The **role and tasks of the human driver** should be examined in more detail to evaluate which parts can be done by the systems and at what point a "real human" is needed. Apart from giving information about the route, next stops, connections, and destination [120] the driver plays an important role for the perceived security, and their absence has to be accounted for.
4. Prototypes for a **"digital companion"** should be developed and evaluated to answer the following research questions: Which modality is the most appropriate (audio, video, chat)? Should the digital companion be visible to all passengers (e.g., on a large display inside the vehicle), or should each passenger have their own display instead? Could the "real human" appear on the passenger's app? How should a non-human companion, e.g., an avatar or hologram, be designed, and would it be accepted?
5. The development and evaluation of **"buddy systems"**. The potential of co-passengers as a source of security offers an opportunity, and the following research questions should be answered: How should the buddies be matched together, e.g., based upon demographic or geographical characteristics (living in the same neighborhood, working in the same district)? How much information should the buddies receive about themselves? Should there be any engagement of the system during the ride to foster a sense of commu-

nity? We propose an interdisciplinary approach with the participation of psychologists, sociologists, engineers, and computer scientists to develop an (AI-based) buddy matching system and the respective measurements and features in the vehicle's inside.

6. Finally, **quantitative data** from a broad spectrum of people is needed to evaluate the proposed concepts (women, men, different education levels, children, people with disabilities, etc.). Also, we suggest including different cultural perspectives. In particular, we would propose large data sets from countries with different gender indices [252].

4.5 Conclusion

In this chapter, we presented a qualitative study using participatory design techniques and focus group discussions to investigate women's security needs in SAVS under the consideration of different age groups and derived system requirements for such vehicles. While women represent half of the world's population and are the majority of our aging society, their needs have not been explicitly considered in the past. We introduce findings on the importance of security in the context of (automated) mobility services and illustrate results from the co-creation part of our sessions, including concrete features to ensure security in SAVs. Based on taking a holistic view on the ride, the presented data underlines the complexity of perceived security in shared mobility solutions. In summary, our contribution to the design of SAVs is 1) a holistic view (booking to arrival) on the ride with shared automated mobility solutions, 2) an in-depth view on potential security issues as well as a catalog with concrete system features for mitigation, and finally 3) an agenda for future research in the context of shared mobility and security. Addressing the fundamental security issues of SAVs could make a huge impact on the freedom of movement and feeling of independence to a large and diverse group of future passengers.

5 Designing for Users' Information Needs on Fellow Travelers: A Comparison of Day and Night Rides in Shared Automated Vehicles

Our qualitative user studies that were discussed in Chapter 3 emphasize security concerns as an important issue for automated ride sharing, especially for women — and particularly during the night. Passenger security will be challenging for SAVs, with the time of the day playing a essential role since passengers are more concerned about trips during the night. In this context, the absence of a human driver is essential [128, 253, 254]. Biermann et al. [170], confirm that there seems to be an increased need for security and future passengers might tend to accept the use of monitoring systems for the purpose of preventing crime, vandalism, and in case of health emergencies.

Lavieri and Bhat [157] found that not having a driver on board in an AV seems to be particularly problematic for Millennials as they see a driver as a kind of “guardian”. In their online survey, Sarriera et al. [133] found that major deterrents for adopting SAVs are being potentially related to unpleasant co-passengers, uncertainty regarding the length of a trip, and preferring privacy during a ride. The authors also discovered biased opinions toward passengers of different social statuses and races, leading passengers to prefer to have more information about their co-passengers [133]. An essential factor for adopting

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Note: both authors contributed equally to this paper.

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SAVs is related to passenger's acceptance to share space and time with strangers [132], which is even more important for leisure trips than business trips [157].

König et al. [169] evaluated whether information about potential co-passengers influences the acceptability of SAVs and measured how different levels of information affected participants' compensation demands. Detailed information about co-passengers proved to be beneficial [169]. Interestingly, they also found that information about men as fellow travelers resulted in higher refusal rates than information about women travelers [169]. In accordance with this observation, women seem to prefer being matched with other women to increase feelings of security [254]. Indeed, women-only vehicles already have been discussed in the context of public transportation [241], ride-hailing [177], and in the context of SAVs [135]. While we critically examined women-only vehicles in Section 3.3.3, the mentioned studies show that potential users have security issues with SAVs and underline the importance for the HCI community to come up with adequate solutions. Building on existing findings, we aim to investigate the effects of an artefact in form of a user interface providing information on fellow travelers on the psychological security of SAV passengers. We are aware of the potential adverse effects on privacy that exposing such information might have. For this very reason, we see the urge to evaluate whether exposing personal information leads to increased security after all and might be worth considering for the interface design of future SAV systems.

To overcome SAVs acceptance challenges, more suitable service concepts and UIs are required. Research in the context of public transportation shows that feelings of anxiety and unease when traveling with strangers greatly influence perceived security [255]. Building upon our findings from Chapter 4.2.2, we hypothesize that knowledge about co-passengers might positively affect perceived security, acceptance, trust, and overall user experience (UX). Consequently, this work investigates the following research question:

RQ5.1. How are SAV passengers' perceptions of security and corresponding UX, trust, acceptance, and emotions influenced by the time of day of a shared ride and their knowledge of co-passengers?

Most related work mentioned above used (online) surveys to examine user acceptance of (shared) AVs. As such, participants lack experience using SAVs. Therefore, we investigate our research question in a user study conducted with 24 participants in Germany using a controlled simulated environment enabling this very experience. On this basis, our empirically grounded findings confirm but also challenge previous works on shared AVs and shed new light on the effects of time of day and the interrelation of (co-)passengers. The paper informs on SAVs passengers' information needs, such as information about fellow travelers (e.g., name and picture) but also points out that providing such information may come with tensions and costs, e.g., reduced privacy. The findings can be

helpful to SAV service providers in designing future interactions in shared AVs that facilitate the technology's adaption and help passengers feel secure.

5.1 Material and Methods

To investigate our research question, we created a UI prototype representing a SAV in-vehicle passenger information display. Variants of the UI were evaluated in an exploratory within-subjects user study with a diverse sample of participants ($N = 24$; gender-balanced, wide range of ages) using a video-based automated vehicle simulator [256].

SAV UIs can range, e.g., from passenger information displays in vehicles and planning and booking applications on mobile devices to terminals at mobility hubs. They will provide the sole basis for the communication of passengers and the intelligent systems as no human operators (e.g., drivers) will be involved anymore. In terms of interaction modalities, already familiar technologies like touchscreens, information displays and control buttons seem to be preferred by potential SAV users [170]. The preference for established modalities, such as visual and auditory, and interior locations, such as the front area, is reflected by the systematic literature review on the in-vehicle design space by Jansen et al. [171]. They provide a comprehensive overview of input and output modalities and information locations and highlight the relevance of multi-modal in-vehicle interactions.

Since most currently available (S)AVs are still limited, prototyping and simulation methods are used to test and evaluate future (S)AV UIs. To ensure a meaningful transfer of study results to the development of SAV systems, it is essential to integrate the highly dynamic element of the context of use [257, 258]. In ubiquitous systems like SAV, this involves not only the consideration of auditory and visual factors but also the inclusion of surrounding elements like other people that might be present, as well as their relation to the respective users [257]. There are several methods to prototype the physical and social context of human-AV interactions [259], including lab-based prototyping with mock-ups, virtual reality, and simulators [256, 258, 260, 261, 262], wizard-of-oz vehicles (WoOz) [263, 264, 265], and experimental AVs [124, 254, 266, 267]. [259] provide a detailed overview of suitable methods and discuss the value of context-based interface prototyping for the AV domain. In general, each method offers advantages and disadvantages that have to be weighed by the experimenters depending on the focus of the study. While the use of experimental AVs for evaluating SAV UIs intuitively seems to be the first choice, it needs to be considered that current setups are still quite limited, e.g., to specific test scenarios and low speed limits [267]. If a study purpose can be

5 Designing for Users' Information Needs on Fellow Travelers: A Comparison of Day and Night Rides in Shared Automated Vehicles

achieved under these limitations, actual AVs might be suitable. However, to investigate human-AV interactions beyond those limitations, e.g., automated rides in complex urban environments, WoOz and simulators offer promising alternative approaches.

As [256] point out, virtual-reality-based simulators are often quite sophisticated constructs that can be applied to investigate driver-vehicle interactions where the simulation needs to adjust to the participants'/drivers' steering input. Since users of SAV systems are passive passengers, it is not necessary to enable study participants to control the simulation. Simulations can thus also be realized using "immersive video" [257], which offers a straightforward and time-efficient approach to prototyping SAV systems, e.g., [256, 261]. The latter is quite fitting to investigate human-AV interactions in specific situations (e.g., at a particular time of day) in a controllable manner but still with an adequate representation of the dynamic environment.

With our study, we aim to have a closer look into the information needs of passengers and counteract the limitations of an online survey by simulating rides in an SAV during different times of the day. At the same time, we do not necessarily say this would be the best solution. Quite the contrary, we acknowledge that 1) serious privacy side effects could arise, and 2) stereotypes could be further manifested. Still, we wanted to let participants experience receiving this information on their fellow travelers and discuss with them how it would influence their perceived security. Our motivation was to evaluate whether such a controversial concept would convey security after all and, if so, under what circumstances people would need and want to use it.

We identified leisure trips as a typical case for the use of SAVs during both day and night times. In each simulated ride, an in-vehicle UI prototype provided participants with information about the ride and fellow passengers. In the respective UIs, we varied the type and amount of information participants received when co-passengers boarded and left the vehicle. Information was either provided *with* personal data on co-passengers (name, age, target destination, profile picture), or *without*. We used a within-subjects design, and each participant experienced four rides: two night and two day trips, one with and one without personal information about co-passengers. The order in which each participant experienced the variants was randomized and counter-balanced.

Since we wanted to investigate shared rides, we identified two options to include the "sharing" aspect in the study: 1) simulating passengers boarding/leaving the vehicle with sounds and visual information displayed on the UI, and 2) using real persons ('actors') that complement the setup. Regarding the latter, Flohr et al. [256] investigated the effect of supplementing SAV simulator studies with actors mimicking co-passengers. While they found some support for the approach, it does not seem to increase participants' immersion in the simula-

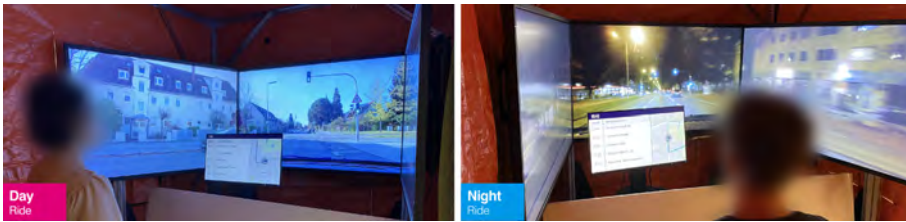


Figure 5.1: Study participants experienced two day and two night rides in the immersive video-based automated vehicle simulator.

tion. Instead, it seems to increase the occurrence of motion sickness symptoms in simulator studies [256]. Therefore, considering the potential adverse effect on participants' well-being during the simulator study and the problematic pandemic situation at the time of the study conduct, we decided to simulate co-passengers getting on and off the SAV only virtually. While this supports, on the one hand, our intended focus on the information display, this can, on the other hand, also be considered a limitation of the study, which we further discuss in our limitations section.

The study was conducted in accordance with the ethical guidelines stated in the Declaration of Helsinki [268]. Participants took part voluntarily, were obliged to provide their written informed consent, and had the opportunity to abort the study at any time without stating reasons.

5.1.1 Setup and Prototypes

Since contextual factors play a crucial role in passengers' travel experiences and information needs, we intended to establish a realistic but still controllable test environment for the user study. Therefore, we adapted the immersive video-based simulation setup used by Flohr et al. [256, 258] and combined it with the tent-based vehicle mock-up that we already used for our user enactment study in Chapter 3 (see Figure 3.2) to provide even more realism. The resulting setup (see Figures 5.1, 5.3) consisted of three LCD screens that played back videos representing a passengers' view out of the front, left, and right windows of a shared AV.

Similar to [256], we used audio and video footage of day and night rides through an urban environment to create simulations for two night and two day rides. The footage was captured using three action cameras mounted in the center of a BMW i3's windshield, as well as on the front side windows. In addition, we enhanced audio footage with additional sounds (e.g., opening and closing noises of sliding doors). Along with a 2x2 seating group, the footage was played back

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on three NEC Full HD 55.1-inch TV screens situated in a tent-based vehicle mock-up. The tent separated the simulation from the surrounding lab environment to support participants' immersion by entering a closed space when boarding the simulated SAV (Figure 5.3). The UI prototype of the passenger information display was displayed visually on an additional 24.1-inch screen (Figure 5.1). Audio sounds and voice prompts were provided by a Logitech 2.1 sound system.

Design Process and Prototypes

The tested UI prototypes were designed iteratively following findings from related user studies and a comprehensive literature review. We used video-based prototyping to create high-fidelity visual and auditory UI representations that matched the video-based simulation. The visual information display featured a split-view of 1) a schedule showing upcoming stops, estimated arrival times, and information on co-passengers getting on/off the vehicle, and 2) a map illustrating the current location of the AV and the planned route (Figure 5.2), which follows proposals of previous work (e.g., [135, 256]). We created two general prototype variants to investigate the research question (Figure 5.2). While the first variant ("without") does not show personal information about co-passengers, the second variant ("with") features such information by displaying name, age, target destination, and profile picture of co-passengers. For each test ride, participants experienced either a prototype with or without information on co-passengers, i.e., the variant stayed consistent within the rides.

Previous research suggests that combining these data reduces overall compensation demands for sharing a ride with a stranger [169]. We did not include a rating of fellow passengers, as rating systems hold discriminating characteristics which we discussed in Chapter 3.2.2. We used AI-generated pictures with neutral facial expressions [269] as photos of the entering fellow passengers. We included fellow passengers' age as we hypothesized that this information might influence participants' perceptions. Thereby, we defined two age groups: young (between 20 and 30) and older (between 50 and 60).

Age of fellow passengers was balanced so that each participant experienced one ride with a younger man/woman and an older man/woman as we expected that age could have an effect on passengers' perceived security. The provided contextual information (map, street names, etc.) matched the real-world environment where the simulation footage was recorded and animated (using Adobe After Effects CC 2021) according to the simulated vehicle's movements (e.g., the position of the AV in the map). For permutation purposes, we created eight video prototypes of the UI to have one variant without and one with information on

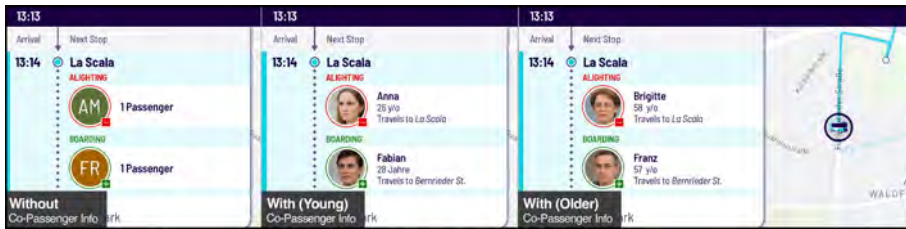


Figure 5.2: Apart from time of day (“day” and “night”), study conditions varied in the amount of provided information on co-passengers: 1) without information, 2) with information. In the two rides with information, co-passengers’ age varied between “young” and “older”.

co-passengers for all four simulated rides. Signal sounds and voice prompts complemented the visual UI (e.g., without: *"Next stop: [stop name]. One passenger gets on. One passenger gets off."*; with: *"Next stop: [stop name]. [Name of passenger] gets on. [Name of passenger] gets off."*). Voice prompts were created using text-to-speech conversion by Microsoft Azure.

Scenarios

We intentionally included participants covering a wide age range in the study, with young people not working yet, and older adults who do not work anymore. To provide for a broad spectrum of participants’ real lives, we chose leisure trips as scenarios for the four rides in the study. Since people are reported to be more likely to reject sharing rides with unknown fellow passengers for leisure trips compared to commute trips [157], we wanted to explore whether information about other passengers would mitigate this observation. All participants engaged in four trips: two during the day and two at night. We used storytelling to create authentic scenarios for each trip to enhance immersion. The day trips went from a bakery to a park to meet friends and back. The night trips started nearby the passenger’s home and had a restaurant as a destination where some friends were supposed to meet and were also round trips. To get even better acquainted with the scenario, participants received a paper ticket before each ride with their name, destination, departure and arrival time. After reading the scenario to them and handing over the ticket, our participants entered the shuttle bus, chose one of the seats in the front row, and one of the investigators started the video simulation. During each trip, one man and one woman as a co-passenger entered the vehicle virtually (i.e., this was only stated by the information displayed in the UI prototype). We did not randomize the order, i.e., it was always the woman entering first to avoid losing statistical power due to too many conditions. However, participants always rode with only one person at a time since we hypothesized that it would affect participants’ perceived secu-

city whether they would be sharing rides with a single man/woman or multiple persons simultaneously. The first (virtual) co-passenger entered at the first stop and got off at the second stop, where the second co-passenger entered the vehicle. At the third stop, participants' reached their target destination.

5.1.2 Participants

In total, 24 participants (12 women, 12 men, 0 diverse, 0 n/a; from 18 to 81 years, $M = 40.5$; $SD = 21.3$; $Mdn = 30$ years) took part in the study. All participants were recruited through university mailing lists and word of mouth and attended the study voluntarily. For participation, all of them received financial compensation (approx. 25 US dollars). Their national background was German, Indian, Turkish, Russian, and Iranian. As senior citizens are among the beneficiaries of SAVs but are currently underrepresented in AV research [178], we intentionally included six participants over 65 years old to cover their perspective.

We used the STAI inventory to measure participants' interindividual tendency to evaluate situations as threatening or to react with increased feelings of anxiety. According to the reference values of the trait anxiety scale (items 21-40; [270]) our participants are at the expected medium level of responding with anxiety. The women in our study had a mean value of $M = 36.5$ ($SD = 7.0$; $Mdn = 38.0$; expected value according to references = 37.0) and the men a mean of $M = 35.8$ ($SD = 4.4$; $Mdn = 36.0$; expected value according to references = 34.5). Participants fall into the average age group between 36 to 65 years and have a high educational level. They correspond approximately to the reference values of the Big5-short (see [271]) for extraversion ($M(SD) = 3.25(1.29)$; reference: $M(SD) = 3.62(.91)$), agreeableness ($M(SD) = 3.56(0.9)$; reference: $M(SD) = 3.43(.79)$), conscientiousness ($M(SD) = 3.93(1.03)$, $M(SD) = 3.47(.95)$; reference: $M(SD) = 4.2(0.77)$), neuroticism ($M(SD) = 2.45(0.94)$, $M(SD) = 2.48(0.9)$) openness to experience ($M(SD) = 3.45(1.21)$; reference: $M(SD) = 3.70(0.89)$). We therefore assume that the obtained results are not falsified through a non-representative sample (e.g., a sample with exceptional high scores in neuroticism could have an impact on the perceived security).

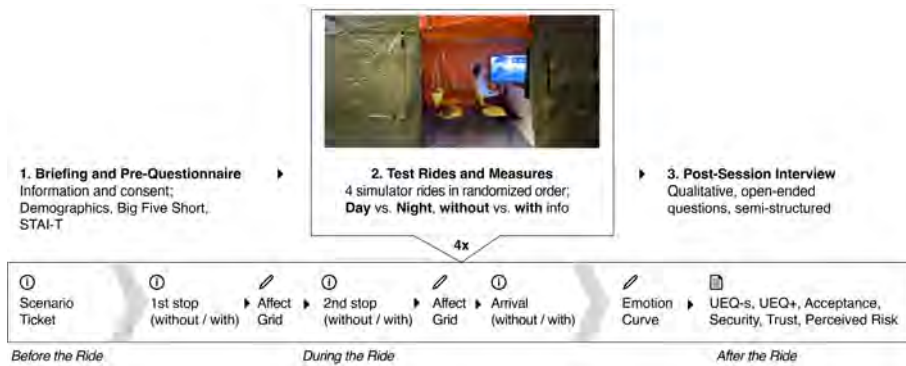


Figure 5.3: Study procedure (top) and sequence of the four simulated SAV rides (bottom).

5.1.3 Procedure and Measurements

We used a mixed-method approach [272] and triangulated quantitative data collected during and between rides with observations and qualitative interview data. Each study session can be divided into three parts: briefing and pre-questionnaire, test rides and measures, and post-session interview. Each session took between 60 to 90 minutes in total.

Briefing and Pre-Questionnaire

After receiving a briefing comprising general information about the study goal and the procedure, participants signed a declaration of consent. Then, they filled out a demographic pre-questionnaire. We also included the short version of the Big Five inventory [273, 274] to get insights into a participant's personality. Prior research showed that psychological factors and attitudes most likely influence people's adoption of AVs [275, 276, 277]. As the level of a person's anxiety influences the perceived security [278], we also included the state-trait anxiety inventory (STAI) [270] in our pre-questionnaire. Since current research is not conclusive on whether having experienced any sort of crime has an influence on perceived security [255], we left this aspect out.

Test Rides and Measures

During each of the four rides, participants filled out Russell's Affect Grid [279] in an adapted emoji-based version inspired by [280] using pen and paper. The

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Affect Grid is one of the most widespread models for emotion measurement and consists of two dimensions to measure: pleasure (displeasure — pleasure) and arousal (low energy — high energy) [281]. Each time information about an upcoming stop and entering or leaving passenger was displayed during the ride, participants were instructed to set a cross to express their current emotional state in the grid.

After each ride, participants got off the simulated automated vehicle and summarized their subjective emotional constitution throughout the journey by drawing an emotion curve on a template also used by [258, 264]. Subsequently, the experimenter accompanied them to a workplace where they filled out a digital questionnaire. Starting with the short version of the User Experience Questionnaire (UEQ-s; 8 bipolar items; 7-point scale; [282]) as well as the Usefulness [283] and Attractiveness [284, 285] dimensions of the UEQ+ (4 bipolar items for each dimension; 7-point scale; [283]) participants assessed their experiences of the ride and respective HMI concept. Since we expected the type and amount of provided information to have an effect on passengers' trust, participants also assessed the Trust in Automation scale of Körber (2 items; five-point Likert-type scale; [286]). Furthermore, we investigated users' acceptance with the Intention to Use (2 items; 5-point Likert-type scale), and Perceived Usefulness (3 items; five-point Likert-type scale) dimensions of Chen's adaption of the technology acceptance model [287]. Subsequently, we included Dekker's Security Concerns scale (1 item; 5-point Likert-type scale; [288]) and the Perceived Risks scale (1 item; 5-point Likert-type scale; [289]) as risk also has an influence on the perceived security [278]. After the last ride, each participant additionally filled out the Igroup Presence Questionnaire (IPQ, 14 items; 7-point Likert-type scale; [290]) to assess the quality and immersion of the simulated environment.

Post-Session Interview

Finally, we conducted a semi-structured post-session interview with each participant. We asked open-ended questions about the rides in general and the co-passenger information that was provided by the UI. Participants were asked which version of the UI they liked best and why. Participants were also prompted about potential feelings regarding security in the respective conditions, and we inquired whether some information was missing from their point of view. With the consent of participants, audio captures of all post-session interviews were recorded for an in-depth post hoc analysis.

5.2 Results

For the quantitative results, descriptive and inferential statistics were calculated using JASP 0.16 [291] and jamovi 2.2.5 [292]. The audio-recorded post-session interviews were transcribed verbatim and analyzed applying qualitative content analysis [232, 233] with MAXQDA [234]. Session notes and anecdotal evidence during the study complemented the data collection.

5.2.1 Dependent Variables

In the following, we report on descriptive and inferential statistics for a comparison of the study conditions in terms of our dependent variables, as well as for an assessment of the simulated setup by having a look at participants' presence perception. One woman (P21) only completed three of the four rides due to occurring simulator sickness symptoms. The missing data of P21 was imputed with maximum likelihood estimates [293] for the respective scales. We computed repeated measures analysis of variances (RM-ANOVA) to explore differences in the study conditions with the RM factors 'time of day' (day, night) and 'information on fellow passengers' (without, with) as well as the between subjects factor 'gender' (women, men). For the calculation of inferential statistics, we want to acknowledge our relatively small sample size ($N = 24$) and the non-normal distributions of some of our questionnaire scales (which can be observed in Figures 5.4 and 5.5) as potential limitations. However, as shown by Blanca et al. [294] ANOVA – and F-tests in general – are very robust against violations of assumptions which is backed by further related work [295, 296]. Thus, we agree with Norman that “parametric statistics can be used with Likert data, with small sample sizes [...] and with non-normal distributions” [295, p. 631]. When a RM-ANOVA returned significant ($\alpha = .05$) for a certain scale, we calculated post-hoc tests in the form of Holm-adjusted pairwise comparisons for all conditions and interpreted effect sizes according to Cohen [297].

User Experience

With reference to the UEQ-s benchmarks [282, 298], the tested SAV system received excellent ratings for both pragmatic and hedonic UX quality throughout study conditions (Figure 5.4). While we did not find meaningful differences in terms of pragmatic quality, hedonic quality, and usefulness, a RM-ANOVA revealed significant differences for the UEQ's attractiveness scale with regard to time of day, $F(1, 22) = 6.82, p = .016, \eta^2_G = 0.03$, and an interaction effect of passenger information and gender, $F(1, 22) = 5.06, p = .035, \eta^2_G = 0.02$.

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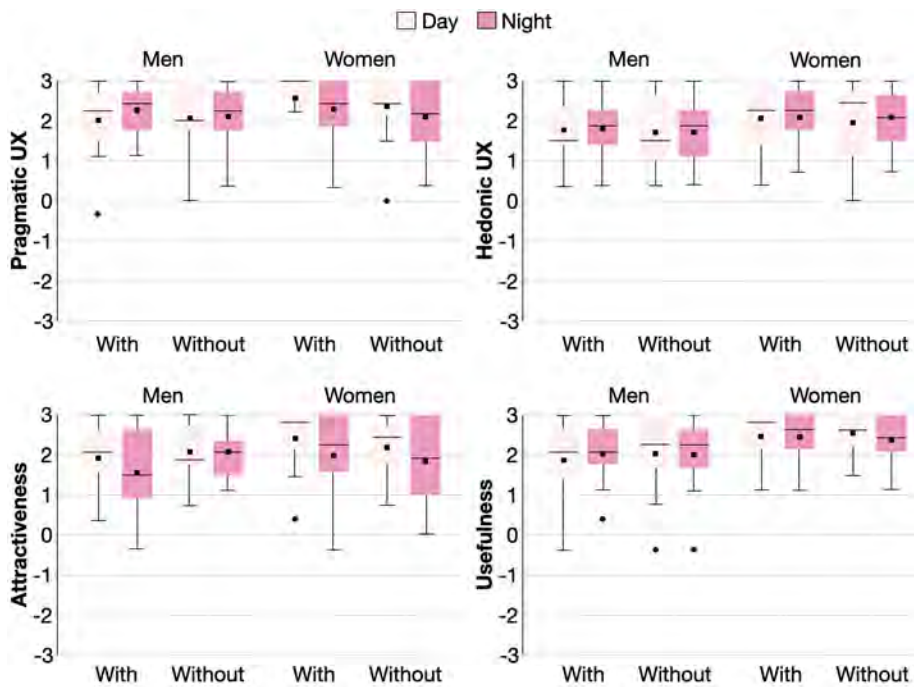


Figure 5.4: Boxplots of UEQ-s scales (pragmatic UX and hedonic UX), usefulness, and attractiveness (-3 = low; 3 = high) for the four study conditions (day, night, with information on co-passengers, without information on co-passengers) and the between-subjects factor gender.

Post-hoc tests show that participants' overall impression was significantly more positive, $t = 2.61, p_{\text{holm}} = .016$, during daytime than during nighttime (Figure 5.4), with a mean difference of $M(SE) = 0.3(0.1)$ and a medium effect of *Cohen's d* = 0.53. Despite the significant results of the RM-ANOVA, an interaction effect of information and gender was not confirmed by subsequent pairwise comparisons.

Acceptance

A between-subjects effect of gender returned significant in the RM-ANOVA for both used scales of Chen's TAM [287]: Perceived Usefulness, $F(1, 22) = 7.59, p = .012, \eta^2_G = 0.19$, and Intention to Use, $F(1, 22) = 6.49, p = .018, \eta^2_G = 0.16$. Post hoc comparisons confirm that women perceive the tested SAV to be more useful than men do (Figure 5.5, $t = 2.75, p_{\text{holm}} = .012$, with a mean difference of $M(SE) = 0.5(0.2)$ and a medium-sized effect of *Cohen's d* = 0.562. Similarly, women show a higher Intention to Use the SAV compared to men (Figure

5.5) with a mean difference of $M(SE) = 0.5(0.2)$ and a medium-sized effect, $t = 2.55, p_{\text{holm}} = .018, \text{Cohen's } d = 0.520$. Apart from the between-subjects effect and the generally medium-high to high acceptance ratings of the SAV, no meaningful within-subjects effects of time of day and passenger information on Perceived Usefulness and Intention to Use were revealed.

Security, Trust, and Perceived Risk

Participants' trust in the automated system was medium-high among all conditions (Figure 5.5). With regards to the medium-rated security concerns (Figure 5.5), participants seem to have some, but no severe concerns on their security during their ride. No meaningful difference induced by time of day or passenger information was detected. A significant difference was found in terms of perceived risks, $F(1, 22) = 7.32, p = .013, \eta^2_G = 0.01$. AMoD rides without information were perceived as significantly more risky than rides with information about fellow passengers (Figure 5.5) with a mean difference of $M(SE) = 0.2(0.1)$ and a medium-sized effect ($t = 2.706, p_{\text{holm}} = .013, \text{Cohen's } d = 0.552$).

Emotion

Judging from visual inspection of the affect grids and emotion curves (Figure 5.6), participants found rides during daytime and without information to be most pleasant. Rides without information seem to receive more positive assessments whereas the UI variants with information show higher dispersion in the affect grids. Generally, rides during daytime seem to be perceived more pleasant than night rides. In accordance with that, the statistical analysis of the quantified ($\text{min} = 1, \text{max} = 10$) uni-dimensional subscales of the affect grid (pleasure, arousal) revealed no meaningful effect in terms of arousal but significant differences in the pleasure ratings with regards to the time of day, $F(1, 43) = 12.39, p = .001, \eta^2_G = 0.03$. Rides during daytime ($M(SD) = 7.6(2.2)$) received higher pleasure ratings than rides during nighttime ($M(SD) = 6.8(2.2)$) with a mean difference of $M(SD) = 0.8(0.2)$ and a medium-sized effect, $t = 3.52, p_{\text{holm}} = .001, \text{Cohen's } d = 0.525$.

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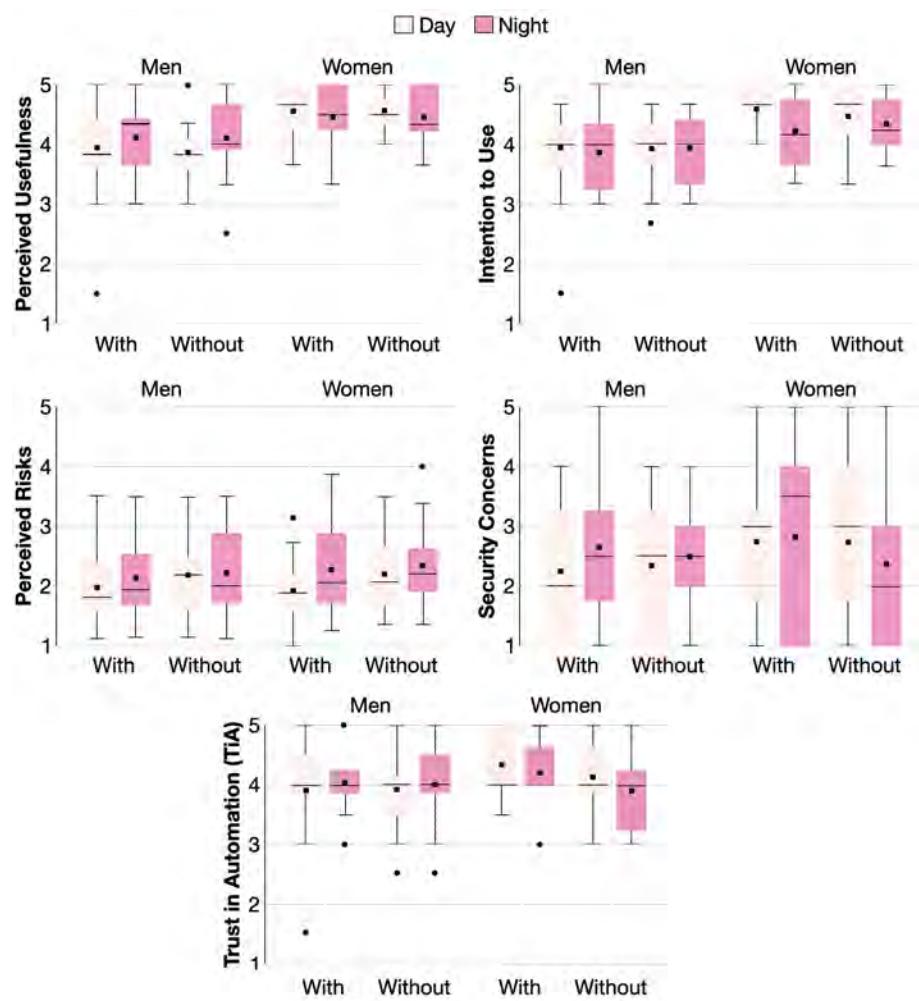


Figure 5.5: Boxplots of acceptance scales (perceived usefulness, intention to use), trust in automation, security concerns, and perceived risk (1 = low; 5 = high) for the four study conditions (day, night, with information on co-passengers, without information on co-passengers) and the between-subjects factor gender.

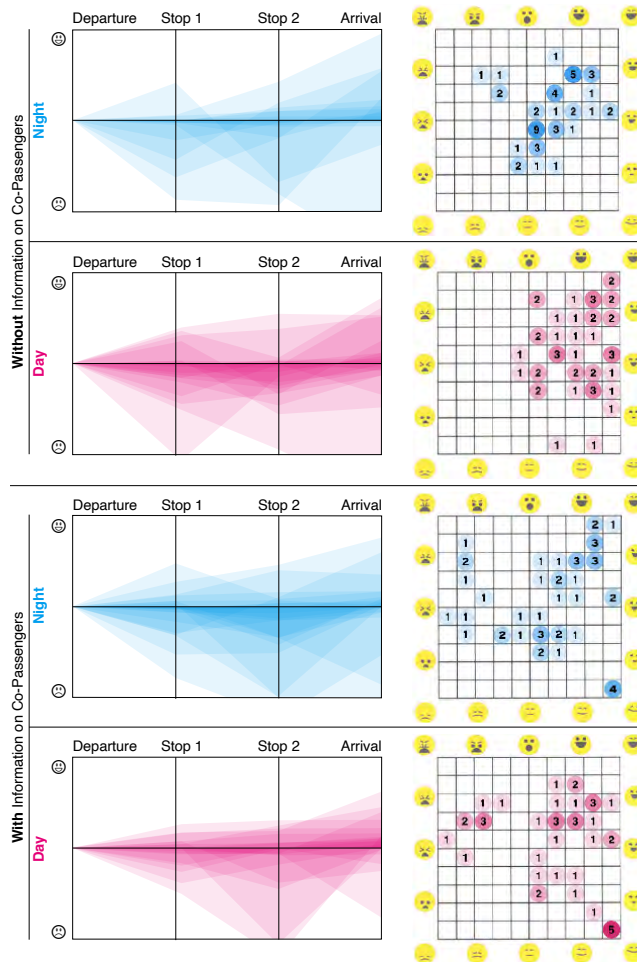


Figure 5.6: Stacked emotion curves (left; opacity: 0.1; normalized at ‘departure’) and affect grids (right) for the four study conditions. The aggregated plots got created with digitized versions of participants’ emotion curves drawn by them after each ride on the template also used by [264, 258] and emoji-based affect grids [279, 280] (see Section 5.1.3 for more information) they filled out during the ride each time information on upcoming stops was presented.

5.2.2 Qualitative Content Analysis

For the qualitative content analysis [232, 233], interview transcripts were initially explored line-by-line. In a second step, we highlighted text passages, searched for keywords, and added notes. Subsequently, the transcripts were scrutinized again and codes were derived from the text by applying inductive coding to refine themes and codes in an iterative process until the final expressions were identified. In the following, we present our main findings (e.g., statements expressed during the post-session interviews) with their number of mentions (n) and the number of women and men in our study mentioning them. First, we present the perceptions of the rides in general. Then, we cluster them according to three main topics: information preferences, day vs. night, and the type of information that participants were requesting.

Presence Perception and Experience of the Rides

In general, participants described the four rides as positive and considered the ride in the simulator as short, entertaining, and pleasant. Moreover, participants emphasized how realistic the four trips felt to them: *“Yes, it was quite real and I didn’t feel I am in the simulation room and it was so real. It was quite good, yeah.”* [P15], which is also reflected in the medium to high ratings for the four IPQ scales (Realism ($M(SD) = 4.0(1.1)$), Involvement ($M(SD) = 3.3(1.1)$), Spatial Presence ($M(SD) = 4.1(0.9)$), and General ($M(SD) = 4.9(0.8)$). Participants’ immersion in the simulated SAV can be judged to be quite high. Participants compared the simulated SAV journey to using public transportation systems such as buses or metros today (16; 6 women, 6 men).

Information Preferences

Overall, the qualitative data obtained in the study show that participants favored to have information about their co-passengers (15; 9 women, 6 men) over having no information (8; 2 women, 6 men). The most important reason for preferring the UI version with co-passenger information was security (22; 12 women, 9 men): *“I would have felt more secure with the display with the information and picture.”* [P05], *“I felt so much more secure compared to the other version.”* [P22]. Participants considered the information as more pleasant (9; 5 women, 4 men) in terms of being connected to others: *“when the person comes in and you have a little info about them, I thought that was pleasant. You could also — in case something happens — address them by name or, yes, it is more pleasant than the anonymous version.”* [P04]. Other advantages of

having knowledge about fellow passengers were that participants considered it to be more interesting (4; 1 women, 2 men) and humane (3; 1 women, 1 men). Participants who preferred having information about other passengers were also willing to share these information about themselves. In line with this finding, the most important reason for preferring the UI version without information was privacy (17; 4 women, 6 men): *“My first thought was ‘Oh no, people will know my name’. I don’t like that at all.”* [P12]. Other participants regarded this information as not important (4; 1 woman, 3 men). Displaying passengers’ details was even seen as insecure (3; 2 men) or untrustworthy (2; 1 man) as these details could potentially harm people. One participant expressed worries about the security of our young faux passenger (“Anna”) as he elaborated: *“Well, at night you’re just a bit more insecure, for example, when drunk, young people hop on. So [my worries] were also related to Anna, because people might think ‘Oh, here comes Anna now, maybe we can hit on her or something’. That would be quite insecure for her then.”* [P05]. Although of our 24 participants, 15 expressed they would prefer the UI version with information, we would like to point out that this was not a clear decision every time. One participant even was unable to decide which version they preferred. Most participants found pros, as well as cons, for both versions and were weighing these off until finally making a decision. While this reflects how security and privacy are antagonists, the appropriateness of the variants was considered to be highly context-dependent, as outlined in the following paragraph.

Comparing Day and Night

Generally speaking, our qualitative data confirms the difference the time of the day makes for sharing rides in SAVs with strangers as their number of mentions is higher (35; 9 women, 7 men) than statements that do not emphasize this importance (9; 2 women, 7 men). In this context, participants stated time-related concerns like *“during the night one is generally more careful and feels vulnerable”* [P09]. Several women (17; 9 women) expressed concerns when sharing rides with unknown men and said they would favor sharing a vehicle with other women at night over mixed vehicles. For instance, [P03] explains *“well, especially in the dark. During the day is not that tragic, but in the dark, I don’t want to share a ride with a man or get off the vehicle with him.”*. Interestingly, some of the men in our study conveyed similar feelings towards sharing rides with other men (8; 7 men) — particularly at night: *“Because it was Brigitte who got on at the first stop and then at the second stop it was a gentleman. That indeed made a difference to me.”* [P11]. As a reason they stated to feel more secure as a statement like, i.e., *“men tend to be more aggressive”* [P05] indicates. Participants also made clear that they would not need the displayed information on co-passenger during the day, but would prefer to have the information during the night: *“Especially at night it was more*

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pleasant for me and more important. [...] The fact that I was registered, for example, the [man/woman], as well. Yes, that was much more important for me at night than during the day.” [P22].

Type of Information

We asked participants which type of information they considered to be the most important one/s. The fellow passenger's profile picture was regarded to make all the difference (23; 7 women, 8 men) since it gives *"an impression of the person that is going to get on the vehicle at a glance"* [P16]. In this regard the photo seem to give participants a feeling of control over the situation while the other information provided was rather a *"nice-to-have"* [P23]. Knowing beforehand who would enter the vehicle also conveys security: *"Yes, I mean, I saw the picture and it looks nice and I actually had less fear."* [P03]. The co-passenger's gender was essential, as well (13; 5 women, 2 men), followed by their age (10; 6 women, 2 men), the name (8; 3 women, 2 men), and the respective destination of the co-passengers (7; 2 women, 2 men). Most of the participants in our study stated that the information the system was offering was sufficient and emphasized how helpful it was to see the vehicle's route and its arrival time on the display. Some participants provided improvement suggestions such as getting information in case people with special needs, big luggage, or strollers would enter the vehicle, or whether seat belt use was compulsory.

5.3 Discussion and Implications

Overall, the results underline people's openness towards SAVs, which is in line with our previous results from Chapter 3. Participants considered SAVs to be useful and reported relatively high trust in the technology, intention to use, and positive experiences of the (simulated) SAV rides. However, participants also expressed concerns regarding security — especially with regard to night rides. In the following, we discuss our findings in detail and situate them among previous work.

5.3.1 Night Trips Require Higher Levels of Information

In general, the SAV rides during the day were evaluated more positively than night rides. Participants consider the overall attractiveness of the SAVs higher and report more pleasant rides during the day. Rides without information about co-passengers were perceived as more pleasant than rides with information.

We hypothesize two reasons as sources of this findings: 1) participants are used to receiving no information about others when sharing a ride (as is the case in public transportation), and 2) people generally prefer rides during the daytime. This interpretation is comprehensively supported by our qualitative data and is in line with existing data from research in public transportation [134, 142, 299].

In contrast, rides with information provided by the in-vehicle UI were experienced to be significantly less risky compared to rides without information about co-passengers. Again, this is reflected in our qualitative data, with 21 participants underlining increased perceived security through the information. This can be taken as a general preference for information about co-passengers — particularly during the night and is in line with [300], who found that people are willing to provide information such as their gender, age, etc. to visually impaired persons in public spaces, if higher security assurances can be made. While during the day, information about fellow passengers seems to have rather adverse effects (e.g., in terms of emotion), this changes during the night, where it has, on the contrary, positive effects. Prior work underlines the importance of privacy particularly in public transportation [301]. Security and privacy are often antagonists in today's public systems and this dynamic has implications for resilience from a human factors perspective. This became evident in our study as participants mentioned privacy concerns when displaying personal information about other passengers, or themselves. During the interviews, participants weighed the pros and cons of having (no) information. Despite a preference for information during the night, this was not a clear outcome, which is also apparent in a higher dispersion of the Affect Grid assessments for the rides with information. While the information on co-passengers positively influenced security for some participants, there were also concerns that this information could have a negative effect exactly on security as strangers would know one's name and destination. To overcome the conflict between security and privacy, it needs to be investigated which information people feel comfortable sharing in order to increase perceived security.

From a human factors perspective, it is crucial to design systems that allow for individual differences and preferences, considering passengers' diverse needs and concerns. Resilience can be fostered by providing customizable options for displaying personal information, allowing passengers to make informed choices that align with their comfort levels.

5.3.2 Both Men and Women Prefer Sharing Rides with Women

While both men and women generally considered SAVs useful, women rated them significantly more so and uttered a higher intention to use such services. We assume that this finding is related to their (security) concerns in today's public transportation systems, especially considering night rides [128, 134] which we reported in Chapter 3. In combination with the qualitative data and the discovered interaction effect of passenger information and gender, this finding provides evidence that women seem to consider SAVs as more secure than 'classic' public transportation. Women and men alike explained in the interviews that they prefer sharing rides with women. This is in line with the findings of [169], who found people have higher refusal rates towards men as co-passengers. On the other hand, Polydoropoulou et. al [254] found different preferences of passengers for sharing with women/men between countries and cultures and that the number of fellow travelers further influences those preferences. In our study, we focused on rides with only one co-passenger as we expected this constellation would have the biggest effect on security. However, our results and the results from previous work [169, 254] underline once more the complexity of the topic.

5.3.3 Balancing Security and Privacy as a Design Challenge

In terms of overall SAV system design, there is most likely no 'one-fits-all' solution [238]. As, e.g., passengers' security needs are higher during the night, our data points toward flexible solutions for different times of the day. Based on our results, we propose that UIs for ride-sharing should provide general information on the route, arrival time, subsequent stops, and further information and functionalities to increase passengers' (feeling of) security for night rides. Providing information on fellow travelers can serve as a suitable option to do so. In our study, having a photo of fellow travelers was considered the most important information unit and was beneficial for passengers' feeling of security, while information on age, name, and destination played a subordinate role.

In the study, we chose portraits with neutral facial expressions. However, other expressions might induce different — positive or adverse — feelings, e.g., feelings of insecurity. Given that photos seem to provide passengers with (at least some feeling of) control over the situation, they might be used in booking apps or in-vehicle displays. Passengers could then look for an alternative vehicle, or leave the vehicle at the next stop if someone's photo would make them feel uncomfortable. The feeling of control has been shown to have a positive effect

on psychological security in the context of public transport [138] and, based on our results, we hypothesize that displaying a photo fosters this control.

However, given the disagreement among our participants and the aforementioned privacy issues, we suggest 1) not exposing sensible data about co-passengers during the ride and 2) considering alternative approaches. In terms of (1), it might be beneficial to relocate the information retrieval about fellow passengers to another time and place, e.g., the booking phase. For instance, [169] compared private and shared options on a mobile booking app and found that people tend to rather opt for shared rides when having detailed information on their fellow travelers prior to booking. This could also serve as a means to increase (perceived) security. In terms of (2), we propose a “buddy system” as introduced in Chapter 3 to address women’s security needs (during the night) that takes advantage of the fact that other passengers can also provide security. Instead of seeing them as potentially harmful, they provide a feeling of not being alone and security instead of the feeling of controlling the situation through information. The concept of “social passengering” [302] among passengers inside the same or different vehicles points to a similar direction and might be beneficial for the perceived security.

5.4 Limitations and Future Work

SAVs are still a relatively ‘theoretical’ subject [303] with real-life applications remaining missing. Therefore, we let our participants experience an SAV in a simulated environment. While participants report high presence perception and immersion, external validity is impaired due to the lab-based setup. As we were weighing off the negative side effects that come with lab studies, we opted for the simulated environment over conducting, e.g., a WoOz study in real traffic conditions, to compare the study conditions while ensuring high internal validity and high controllability.

As mentioned in section 5.1, we decided to simulate the presence of other passengers in a shared ride only virtually with sounds and display visualizations. While this was in line with the recommendation of [256] and facilitated the study’s conformity with applicable hygiene regulations during the Covid-19 pandemic, the representation of a shared ride’s social contextual is limited. On the other, considering our study design with multiple measurements during a test ride, the physical presence of another person might have affected participants’ assessment of the information and consequently the study’s reliability. Furthermore, we did not intent to focus on the inherent social factors or mutual relationships (that definitely play an essential role in the context of shared

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mobility), but focused on the provided information. Nevertheless, this should be considered when conducting further studies on SAVs.

Taking into account the large and diverse population of future SAV users, our study has been conducted with a small sample and, although having placed value on a broad spectrum of people (gender-balanced, different age groups, different cultural backgrounds, different education levels), it covers only a part of the variety of potential users. According to the STAI inventory, our participants had relatively low levels of trait anxiety. Since this trait likely has an effect of risk and security evaluation, generalizability is limited.

Furthermore, the study was conducted during the COVID-19 pandemic. We applied precautions like distancing and hygiene measures and followed the regulations of local and national authorities. While we consider the pandemic's effect on the study conducted to be minor, it might have affected the sample composition as, e.g., only people with medium fear and anxiety have signed up for the study. It would be interesting to repeat this study with people that show higher levels of trait anxiety as this trait influences the evaluation of risk and security of situations, and we hypothesize that these people could have evaluated the presented prototype in a more positive way.

The selection of the displayed information on co-passengers covers only a part of the potential variety and might have fostered stereotypes. We derived the solution with information about co-passengers based on existing research findings [169] and our own findings (see Chapter 3) and aimed to evaluate whether the availability positively influences security, UX, trust, and acceptance of SAV passengers. By no means we intended to manifest potential stereotypes or the exclusion of people through our selection. However, we want to point out that the selection likely affects the results (e.g., people might refuse rides with others due to their “look”). We are aware that the gender and age of other passengers is a limited view. Other factors, such as race, appearance, or the supposedly associated social statuses definitely play a role in people's assumptions about other people. However, we did not include more personal characteristics to 1) not confound too many different independent variables in the display variants and 2) we wanted to draw a clear line between evaluating the information about other passengers and participants' potential biases about, e.g., other cultures, as we aimed for the former.

Passengers' information demands in SAVs are a highly complex and context-dependent issue requiring more research, especially on how to overcome the conflict between security and privacy by design. Based on our results, we suggest extending the conduct of context-based empirical studies investigating factors like daytime and fellow passengers in SAVs along the whole travel journey. Since, e.g., security issues are relevant for the booking, the ride itself, and on-/off-boarding (see Chapter 3). While our study focused on the

ride itself, further (empirical) studies should also consider the booking phase and the off-boarding when investigating the effect of co-travelers and time of day on passengers' need for information and controls. Here, additional information and safety measures (e.g., emergency/support button) might support passengers' feeling of control and security. To yield results with high external validity, future studies might include more contextual factors such as the (physical) presence of various and multiple other people in SAV rides during different situations. E.g., actors could be used to mimic specific situations [256].

It would also be interesting to repeat this study in different cultural contexts, as we conducted our study in Germany, where security in public transportation offers high levels of security [138]. However, we assume that conducting similar studies in countries, such as India or Latin American countries, where public transportation is more difficult to access — especially for women [142] — might yield different results. The applied simulation environment presents a context-based prototyping approach that can be used, e.g., to replicate this or similar studies in other countries and investigate potential cultural differences regarding passengers' (information) requirements. Future work might also consider the potential impact of culture and race as an independent variable in the information display. This could result in an exploration of people's explicit and implicit biases based on given prior knowledge.

We used the front of the vehicle as the output location of the information, as these are common modalities [171]. Future concepts might also investigate whether (the combination with) other modalities, such as tactile, influence the perception of the presented information and the feeling of security.

5.5 Conclusion

In this chapter, we report on an investigation regarding the effects of time of day, information on co-passengers, and gender on SAV passengers' perception of security, UX, trust, and technology acceptance. While the evaluated SAV system received excellent ratings in hedonic and pragmatic UX quality and positive trust and acceptance ratings, participants emphasized security concerns — mainly when using a SAVs at night. Both women and men in our study preferred sharing rides with women over rides with men as co-passengers during the night, whereas during the day, this information negatively affected participants' evaluation of the SAV. Risks were experienced to be lower when participants were provided with (personal) information about their co-passengers. In general, most participants preferred such information, with a photo of fellow travelers considered the most important information element. However, our results yield ambiguities since providing personal information also triggered

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privacy concerns among participants, which can be taken as an illustration of the complexity of psychological security, as well as its context dependency. Building upon these findings, we conclude that providing information on fellow passengers can support SAV passengers' feeling of security in shared rides and potentially improve UX and overall acceptance. However, due to privacy concerns and associated risks, the time and place of the information need to be questioned. I.e., it might be beneficial to provide this information during the booking phase but not within the vehicle. Future work should consider the whole travel journey of SAVs, foster the inclusion of contextual factors and investigate how the provision of additional information and safety measures (e.g., emergency/support buttons as in Chapter 3) can increase passengers' feeling of control and security.

6 Understanding Operator Influence in Automated Urban Shuttle Buses and Recommendations for Future Development

Shared mobility could experience a considerable increase through shared automated shuttle buses [304]. This concept is expected to bring the most environmental and economic benefits [305]. With rides being shared among several passengers, congestion and emission reduction is possible [158]. For passengers, automated buses and people mover are promised to become affordable means of transport with equivalent prices of today's shared mobility [306, 307, 308]. However, to exploit all the potential benefits of these buses, many individuals would have to switch from private to shared transportation [50], which at least is questionable [156]. In the studies we discussed in Chapters 3 and 5 we found a general willingness to use shared automated vehicles (SAVs), particularly for their environmental advantages. At the same time our results give evidence that security issues could prevent people from using SAVs. As a matter of security, the absence of a human driver is indispensable [128, 253, 254] as they are seen as “guardians” [245]. This might keep passengers away from using mobility systems without a human on board. In this context, Biermann et al. confirm [170] that there seems to be an increased need for security, and in Chapter 4.3.4 we offered suggestions for design solutions accounting for the absence of a human driver on board.

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When aiming for SAE level 5 automated shuttle buses, the system will have to substitute for the driver in terms of operation and security aspects. To achieve this, first, the roles of operators today have to be identified, and concepts have to be developed for how automated shuttle buses will take over these roles. In the context of ride-sharing services, a study by Brewer revealed that taxi drivers occupy several additional tasks (physical, relational, etc.) apart from driving [309]. To the best of our knowledge, no literature yet analyses the role of the operator on board today's automated shuttle buses. In on-site studies, the safety operator is disguised as a co-passenger to examine people's acceptance when riding without personnel on board [154, 267].

Accordingly, we pose the following research questions:

- **RQ6.1.** What are the roles of operators in automated shuttle buses?
- **RQ6.2.** What are the preferred concepts for replacing operators aboard automated shuttle buses for the targeted SAE Level 5 scenario?

6.1 Material and Methods

To answer these questions, we followed a mixed-method approach and combined in-depth interviews with operators employed in current pilot projects in Kelheim and Kronach, online questionnaires, observations, and interviews with passengers using the shuttle buses in these projects and with people that never used such buses. Through this combination of methods and participants, we aimed to gain holistic insights into the operator's role from several perspectives and to evaluate the concepts we proposed in Chapter 4.3.4 as a substitute for the driver on board: a virtual operator or "digital companion" that would appear on the screen or in the vehicle's interior as a substitute for a driver or operator. In the respective chapter within this thesis we present different implementation scenarios ((a) a human tele-assistant, (b) a hologram or avatar, (c) a chatbot, (d) ear pods) that we adapted by replacing their concept of the "ear pods" with an assistant robot. A companion based exclusively on voice interaction is less embodied [310] than other human-like appearances as, e.g., robots and the other three concepts are more materialized. Building upon Sanguinetti et al. [135], who propose a remote human or a robot to monitor the vehicle's inside and account for the absence of a driver, we included a robot in our study. Our resulting four concepts are ((1) a human tele-assistant from the service provider, (2) a hologram, (3) a robot, and (4) a chat (bot) communicating with passengers through the app or a screen integrated into the seats, see Figure 6.1), and have been evaluated during our study. As we aimed to iterate our concept of the digital companion from Chapter 4 and develop it further, we

also explored what roles, characteristics, and personalities a digital companion should represent from a user perspective and investigated them in an online questionnaire. Thereby, we were guided by the design space that Bouquet et al. [311] propose for assistants in video games, which emphasizes the importance of their behavior, personality, and relation to the player.

6.1.1 Interviews with Operators and Observations

For our interviews and observations, we visited two pilot projects of automated shuttle buses on-site: Kelheim with the corresponding project KelRide [102] operating an EasyMile EZ10 and Kronach, which is part of the SMO [101] operating with a Navya. During our two on-site visits, we interviewed five operators (1 woman, 4 men, 0 diverse, 0 n/a; from 22 to 63 years; $M = 45.4$; $SD = 16.6$, $Mdn = 45$ years). Two in-depth interviews with chief operators were conducted at the headquarters of the shuttle bus service provider with a duration of approx. 90 min each. Additionally, we accompanied three operators during their shifts in the automated shuttle bus for 12 h in total and conducted contextual interviews. For the interviews, we used a semi-structured interview guide and started with warming-up questions and continued with open-ended questions about the following topics:

- (a) *Operators' tasks*: What activities do operators perform during a normal workday? What does a typical workday look like?
- (b) *Passengers*: What works particularly well for passengers in their everyday use of the shuttle bus? What are the challenges for passengers in their everyday shuttle bus use? As an operator, what requests do you receive from passengers, and how do you respond to them?
- (c) *Roles and Characteristics*: What roles do you have as an operator? What are the expectations/needs of the passengers from you? What qualities should an operator have? Which of these roles do you find particularly challenging? Which of these roles could be taken on by a technical system, and which not?
- (d) *General Challenges*: What are the biggest challenges in your everyday professional life? The interviews with the chief operators were audio recorded and transcribed verbatim afterward. The interviews with the three operators were combined with observations during the regular shuttle bus operation and were partly video and audio recorded and transcribed afterward. Additionally, one of the researchers took notes.

6.1.2 Interviews and Online Questionnaire with Passengers

In total, we interviewed 40 participants (21 girls/women, 19 boys/men, 0 diverse, 0 n/a; from 8 to 85 years; $M = 49.0$; $SD = 21.3$; $Mdn = 44.5$ years) of which 25 participants were interviewed during our on-site visits after their rides with the automated shuttle buses (5 in Kelheim, 20 in Kronach) and 15 participants were interviewed during an on-campus festival at our university and had no experience with automated shuttle buses. Additionally, 40 people (18 women, 21 men, 0 diverse, one n/a; from 18 to 72 years; $M = 32.3$; $SD = 14.6$; $Mdn = 24$ years) filled out our online questionnaire.

On-Site Interviews

During our observations in the automated shuttle bus, we took notes about the passengers' reactions towards the vehicle and any other incidents that took place during the rides. When passengers entered the bus, we informed them about us observing the rides, and we were not actively engaging with the passengers. After the rides, we kindly asked them whether they would participate in the interview. All interviews took place inside the bus as it usually had a 15 min break at the final stops. One of the researchers conducted the interviews and the other researcher took notes. The interviews were semi-structured and covered the following topics:

- (a) *General Usage*: Was that your first ride with an automated shuttle bus? What was the purpose of your ride? Do you use it regularly? Why do you use it?
- (b) *General Impression*: What is your general impression of the shuttle bus? Which aspects/functions did you enjoy the most? What could be improved?
- (c) *Operator*: From your perspective, what is the operator's role? What influence would it have on your shuttle bus usage if no operators were on board anymore? How could a technology replace the operator? We then introduced different concepts of how technology could replace the human operator (see Figure 6.1) and asked our participants which concept they preferred and why. Additionally, we asked open-ended questions when participants came up with new topics.

The first five interviews were audio recorded and transcribed verbatim afterward. During the 20 interviews that took place throughout the second on-site visit, one of the researchers took notes, as we were given restrictions by the service provider about the audio recording of passengers.

On-Campus Interviews

During an on-campus event at our university, we interviewed people with no prior experience of automated shuttle buses. We briefly introduced the concept of such people movers and explained that, currently, an operator has to be on board for safety reasons. We explained that in the future, the role of the operator will be replaced by technology and introduced four prototypical concepts (see Figure 6.1) of how this technology could look like and asked participants to rank them by which concept they desired for trips in an automated shuttle bus with no operator on board. We then asked open-ended questions about each concept and the respective rankings. The rankings of the concepts were photographed, and the main researcher took notes of the interviews. The focus of this study was to gain qualitative insights about the reasons for preferring one concept over another.

Online Questionnaire

We recruited participants for our online study through an announcement in a university newsletter and through flyers that we distributed during our on-site studies. The questionnaire included open and closed questions and was structured as follows:

First, participants were asked about their experiences with automated shuttle buses. Participants with experience with shuttle buses were asked follow-up questions about the advantages and disadvantages of a people mover, their opinion about the operators, and in which situations they needed assistance.

Second, participants were asked whether they would use automated shuttle buses without an operator on board, and an introduction was given about the operator being replaced by technology. The following questions were about the modality, appearance, roles, personality, and several characteristics of such technology. We used polarity profiles of two opposing with an 11-scale slider to indicate the preference and multiple-choice questions.

Third, we introduced the four concepts (see Figure 6.1) that were used during the interviews on-campus and asked about participants' most and least favored concept for trips in an automated shuttle bus with no operator on board, and why. We did not specify any capabilities and limitations of the concepts to our participants, as we followed an exploratory approach of their evaluation. As these concepts are set in a future scenario with the vehicle being able to drive in fully automated mode, these concepts do not provide any driving functions. Finally, we closed the questionnaire with demographics.

6 Understanding Operator Influence in Automated Urban Shuttle Buses and Recommendations for Future Development

In this questionnaire, we focused on gaining quantitative insights about the preferred concepts and further requirements for a technology as a substitute for the operator. The online questionnaire took approx. 10–15 min.

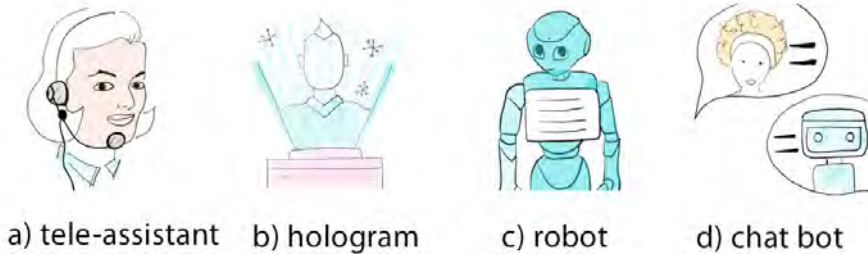


Figure 6.1: Four Concepts: (a) human tele-assistant, (b) hologram, (c) robot, (d) chatbot. ©Martina Schuß.

Data Collection and Analysis

Part of our qualitative material (in-depth interviews with the two chief operators and five semi-structured interviews with passengers) was transcribed verbatim and analyzed using qualitative content analysis [232, 233]. We used inductive coding and refined the themes and codes in an iterative process until the final themes and codes were identified. The main researcher conducted the analysis using MAXQDA [234]. Other parts of our data (observations inside the automated shuttle buses, 20 semi-structured interviews, and interviews that took place at the on-campus festival) were not recorded. Instead, one of the researchers took notes, and the results were synthesized with the transcribed results. We clustered the results from the interviews and observations iteratively during discussion sessions among the researchers combining statements from the transcribed and analyzed material and the observations. Here, our primary focus was the status quo of the usage of automated shuttle buses, passengers' opinions on them, and a collection of incidents inside and outside the vehicle. Thus, we are not quantifying our qualitative materials and instead are following the good practice of qualitative content analysis [232, 233] by presenting the obtained categories. For the evaluation of the four concepts that we presented to our participants, we will offer descriptive statistics of the respective rankings, as well as for the online questionnaires.

6.2 Results

In the following, we will introduce the synthesized findings from our interviews, observations, and the online questionnaire, which we structured according to their content. First, we report on the roles that operators assume. Second, we report on other road users' interactions with the automated shuttle bus. Third, we explore how the perceived and actual roles of operators differ. Finally, we report on the evaluation of the concepts of digital companions and further requirements for them.

6.2.1 Roles of the Operators

From a legal point of view, the operator is an indispensable technical supervisor who acts as a monitor and emergency level of the automated driving function [312]. However, our interviews with the operators and passengers and our observations show that the operator has multiple additional roles beyond, which we will present in the following.

Traffic Controller and Road Safety Educator

One dominant function of the operator is communicating with and regulating other traffic participants, such as car drivers, cyclists, or other vulnerable road users. We observed that the operator used hand movements to give a short signal to other drivers (mostly cars that followed the automated shuttle bus for a slightly longer time) for safe overtaking maneuvers. Many drivers would not overtake the shuttle bus despite its very low speed because they were hesitant and expected a human signal as a reassurance. As a result, minor traffic jams frequently occurred behind the automated shuttle bus—especially in narrow streets (see Figure 6.2)—leading to nervousness and impatience among the drivers. Again, the operator waves them through by hand gestures and manually stops the bus to clear the congestion. Other drivers stop, although they have the right of way because they are unsure how the automated bus will react. In these cases, the operator waves them through to reassure their way of right. At the same time, we observed risky overtaking maneuvers by both car drivers and cyclists. These sometimes cut the automated vehicle so that it also triggered an emergency stop.

The operators explained that one of the most frequent reasons for the vehicle's unplanned stops is wrong parking cars that are in the vehicle's way and sometimes even prevent its onward journey. If possible, the operators talk to the

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Figure 6.2: Slow moving traffic behind the automatic shuttle bus.

car drivers to ensure they do not park the cars wrongly in the future: *“I then tell them ‘You know, it is an automated bus, it has sensors, and when you park here it detects your car as an obstacle and cannot continue its ride. Please, do not park here next time’* [Operator4].

Technician

Apart from wrongly parked cars, obstacles in the vehicle’s way may cause the people mover to stop and have to be removed by the operators. In such cases, the operators clean the sensors and clear away small obstacles. If the shuttle bus has any technical problems and errors they cannot solve themselves, they dump the vehicle’s backlog and forward it to the technical support from the vehicle manufacturer.

“Driver”

The operators act like drivers as they permanently monitor the vehicle’s surroundings and other traffic users through the windows and the mirrors. When the vehicle stops, it either finds its way back on route, or the operator has to put it back on track with the joystick as the vehicle can only continue its trip from the precise position. The process is cumbersome and has to be carried out *“by experience”* [Operator1, Operator5] with the vehicle’s position that is displayed inside the vehicle. At dedicated points where the vehicle stops on purpose, the operators react with foresight, for example, by looking into the intersection and proactively switching into manual mode to avoid a stop when it is possible to continue safely.

The Psychologist

One of the essential parts of the operators is being a “*psychologist*” [Operator1] as the majority of the passengers are tourists and use the automated vehicle for the first time and are cautious, reserved, or even anxious. During the observations, it became evident that each operator had their strategy of “*taking away the fear*” [Operator3]: One operator explained: “*I start with a joke. For example, I say “Is this your first time on the autonomous bus?” and when they say “yes” I say “me too.”. And then everybody laughs, and it breaks the ice.*” [Operator1]. Other operators stated they would be explaining how the automated system works to calm passengers down, and all of them emphasized the importance of their presence in the context of anxiety and insecurity that passengers go through when traveling for the first time.

Informant

During the observations, it became evident that passengers desired information on the vehicle’s behavior. The observed shuttle bus projects are currently in their pilot phases, and the system’s sensors are very sensitive. This leads to many (unnecessary) stops, irritating passengers. In these situations, we could observe that passengers usually turn to the operator and ask them why the vehicle stopped, and the operator then explains the reasons. Passengers also asked diverse questions about how the autonomous system works and about future prognostics towards automated systems in general. The operator must have versatile technological knowledge about the system to be able to respond appropriately. All operators undergo a two-week training about the handling of the vehicle and information about its technology and this training has to be renewed every year.

Supervisor

The operator acts as a supervisor who reacts to the behavior of the passengers with instructions. Often the vehicle breaks abruptly, and it is indispensable for passengers’ safety to have their seat belts fastened. Furthermore, it is not allowed to drink or eat during the rides to avoid choking, and suffocation, and these instructions have to be given to the passengers as they are not accustomed to it from regular public buses.

Other Road Users

Our observations and the interviews with the operators clarified that other road users generally are annoyed by the shuttle bus. Due to its many stops and switches from automated to manual mode and its average velocity of around 3 miles per hour, the bus is a slow means of transport. This underlines the gap between car drivers', cyclists', and pedestrians' expectations and the reality, leading them to say: *"Why doesn't it keep on moving? Why doesn't it drive around the obstacle?"* [Operator1]. Car drivers and cyclists behind the automated vehicle become impatient, grumble and overtake it, which results in abrupt stops of the bus if cars or bicycles shear in too tightly in front of it. On the other hand, our video material shows that cars sometimes do not drive, although they have the right of way and are hesitant and unsure of what the people mover's next move will be. In these cases, the operator signals other traffic participants that driving is safe. Still, others accept the way the shuttle bus works and even make space in oncoming traffic sometimes because they know that there are sensors and if the distance is too short, the bus would reduce its speed. Pedestrians react with enthusiasm and awe towards the self-driving bus. They turn their heads toward it and point to it with their fingers or take pictures with their smartphones when it passes them.

6.2.2 Disparity Between Perceived and Actual Roles of Operators and Their Importance

From our questionnaire interviewees' point of view, the central role of an operator on board the automated shuttle bus is the informant (55%) followed by the supervisor (22.5%). Service personnel (7.5%) and entertainer (5%), bodyguard (5%), and guardian (5%) were less mentioned, and surveillance was not mentioned at all. Interestingly, informant and supervisor are among the dominant roles we could observe during the rides in the shuttle buses. These responsibilities have rational and distanced attributes. However, as explained in the previous section, we noticed that many operators' tasks also have emotional and approaching attributes. They calm and reassure nervous passengers and embody the human guardian to rely upon. While these roles could be underestimated at first sight, they are crucial for passengers' trust and comfort, especially during the introduction of automated shuttle buses, as many passengers may be first-time users that will need guidance and information. The results of our online questionnaire show that the ratio of responses that perceive the presence of an operator as unimportant (44%) and those that perceive it as important is balanced (48%), with only a few participants being indifferent about it (8%). Despite that, most of the participants in the online questionnaire indicated they would use the automated shuttle bus without an

operator on board (68%), and around one quarter stated they would not use it (24%, and 8% were indifferent). More detailed descriptive statistics of the answers on an 11-scale slider are presented in Table 6.1. Our findings show that the operator is regarded as essential, but most of our interviewees would use an automated shuttle bus without an operator on board (see Table 6.1).

Table 6.1: Descriptive Statistics: Importance of Human Operator from 0 (= not at all/unlikely) to 10 (= very important/very likely).

How Important Do You Consider the Presence of a Human Operator?										
0	1	2	3	4	5	6	7	8	9	10
8%	16%	12%	4%	8%	8%	8%	16%	4%	0 %	16%
How Likely Would You Use the Shuttle Bus With No Human Operator?										
0	1	2	3	4	5	6	7	8	9	10
8%	4%	0%	8%	4%	8%	0%	16%	16%	12 %	24%

Even though there is a general openness towards using the automated shuttle bus without an operator on board, we argue that concepts are needed to account for the operator’s multiple rational and emotional roles.

Acceptance

In general, the acceptance of the automated shuttle bus is ambiguous. From the passengers’ and other traffic users’ perspective, its slow velocity is considered the main disadvantage leading to the bus being a traffic obstacle. Even though people do consider the operator as an important and supportive factor (see Section 6.2.2), at the same time, their presence on board confuses people (*When will it drive by itself? We thought it was an autonomous bus, what is the man doing in there?*, [P02].) and they question the vehicles “automation”. Indeed, at the moment, around 50% of the time, the vehicle operates in manual mode with the support of the operators (these numbers were communicated to us by the service providers who track the status of their vehicles permanently). On the other hand, passengers’ confusion about operators inside the vehicle reflects that a large part of the population is unfamiliar with the experimental and early stages of automated driving. Due to the missing awareness of how the sensors of the vehicle function, other road users are a challenge for the bus as they pass it too closely or park their cars and bicycles in the vehicle’s way leading to stops. Due to their velocity and the few stops, the people mover as they currently operate in Kelheim and Kronach are not suitable for daily use and instead function as a highlight for tourists. Still, passengers are impressed

by the comfort of the vehicle’s interior and its orientation towards the future of mobility and pedestrians stop and take photos as the vehicle passes by.

Technical Maturity

The biggest challenge currently is the technical maturity of the automated mode and the vehicle’s ability to react to obstacles, wrongly parked cars, and unforeseen events. Its inability to maneuver itself out of these situations is its greatest drawback and is at the same time deeply connected to people’s disagreement towards this technology. In such cases, the operator has to put the vehicle back on track with the joystick. As one of the interviewees puts it: *“Because that is now just an obstacle here. If they want to sell this as a vision of the future for the young generation, they should improve the technology first, because at the moment it will rather scare people away.”*, [P04].

6.2.3 Concepts of Digital Companion

We synthesized the results of the questionnaires and the interviews at the on-campus festival and will present the derived themes and topics in the following.

Human or AI?

In the online questionnaire, we asked for the solution they liked the most and they liked the least and present the descriptive statistics of the results (see Table 6.2). In the interviews that we conducted on campus and in the online questionnaire, we presented four different concepts of a digital companion as a substitute for the operator to our participants. During the interviews, we let participants rank the four concepts and asked follow-up questions on why they (did not) choose one or the other design solutions. We created a Borda count analysis of the results (see Table 6.3).

Table 6.2: Descriptive Statistics: Preference for Digital Companions.

Which Concept Do You Like the Most?			
Tele-assistant	Hologram	Chat-Bot	Robot
40%	30%	22.5%	7.5%
Which Concept Do You Like the Least?			
Tele-assistant	Hologram	Chat-Bot	Robot
15%	17.5%	27.5%	40%

Table 6.3: Borda Count Results: Preferences for Digital Companions.

Tele-Assistant	Hologram	Chat-Bot	Robot
54	42	40	28

In both data collection methods, the human tele-assistant and, surprisingly, the hologram were the most favored concepts, whereas the robot and the chat-bot were the least liked concepts. As expected, people prefer having a human assistant even in automated concepts such as automated vehicles. Some of our participants explained that they would trust a person more than an automated system (*“I wouldn’t ride without the operator. That’s where I lack confidence in the technology.”*, [P28]) and expressed skepticism towards the flawless functioning of automated shuttle buses (*“It’s a real person who is able to react in cases of emergency.”*, [P15]). As an example, our participants mentioned their poor experiences with nowadays chatbots and how frustrating it was when there were real problems that the system would not be capable to resolve (*“We already have them today, so we already know, that they won’t work.”*, [P20]). These experiences explain the chatbot’s bad ratings during the interviews and in the questionnaire alike. Apart from that, its modality was considered cumbersome and inefficient as it is *“totally annoying that you have to write there”* [P15]. Despite the fact that the hologram still is a very futuristic concept more known from science fiction movies, such as Star Wars, Blade Runner, or Iron Man, participants were very open towards this form of a digital companion precisely because of its futuristic character. Participants emphasized the concept of being fancy and a good fit for the vehicle’s forward-oriented flavor. Another reason was the *visibility* and *presence* of this solution, as *“it can also be a human and as I can see it clearly, it gives me this sense of security”*, [P09].

Characteristics of the Digital Companion

Apart from the modality and technology of the digital companion we researched the characteristics that people would prefer for it. Accordingly, we proposed duties that the digital companion could have and presented polarity profiles of two opposing adjectives to our participants. On an 11-scale slider, they expressed their preferences for a companion.

Participants were indifferent about whether a human (40%) or artificial intelligence (40%) should be behind the digital companion. The reasons for the human were flavored “with gut feeling”, if the technology does not work properly a human could still intervene, whereas the reasons for an AI were more rationally flavored with being more efficient in terms of time and money, and capable of neutral evaluations of situations.

In the following table, the opposing adjectives are listed together with the percentage of participants that indicated the respective values between 0 and 10. For better readability, we illustrate them in Table 6.4. Interestingly, the clearest result is about the companion’s gender with 55% of our participants indicating a neutral 5 between male and female. Another 37.5% of participants tended towards the female spectrum of the polarity profile which seems to be preferred over a male. With 62.5%, 65%, and 60% of answers lying in the spectrum of light, human, and realistic we see a tendency towards these adjectives in comparison to their opposite poles dark, imaginative, and abstract. Furthermore, futuristic (45%) and soft(55%) are preferred slightly over traditional and hard with a considerable amount of answers in the neutral five. It should behave in a friendly (45%), reserved (22.5%), open (12.5%), and calming (7.5%) way.

Table 6.4: Descriptive Statistics: Characteristics of Digital Companion

How Should a Digital Companion for Automated Shuttle Buses Be Designed?											
0 = male	1	2	3	4	5	6	7	8	9	10 = female	
7.5%	2.5%	0%	2.5%	0%	55%	5%	7.5%	2.5%	2.5%	20%	
0 = light	1	2	3	4	5	6	7	8	9	10 = dark	
20%	5%	20%	17.5%	0%	17.5%	5%	5%	7.5%	0 %	2.5%	
0 = naturalistic	1	2	3	4	5	6	7	8	9	10 = futuristic	
12.5%	2.5%	12.5%	5%	0%	22.5%	5%	15%	10%	2.5%	12.5%	
0 = hard	1	2	3	4	5	6	7	8	9	10 = soft	
5%	0%	2.5%	2.5%	7.5%	27.5%	20%	7.5%	12.5%	7.5%	7.5%	
0 = human	1	2	3	4	5	6	7	8	9	10 = imaginative	
15%	10%	7.5%	22.5%	10%	15%	2.5%	7.5%	7.5%	0%	2.5%	
0 = realistic	1	2	3	4	5	6	7	8	9	10 = abstract	
20%	12.5%	10%	15%	2.5%	20%	5%	2.5%	5%	5%	2.5%	

6.3 Discussion and Implications

6.3.1 Acceptance Challenges

From our results, we conclude that, at the moment, pilot projects of automated shuttle buses still have considerable acceptance hurdles to overcome. Due to their low velocity, they are considered an obstacle for other road users and not feasible for passengers' everyday mobility. Moreover, precisely because of this, they are almost exclusively used by tourists, mainly first-time users. The technology does not work as passengers and other road users expect it to, which leads to negative user experiences and can have a significant unfavorable influence on the acceptance of automated shuttle buses. This is especially problematic when considering that, e.g., younger people hope that automated vehicles will save them time [129]. Furthermore, the presence of a human operator and their dominant intervention in "driving" and their influence on the trust in automated shuttle buses is at least ambiguous. Operators do function as a source of security and human backup for many passengers, while at the same time, people are disappointed that the vehicles still need a human on board. The broad public seems to overestimate the shuttle buses' technical maturity, which leads to frustration on the one side and misconduct on the other side. We propose that citizens, particularly at locations where pilot projects are running, should be proactively informed about the shuttle

buses' state of technology and included in the design and development processes to foster awareness and acceptance. This could be through educational work and participatory events such as workshops. These activities should also include other stakeholders in the ecosystem, such as pedestrians, cyclists, and car drivers, as they will have to interact with the automated shuttle buses in the future.

6.3.2 Communication With the External World

At the moment, the operator takes on several important tasks for the passengers and other road users. On the one hand, people will become used to technology. On the other hand, the design of the shuttle buses should support users in the transition phase to enable a smooth adoption and conversion to fully automated modes. Currently, human operators handle the majority of communication with the outside world. As a result, other road users rely more on the human driver than the actual signals from the automated shuttle bus. This is an obstacle to the futuristic vision of a fully automated shuttle bus. Since the goal of automated shuttle buses is to operate without a human driver in the future, external communication needs to be enhanced. Thus, the exterior design of the automated shuttle bus indicates future driving maneuvers and reduces the uncertainty of all involved. In the interaction between automated vehicles and other road users, there are already some approaches by other researchers and designers for external human-machine interfaces (eHMI) for vehicles. In this context, a solid taxonomy on current eHMI concepts was created by Dey et al. [313], which both ranked existing eHMI designs and identified research gaps. This way, the current eHMI concepts can be divided into 12 design patterns, including projection on the road, 1D/2D abstract light bar, tracking light, audio, and many more. However, it should also be emphasized that some attractive approaches should be viewed with caution, as they were mostly laboratory studies that only marginally examined poor conditions or represented a small sample.

Despite the proven benefits that eHMI offers, legislation in Germany is a significant obstacle for many eHMI approaches. An example is the regulation regarding externally mounted light sources, which states that “only the prescribed lighting equipment and that which has been declared permissible are allowed to be mounted on motor vehicles and their trailers (Cf. § 49a Para. 1 StVZO [314])”. This also includes light bars or rear windscreen displays, also used in some eHMI concepts. These regulations ensure that other road users are not distracted from what is happening on the road. Still, there are major constraints in the eHMI development process, without proper adaption.

6.3.3 Operators and Digital Companions

Our results show that people consider informant and supervisor as the operators' main roles. Through our observations and the interviews with the operators, we found that they actually have large tasks and responsibilities, particularly those that address emotions such as trust and feeling comfortable. We already discussed that operators' presence was perceived as necessary but at the same, time it irritated people as they had the expectations of the vehicle driving in fully automated mode with no personnel on board. Most of our participants stated they would use automated shuttle buses without them. Nevertheless, the abundance of duties on board leads us to conclude that it is indispensable to account for all roles, particularly the ones that have an emotional flavor. One solution of how the system could cover this is the concept of a digital companion, which we evaluated during our study. Previous work demonstrated that the driver in public transportation is considered a "guardian" [245], and we, therefore, hypothesized that a concept that includes a human, such as the human tele-assistant, would be favored by participants. While our interview and questionnaire results confirm this, to our surprise, the concept of a hologram was nearly well accepted by our study sample.

Our hologram was presented as an anthropomorphized, meaning human-like [315] version. This could be one explanation for its reception by our participants as several prior works confirm that human-like appearances, behavior, and voices foster acceptance of technologies, robots, or digital assistants [316, 317, 318]. The concept is not sufficiently realistic to run into an *Uncanny Valley* trap [319]. On the other hand, more recent work disproves the hypothesis that suggests we should no longer hold back the development of highly realistic androids [320]. Our interviewees stated that the hologram, as it is located inside the vehicle, radiates a certain presence that is essential for a digital companion. We hypothesize that a more embodied concept than a voice-based assistant is more appropriate for substituting a human on board. Nevertheless, the robot concept was mainly rejected because it was in the way or took too much space. Human-like looks and comportment are not as important as human-like communication [321]. We suggest future studies consider this finding and explore whether the presence or level of anthropomorphism is more crucial in the context of shared automated shuttle buses. The participants of our questionnaire expected the digital companion to be friendly and human-like- which goes in line with it being an anthropomorphic version. From our participants' point of view and from what the operators have reported from their experience, the role of a supervisor on board was similarly important. In the context of design spaces for companions in video games, power dynamics have been identified as essential category [311]. With the abundant roles of operators that have been identified in our studies, we argue that power dynamics become important for a digital companion in automated shuttle buses.

While we hypothesize that a friendly informant or psychologist might take a role at eye level or hierarchically inferior to the passenger, a superior hierarchical role might be more appropriate for the supervisor, traffic educator, or when handling, e.g., inappropriate behavior of passengers. While more than half of our participants indicated a neutral position towards whether a digital companion in automated shuttle buses should be male or female. This conflicts with previous work in the field of assistance robots claiming that people identify more with digital assistants that represent the same gender [322]. Although we hypothesize that gender might not be important to our participants, and personalized digital companions to allow for high identification might not be feasible if we want to keep the role of one operator for all passengers, representing a neutral gender might be challenging on the one hand, and innovative and future-oriented on the other one.

6.4 Limitations and Future Work

We have conducted on-site studies visiting two current pilot projects of automated shuttle buses in two cities in Germany. All passengers that we interviewed were first-time passengers. Thus, we can assume that our results are not generalizable for long-term usage as we could not consider familiarizing or learning effects. Furthermore, our results apply specifically to Germany, where, due to legal restrictions, an operator has to be on board the SAVs by law. These effects might differ in areas where these vehicles are already on the roads for a longer time with no operator on board. Moreover, in countries facing various mobility challenges, such as, Latin America, where personal safety and gender-based violence are among the most critical issues in public transportation [35, 142, 191], the results may vary. The operator's role is very important as they communicate with other road users, inform passengers about the system's behavior and foster trust. However, they might become less relevant as passengers, and other traffic participants become used to automated shuttle buses. The locations where our study took part were two smaller cities with low traffic density and high urbanization, and user needs might be different in other (traffic) contexts or different cultures or locations. Further research is needed as well as the speed of these vehicles increases. While we found that their low speed is one of the most significant downsides of these pilot projects, safety and security concerns might increase with the vehicle's velocity.

6.5 Conclusion

In this Chapter, we presented a mixed-method user study including in-depth interviews with operators and with passengers, questionnaires, and in-the-field observations to investigate the current opinion on automated shuttle buses and the roles of the operators on board the buses. While the idea of automated shuttle buses is being sold as fully automated vehicles that do not require the presence of a human fallback on board, in today's pilot projects, the buses circulate with operators. We introduce findings on current acceptance hurdles of automated shuttle buses from the perspective of passengers, operators, and other road users, and dismantle the abundant and heterogeneous roles of the operators. As these roles have to be overtaken by the system in the future, we presented the evaluation of proposed concepts for digital companions for automated shuttle buses. We identified the human tele-assistant and the hologram as the preferred solutions and proposed further (design) requirements for such companions and ideas for further work. To summarize, there is still a wide range of issues that urgently need to be resolved before automated road vehicles become a well-established part of the transport infrastructure. Besides the technical challenges and legal regulations, there are still several problems in individual and social acceptance. These must be thoroughly investigated in early development phases and further pilot projects to avoid initial negative associations with the innovative technology. A technology that is accepted and used by society could greatly benefit the population in the upcoming years, especially in the area of public transport.

7 Human or Robot? Exploring Different Avatar Appearances for Shared Automated Vehicles

The research we conducted in Chapters 3, 5, and 6 has revealed pivotal insights into the limitations of certain concepts and the potential efficacy of a digital companion (DC) and has delineated the distinct roles held by operators and highlighted the imperative transition for a companion to assume these responsibilities (see Chapter 6.2.1). Our investigation underscored the potential of providing co-passenger information to mitigated anxiety and increase perceived security, particularly during night-time rides (see Chapter 5). Yet, this concept comes with consequential privacy concerns as a drawback. In the previous chapters the concrete realization of a DC in for shared automated vehicles (SAVs) has been left open. Before we will delineate the development of two distinct designs of conversational agents (CAs) in this chapter, a recap of the roles of DC and a comprehensive literature review on these agents are necessary. Subsequently, this chapter proposes two contrasting concepts for conversational agents: one intentionally designed as a man, focusing on the preference for a robot or a human-like version (7), while the other emphasizes the preference for different personalities designed as a woman (8).

Apart from being the one in charge of maneuvering the vehicle, a driver has many other functions in today's buses. They are acting as a source of knowledge and are indispensable for users who are new to the bus system, such as, for example, tourists [120]. Today, passengers rely on the fact that there is a human being driving the bus, and get in contact with the driver during different occasions. For example, passengers will wave to the driver if they want the bus to wait for them. Other, more insecure passengers, often ask the driver where the bus is going and whether it will pass by their destination and the driver will notifies them of their stop [120]. Passengers can tell if the driver is about to leave or if there is still time to board the bus without rushing by judging the driver's posture and activities [120]. The bus driver becomes particularly important in cases of emergency and previous work has shown how complex and multifaceted the tasks of drivers are and has broken down the relationship between driver and passenger of ride-sharing services into different levels, such as physical, emotional, and relational [309]. Indeed, in their daily

work the driver's tasks are expanded to those of a helper (e.g. assisting during on/off-boarding, helping with luggage), a psychologist (e.g. listening to personal sensitivities), or guide (giving tourists or visitors advice on attractions and other information about local things) [323]. Evidence exists that potential users are already willing to accept and trust automated vehicles in the same way they accept and trust human drivers [324]. However, in a field study Wintersberger et al. [83] compared the user experience (UX), trust and acceptance in an automated shuttles bus and a human driver and although they found increased positive attitudes towards the automated shuttle bus after experiencing the ride, their results indicate that the presence of the operator on board has a significant impact on trust and perceived security.

Designing a DC tailored for SAVs involves a deliberate consideration of assuming tasks currently managed by the driver or operator, especially those integral to ensuring passenger security. As we conceptualize this companion, prioritizing its appearance emerges as one of the pivotal facets. Beyond its functionality in assuming roles such as helping passengers during the ride, offering emotional support akin to a psychologist, or providing guidance like a local expert, its visual presentation becomes paramount. The appearance of this DC serves not only as an interface but as a conduit for engendering trust and fostering a sense of security among passengers. Thus, its design requires thorough attention to ensure it encourages acceptance and trust comparable to that of a human driver, while adeptly carrying out crucial security-related tasks.

As we aim to design an effective DC for SAVs, a central inquiry arises regarding its form: whether it necessitates an anthropomorphic, human-like appearance or if a radically distinct design would suffice. This contemplation extends beyond mere aesthetics; it delves into the psychology of passenger trust and acceptance [325]. While the companion's functionality in assuming security-related tasks remains paramount, the exploration of its appearance as either humanoid or divergent holds significance. Understanding whether passengers might gravitate towards a familiar, human-like representation for ease of interaction and trust-building or embrace a novel, non-human appearance challenging traditional paradigms is fundamental in shaping a companion that resonates with and reassures diverse passenger sensibilities. Thus, our investigation aims to uncover the nuanced preferences for the visualization of a digital shuttle bus companion, considering both the conventional and the unconventional with regards to its form and presentation.

In the realm of conversational agents (CAs), the landscape epitomizes artificial intelligence (AI) applications that support users in their tasks [326]. Niess et al. [327] explore distinct traits of DCs classifying them into active (innovative, dominant, proactive, independent) and passive (caring, empathetic, cautious, subdominant) types, proposing these categories without favoring one over the

other and emphasizing the contextual suitability as the determining factor. Consequently, DCs smoothly transition between diverse roles, ranging from friend to advisor or coach [327]. Johal et al. [328] advocate for varying appearances and capabilities, signaling a shift from traditional hierarchical human-DC relationships towards multifaceted social dynamics [328].

When strategizing the design of DCs for SAVs, several crucial aspects from past research come into focus. Security, feedback, and memory, as enumerated by Burmester et al. [326], gain significance given the observed need for perceived security in SAVs, functioning as public transportation (PT). Due to automation, the absence of human drivers will create a void in the service experience, both functionally and socially. Human drivers typically offer assistance and guidance to passengers [329], often serving as a point of contact in emergencies. The multifaceted roles that a human driver typically fulfills in these vehicles pose intriguing challenges. The suggested roles for DCs—spanning from psychologist to supervisor (see Chapter 6.2.1)—underscore the diverse requirements in human-DC relationships as they evolve from hierarchical to multifaceted social dynamics [328]. Hence, it is essential to broaden the scope beyond mere transportation and encompass the notion of the “affective atmosphere” [330] referring to a space’s propensity to evoke specific emotions and feelings over time [331], among other aspects. Recognizing the central role of emotional intelligence in establishing trust and engagement [332], alongside the importance of conversational abilities and accessibility considerations, becomes paramount in the evolving landscape of shared automated mobility.

In this context, anthropomorphism—commonly known as personification, involves attributing human-like properties, characteristics, or mental states to nonhuman agents or objects [315]—needs to be taken into account. Applying human characteristics such as gender, voice, and facial expressions to technological systems is used in the context of automation and has been shown to increase user’s trust in automated vehicles [325]. Research examining the anthropomorphism of intelligent voice-controlled assistants, such as Siri, Google Assistant, and Alexa, unveil the varied degrees of personification among users [317, 333]. Interestingly, individuals often fluidly shift between categorizing voice assistants as either ‘human-like’ or ‘object-like’ rather than settling on one definitive classification [316]. Some studies tend to favor robots possessing characteristics that are similar to humans [318], but other studies suggest that human-like communication holds more significance than physical appearance [321]. In this context, Eyssel et al. [322] emphasize that a robot sharing the user’s gender, coupled with a human-like voice, could strengthen anthropomorphism, fostering positive perceptions and psychological closeness. Sproull et al. [334] suggest that attributing personality traits to systems through anthropomorphism tends to arouse users’ interest, presenting themselves in a more favorable light and enhancing user satisfaction [317, 333]. A study by Pak et al. [335] revealed that participants’ trust in masculine and feminine represen-

tations of agents was affected by the agent's perceived age and gender, as well as the reliability of the system. People's willingness to use automation may be affected by the gender they perceive the automation as having, depending on the user's tendency to apply stereotypes to the computer. According to the study, if the agent appears young, masculine agents were more trusted than feminine agents, but only when reliability was low and this gender difference disappeared when reliability was higher [335]. This suggests that people are more likely to rely on stereotypes when the system is not reliable, but are less likely to do so when it is more reliable. The authors conclude that younger masculine agents would be preferred if it is crucial for users to maintain high levels of trust in imperfect automation because it seems less susceptible to large fluctuations in perceptions of trust as a function of gender (i.e. gender stereotypical thinking) [335]. However, there was no significant difference in trust as a function of agent age group for older adult users in comparison to young participant group.

As discussed in Chapter 2.3.2, cultural influences play a substantial role in shaping individuals' values, behavior, and cognitive patterns [183, 184]. These cultural nuances significantly impact people's perceptions and adoption of products, artifacts, and digital services [180]. Consequently, in the realm of Human-Computer Interaction (HCI) research and the development of CAs, understanding and accommodating these values becomes imperative. Nori et al. [336] propose a framework aimed at designing culture-adapted CAs, while culture's significance in the context of conversational chatbots is explored by Zhai et al. [337]. Similarly, Huang et al. [338] emphasize the need to address cultural disparities when designing Embodied Conversational Agents (ECA). Kim and Yoo [339] delve into the differences in preferences related to the appearance of two-dimensional (2D) and three-dimensional (3D) CAs, considering gender in the context of automated vehicles. Their cross-cultural survey spanning South Korea, the United States, China, Russia, and Brazil reveals a preference for 2D appearances among South Koreans, Chinese, and North Americans, while respondents from Brazil and Russia favored 3D appearances. Lopatovska et al. [340] explore cultural gender stereotypes within CAs, studying user reactions to feminine, masculine, and gender-ambiguous voices in stressful and non-stressful interactions. Their findings indicate a preference for contextually dependent voices, despite an expressed preference for an agent with a gender-ambiguous voice, albeit receiving lower scores during experimental interactions.

Within the framework of our previous discussions on the design of a DC for SAVs, we assert the intricate nature of security, emphasizing its nuanced relationship with cultural contexts. We posit that preferences concerning the appearance and personality of such DC, specifically tailored to foster security, may entail different user needs across cultures. Concurrently, we align with the insights of Cuciniello et al. [341], who, adopting a cross-cultural perspective, affirmed the high value attributed to CAs in security roles. Their findings res-

onate significantly with our endeavors, especially in envisaging a DC responsible for security in SAVs, showcasing the potential promise to transcend cultural boundaries. This suggests that the DC's design and functionality might cater effectively to diverse cultural inclinations, fostering a sense of security and trust across varied societal landscapes.

Hofstede's framework of cultural dimensions as discussed in Chapter 2.3.2 is widely used to describe the preferences and behavior of people from certain cultures [186]. For the conceptualization of the DC we present in this subchapter, we included Colombia, Germany, and South Korea in the Human-Centered Design (HCD) process and in the following will explain the commonalities and differences among these cultures based on Hofstede's framework. Asian cultures, such as South Korea, Japan, and China, along with Latin American nations, demonstrate a high regard for power distances, emphasizing collective values that prioritize cohesive unity. In contrast, most Germanic countries exhibit lower power distances and lean toward an individualistic ethos [186]. Colombia, Germany, and South Korea are all classified as uncertainty-avoidant nations. In comparison, Germany exhibits a moderate level, while Colombia demonstrates a higher level of uncertainty avoidance [186]. Notably, South Korea stands out as one of the world's most uncertainty-avoidant nations [186]. In South Korea, a society known for its tightly-knit social structure, collectivism prevails and Koreans exhibit strong loyalty and rely on their group, often including relatives, to assume responsibility for each other. Similarly, Colombians, also deeply rooted in collectivism, place significant importance on belonging to a specific in-group and aligning with its collective opinions. Conversely, Germany stands out as an individualistic nation, characterized by a more open social structure. Here, emphasis lies on the pursuit of self-realization, with individuals expected to prioritize their own well-being and that of their immediate families, embodying a more independent approach to societal dynamics. In South Korea, regarded as a feminine society, values encompass equality, cooperation, modesty, solidarity, and a pursuit of quality of life. Conversely, Germany adopts a focus on achievement, heroism, assertiveness, and frequently emphasizes status display. Both Germany and Colombia are identified as masculine societies and prioritize competitiveness and a strong orientation towards success. Koreans and Germans exhibit characteristics of restraint in their cultural tendencies, both cultures emphasizing control and regulation of desires within rigid social norms. There is a prevailing pessimism surrounding self-indulgence, with a sense that it runs counter to societal expectations. In contrast, Colombians display a higher level of indulgence, reflected in their optimistic outlook and positive attitude. Their cultural inclination leans towards embracing impulses and desires, emphasizing the enjoyment of life and a penchant for fun and fulfillment. Korea and Germany stand as nations oriented towards the long term, prioritizing a forward-looking perspective. In stark contrast, Colombia scores low in long-term orientation, holding a profound reverence for traditions. Their inclination leans towards a limited

propensity for future savings, instead prioritizing quick results and immediate achievements. Moreover, beyond these cultural nuances, it is central to consider the distinct status quo of security levels prevalent in PT within these cultures as discussed in Chapter 2.3.2. The varying perspectives on and approaches to security in PT significantly shape passenger expectations and perceptions of safety. Hence, integrating an understanding of these disparities in security levels alongside cultural differences becomes paramount in the design of a DC. The development of such agent for SAVs necessitates not only cultural adaptability but also a keen awareness of the prevailing security norms, ensuring a companion that not only resonates with diverse cultural backgrounds but also aligns with and enhances the existing security standards in each respective cultural context. This comprehensive approach enables the creation of a DC that not only fosters trust and assurance but also effectively addresses the distinct security requirements across cultures.

In this chapter we pose the following research questions:

RQ7.1. How should a digital companion for shared automated vehicles be designed from the perspective of people from Colombia, Germany, and South Korea?

RQ7.2. Does a digital companion enhance perceived security in shared automated vehicles?

RQ7.3. Which concept for a digital companion is preferred across Colombia, Germany, and South Korea?

To investigate these research questions we followed the HCD approach and included potential users in the early design stages when developing our DCs through a series of interviews and co-design workshops. Subsequently, we conducted an online survey involving participants from Colombia, Germany, and South Korea to evaluate these concepts.

7.1 Material and Methods

7.1.1 Pre-Studies: Interviews and Co-Design Workshops

To answer RQ1. we conducted in-depth interviews with participants from Colombia, aiming to delve into their perceptions of security within public transportation and extract insights applicable to security considerations in SAVs. Following this, we facilitated co-design workshops employing participatory de-

sign techniques [207, 208] involving participants from Germany and Korea. The results of these workshops have been partly published by Pizzoni [12].

The objective of these workshops was to extract design implications for DCs that enhance security perceptions in SAVs, aligning with the preferences of potential users. Due to the constraints posed by the COVID-19 pandemic, conducting the co-design sessions in Latin America was unfeasible at the time. Consequently, we will elaborate on the findings from the interviews with Colombian participants and the outcomes of the co-design workshops involving German and Korean participants in the subsequent sections.

Interviews with Colombian Participants

We conducted interviews via Zoom with 8 participants (4 men, 4 women, 0 diverse, 0 n/a; from 27 to 46 years; $M = 33.3$; $SD = 6.2$; $Mdn = 33$ years) from Bogotá in Colombia. The participants for the interviews were recruited via snowball-sampling by our acquaintances in the city of Bogotá and the aim of the study was to explore the general attitude and security needs of the participants in SAVs. The interviews have been conducted in Spanish. All sessions were video and audio recorded and transcribed verbatim afterwards. The material was analyzed using qualitative content analysis [232, 233] and the results have then been translated into English. We applied inductive coding and refined the themes and codes in an iterative process until the final themes and codes were identified. The analysis was carried out using MAXQDA [234]. In this section we will focus on the results relevant for the design of our DC.

Our results confirm that security is of superior importance for people’s mobility in Bogotá. In this context the bus driver plays an important, although ambiguous, role. They would stop and close the door if something happens in the bus, or they would close the door and pass by people and do not let them in the bus for security reasons: *“Normally, in Latin America, the driver also functions as a kind of controller or security of what happens inside the vehicle. I don’t know how it [SAV] will make up for that lack of security of the shared vehicle.”*, [P01]. This is in line with previous research from Europe where participants are not used to traveling without a driver either and were expressing concerns due to sharing trips with strangers [124, 134] and with our own work presented in Chapter 3. In other cases, the driver may not be able to do anything (*“But many times they don’t want to risk anything happening to them either.”* [P06]). Contradicting to that, the drivers themselves were seen as a cause of risk for accidents or even for crime and harassment, which corresponds to previous research on ride-sharing services [342] pointing at passengers particularly worrying about the driver “being creepy” [343], distracted, or causing an accident. This is particularly interesting, as related work emphasizes that

the absence of a driver in SAVs is potentially problematic for passengers and could lead to the rejection of these vehicles. However, it needs to be evaluated whether this will hold true for Colombia, as well.

Co-Design Workshops with German and South Korean Participants

In total, 19 participants, 9 Koreans (4 women, 5 men, 0 diverse, 0 n/a; from 19 to 35 years; $M = 24.56$; $SD = 4.90$; $Mdn = 25$ years) and 10 Germans (5 women, 5 men; from 16 to 64 years; $M = 29.30$; $SD = 17.72$; $Mdn = 30$ years) took part in the co-design workshops [12]. Four workshops were conducted, with each workshop accommodating three to six participants. We had one workshop with only Korean participants and one with only German participants. The remaining two workshops were mixed and included Korean and German participants, to foster cross-cultural discussions and to allow for a broader spectrum of insights regarding potential divergent needs and concepts regarding the DC [12]. The participants consisted mainly of students or individuals interested in the subject, with diverse levels of familiarity with SAVs. All workshops were conducted in English, only the workshop with exclusively German participants was conducted in German. Participants were recruited through informal channels, attending the workshops voluntarily after signing a consent form. We used Zoom as the platform and Miro, a digital whiteboard tool, to facilitate collaborative engagement among participants. To familiarize our participants with Miro, all participants received a preparatory video tutorial [12].

The workshops included an introductory session, four exercises, breaks in between, and dedicated time for feedback. Following recommendations from Lee et al. [344, 345], an introductory round was incorporated as a warm-up activity. Participants engaged in activities to explore challenges and express personal opinions on SAV security. They brainstormed individual security needs and created moodboards depicting ideal Security Compartments (DCs) within SAVs. The activities aimed to foster creativity, motivate participants, and facilitate discussions, with attention to cultural considerations. Teams presented their choices and discussed diverse opinions and ideas generated within their groups.

During the subsequent exercise participants were sketching their envisioned design of the DC for SAVs within a 20-minute timeframe. After finishing, the drawings were placed on the Miro board, and each participant presented their designs, allowing for comments on the other designs. The workshop concluded with a brief group discussion and additional elements that were considered as central for the DC were collected. Each workshop terminated with an opportunity for participants to offer feedback. Each workshop lasted approximately 150 minutes [12]. Participants sketched their envisioned designs for SAV Se-

curity Compartments (DCs) within 20 minutes. Designs were presented and discussed on a Miro board. The workshop ended with a group discussion and collection of central DC elements. Feedback was gathered, and each workshop lasted about 150 minutes [12].

Findings from the Co-Design Workshops

The completed Miro boards and video recordings of the workshops were analyzed using qualitative content analysis [232] to categorize the findings across all workshops. In the subsequent sections, we report on the most significant results. Some quotes were translated from the respective languages into English.

The most commonly mentioned challenge among all participants, regardless of nationality, was related to general security. German participants particularly focused on this issue, raising questions about how conflicts or disturbances would be managed in SAVs, noting the absence of a bus driver who typically handles such situations. Korean participants, however, expressed broader concerns, including worries about personal information privacy and cybersecurity, extending beyond in-vehicle security [12].

Discussions also revolved around challenges related to the fear of losing control, particularly expressed by German participants. They stressed the importance of maintaining control over the vehicle, pointing out a desire to have the ability to stop it if needed. Additionally, there was consistent emphasis on the necessity of receiving system updates, with concerns raised about knowing the vehicle's destination and ensuring it aligns with their intended route [12].

Participants associated characteristics such as reliability, trustworthiness, friendliness, security, and comfort with the envisioned Security Compartments (DCs) for SAVs. Nine moodboards were created during the workshops, comprising images, colors, and words that received multiple selections. A consistent choice across all teams was an image portraying a young girl holding hands with a robot, symbolizing the interaction between humans and digital companions, perceived as friendly by Korean participants. Another recurring choice among mixed teams was a photograph depicting trust and comfort, exemplified by someone resting their head on another person's shoulder or clasping hands. Additionally, images of phones with connected headphones symbolized entertainment, while martial arts and waves represented fun, cultural diversity, and reliability, respectively. The interpretation of stormtroopers from Star Wars varied among participants, with associations ranging from technology and robots to notions of law, order, and obedience. Superman images were repeatedly selected, aligning with notions of security [12].

Participants associated specific meanings with colors, such as white for openness and space, black for security and contrast, and blue and purple for modernity and futurism. Light blue was chosen for its brightness and softness, symbolizing safety and comfort [12].

In terms of the visual appearance of the Digital Companions (DCs), German participants tended to envision human-like DCs (HDCs), with some opting for abstract or animal-like designs. Korean participants mostly imagined robot-like DCs (RDCs), while some preferred unconventional designs like a cat or a genie. Germans generally emphasized the importance of visual appearance, while Koreans prioritized acoustic communication but also desired visual cues. Preferences varied regarding whether there should be one DC for all passengers or individual DCs for each passenger, with Germans leaning towards HDCs and Koreans favoring RDCs [12].

Opinions on the voice of the DC varied, with some Germans preferring a realistic and organic voice, while Koreans had contrasting views, with some preferring a robotic voice and others suggesting a human-like voice akin to a call center operator [12].

7.1.2 Conceptualization of the Digital Companions

Building upon the findings from the co-design workshops and relevant research, we developed two distinct concepts for a DC designed specifically for SAVs: one characterized by a robot-like appearance and the other resembling a human-like figure [12].

As the security challenges inherent in SAVs appear notably similar across Colombian, German, and Korean contexts, the envisioned roles and personalities for the DC remain akin. Consequently, our aim was to design two agents perceived as both competent and warm [346], given the relevance of these traits in addressing security concerns. Additionally, we aimed to implement empathy within our companions, as advocated by [347], shaping their behavior to be passive, emphasizing a caring and cautious disposition [327]. Nonetheless, our two concepts differ mainly in terms of appearance and vocal characteristics.

Robot-like Digital Companion

Given the requirement for a friendly DC, initial sketches focused on creating a robot with a welcoming appearance, emphasizing features like a kind face and large eyes to convey friendliness [348]. Korean participants desired a protective yet obedient DC, often associating stormtroopers from Star Wars with SAV DCs, reflecting cultural perceptions of robots as socially subordinate [349]. Consequently, the RDC was depicted with armor inspired by stormtroopers to evoke notions of law and order. To convey supervision, shining ears with antennas were included, drawing from previous research. The final design, named “Bo” (see Figure 7.1 and [12]), was created in Adobe Illustrator.

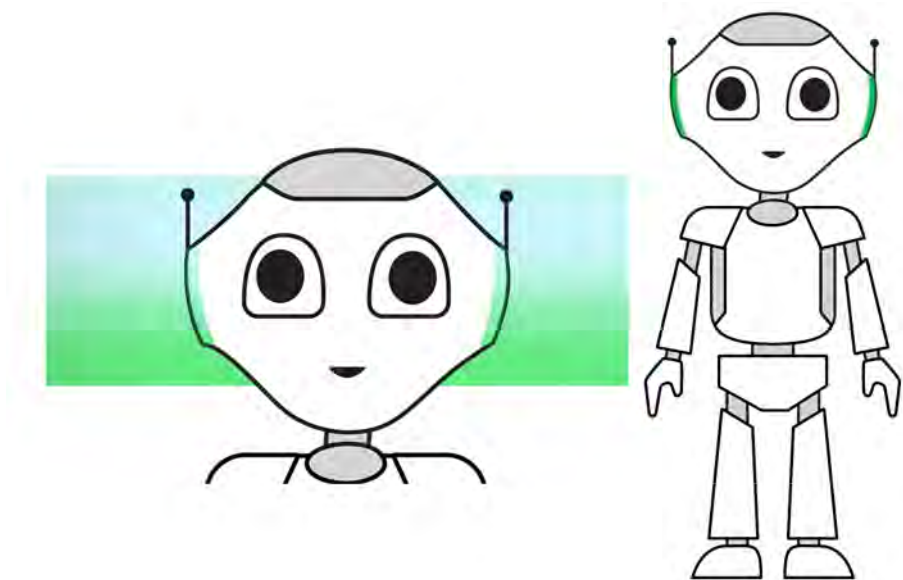


Figure 7.1: Final design of the robot-like DC “Bo”: Shining ears effect (left) and complete appearance (right); Image source: own illustration (also see [12])

Human-like Digital Companion

We designed three culturally adaptable designs for the HDC with two key motives. Firstly, there have been observations from social critics highlighting concerns regarding the predominantly white appearance and blue eyes commonly found in robots and avatars, raising ethnic perspective issues [350]. Our aim was to mitigate any potential racial biases in the human-like portrayal of our HDC. Secondly, the cultural representation of our HDC might sway

participants’ perceptions. Thus, we sought to sidestep any possible influences stemming from individuals’ self-identification with their respective cultures.

Yet, it remained crucial for the HDCs to maintain comparability across the three cultures encompassed in our study. Consequently, we made slight adjustments to their appearances to align with the respective cultures (refer to Figure 7.2). During the workshops, participants emphasized the significance of a serious and professional demeanor in the DC, coupled with a sense of approachability. To address these expectations, the HDC was fashioned with a casual shirt [12]. We opted for a light blue hue as this color was popular among the workshop moodboards. Additionally, we added a pair of glasses, to add competence and trustworthiness to the DC’s appearance. Similar to the RDC, it is crucial to note that the HDC assumes a supervisory role. Thus, akin to the RDC’s ears, we equipped the HDCs with luminous headphones, symbolizing their attentive listening to users [12]. The HDCs were designed using Ready Player Me [351].



Figure 7.2: Final designs of the human-like DCs (from left to right): Colombian “Roberto”, German “Bruno”, Korean “James” (also see [12])

Voice and Animation

The voices of the DCs were generated using an online audio creating tool. Initially, we selected suitable voices from the tool’s available options. Drawing from insights garnered from the workshops, we opted for an organic voice for the HDC, emphasizing natural speech with a pleasant tone to infuse a human-like quality. For the RDC, we chose a less natural but human-like voice [12].

Moving on to animation, the RDC’s design was crafted using Adobe Illustrator, and Adobe Character Animator facilitated its animation. Conversely, the two HDCs were animated using Animaze by FaceRig [352] allowing to include facial expressions and lip synchronization. The internal recording tools embedded within these programs were employed to capture the animations [12].



Figure 7.3: Setup in Unity (also see [12])

7.1.3 Scenario-Based Online Experiment for Evaluating the Human and Robot Digital Companion

In our main study we evaluated the RDC and HDC and compared them with a baseline without a DC. To make the concepts more realistic, we implemented Virtual Reality (VR) scenarios in an SAV using Unity (see Figure 7.3). We opted for three scenarios showing situations in which people might feel insecure or anxious. These scenarios were presented to our participants as videos in an online questionnaire and we followed a within-subjects design with every participant experiencing all three versions (baseline, robot-like digital companion = RDC, human-like digital companion = HDC). We used an online questionnaire to be able to conduct the study with participants from Colombia, Germany, and South Korea. The scenarios were recorded from the first-person perspective to deepen the sense of immersion.

The study was conducted in accordance with the ethical guidelines stated in the Declaration of Helsinki [268]. Participants took part voluntarily, were obliged to provide their written informed consent, and had the opportunity to abort the study at any time without reasons.

With this study we aimed to answer the following research questions:

RQ7.2. Does a digital companion enhance perceived security in shared automated vehicles?

RQ7.3. Which concept for a digital companion is preferred across Colombia, Germany, and South Korea?

The spoken and displayed text in the videos was translated from German into Spanish and Korean and corresponding subtitles were added to the videos to improve accessibility. A pilot study with three participants was conducted to ensure that the content of the videos was comprehensible. We used the following three scenarios [12]:

Scenario 1: Alone with Stranger The participant is accompanied by a stranger (see Figure 7.4). The role of the co-passenger was deliberately designed to evoke a sense of discomfort in the participant. Positioned opposite the participant, the co-passenger maintained a constant gaze throughout the ride, exhibiting unnaturally rigid movements—leaning back and forth while nervously tapping their knee with their fingers. In scenarios involving a DC, the ride starts with the DC warmly welcoming the passengers, introducing itself by name, and emphasizing its availability for any inquiries throughout the journey. This intentional introduction aimed to immediately draw the participant’s attention to the DC’s presence, alleviating the sense of being alone with a stranger. Additionally, to provide security, the DC informs the passengers that two passengers will get on board shortly.

Scenario 2: Alone with Group of Men The participant within the SAV is surrounded by a group of men (see Figure 7.4). The behavior of the group aims to evoke a sense of insecurity in the participant: one standing man continuously singing and performing dance moves throughout the ride, while the two seated men loudly laugh, make exaggerated gestures, and wave with their hands or make victory poses.

To amplify the atmosphere, the sound of a YouTube video with a boisterous group of people [12, 353] served as a backdrop, portraying the other passengers as excessively noisy. Similarly, within the scenarios involving a DC, the ride starts with the DC offering the same introductory announcement as in scenario 1. As the noise in the SAV persists, the DC intervenes by requesting the other passengers to lower their voices. As the request is disregarded, the DC issues a second admonishment and warns to report to the control center if the situation does not improve [12]. The intention of this intervention was to reassure the participant that the situation was under supervision and would be taken care of, thereby fostering a sense of security.

Scenario 3: Sudden Stop

The participant is riding alone within the SAV when it unexpectedly stops without apparent cause (see Figure 7.4). The stop was simulated by freezing the 360° video environment [12]. Consistently, scenarios involving a digital companion (DC) commenced with a similar welcoming

approach as observed in prior situations. After the stop of the SAV the DC provides the participant with an explanation regarding the interruption and assures them that the journey will promptly resume, mitigating any apprehension. Subsequently, the DC elucidates further details and announces the continuation of the ride.



Figure 7.4: Setup of the three scenarios in Unity (from left to right): scenario 1 with RDC, scenario 2 with German HDC, scenario 3 with Korean HDC (Image source: Screenshot of Unity Scenarios, also see [12]).

7.1.4 Participants

In total, 136 participants, 29 Koreans (15 women, 13 men, 0 diverse, 1 n/a; from 19 to 67 years; $M = 29.14$; $SD = 11.0$; $Mdn = 25$ years), 50 Germans (23 women, 26 men, 0 diverse, 1 n/a; from 18 to 78 years; $M = 35.6$; $SD = 19.13$; $Mdn = 24.5$ years), and 57 Colombians (30 women, 27 men, 0 diverse, 0 n/a; from 19 to 73 years; $M = 31.89$; $SD = 15.37$; $Mdn = 24$ years) participated in our main study. Participants were recruited through social media, word-of-mouth, and university mailing-lists. All participated voluntarily and we offered three gift cards per cultural group worth app. 15 US dollars that were raffled among participants [12].

Most Korean participants had a bachelor's degree (48.3%) and most Colombian and German participants had a high school degree or equivalent as their highest degree of education (Colombians = 42.1%, Germans = 48.7%). Most Korean participants traveled by car at least once per week (31.0%) or several times per week or daily (20.7%). German participants traveled by car at least once per week (30.8%) and most of them several times per week or daily (33.3%). Most of our Colombian participants traveled by car several times per week or daily (45.6%). The majority of Colombian and Korean participants used public transportation several times per week or daily (Colombians = 63.1%, Koreans = 58.6%) and some German participants used public transportation several times per week or daily (33.3%) while others used public transportation less than once per month (25.6%).

We used a 6-item short version of the State-Trait Anxiety Inventory Trait Measure (STAI-T) [354, 355] to measure trait anxiety. All men, Colombian

($M = 39.13$; $SD = 5.66$, $Mdn = 40.00$), German ($M = 41.04$; $SD = 9.94$, $Mdn = 40.00$), and Korean ($M = 43.59$; $SD = 10.04$, $Mdn = 40.00$), showed above-average anxiety traits (Mean of men from 30 to 59 years = 34.59; $CI = +/- 5.5$). The Korean women ($M = 46.44$; $SD = 9.47$; $Mdn = 43.33$) and Colombian women ($M = 43.44$; $SD = 8.77$; $Mdn = 40.00$) also scored high on trait anxiety (Mean of women from 15 to 29 years = 35.65; $CI = +/- 5.7$). The trait anxiety scores of the German women ($M = 41.82$; $SD = 12.84$; $Mdn = 40.00$) tended to be average, yet rather high (Mean of women from 30 to 59 years = 36.85; $CI = +/- 5.7$) [356].

7.1.5 Procedure and Measurements

We conducted an online survey and the recorded VR scenarios were integrated in the questionnaire. We had a mixed design approach with the between-groups design condition “culture”. Participants were split into three groups—Colombians, Germans, and Koreans. Each participant experienced the three concepts as the within-groups design condition (baseline = BL, robot-like digital companion = RDC, human-like digital companion = HDC) in a randomized order. Within each condition, participants engaged with the three VR scenarios and provided evaluations. To keep the process within limits and reduce participants’ cognitive workload, the scenarios were presented consecutively, minimizing the need for respondents to fill out the questionnaires more than three times in total (for the conditions BL, RDC, HDC). However, the baseline was consistently displayed as the first scenario. This decision aimed to prevent the revealing information that could potentially influence participants’ interpretations, particularly in the third scenario, where the objective was to maintain participants’ unawareness regarding the cause of the SAV’s sudden stop. All scenarios were combined in one video for each concept and the sequence of scenarios was consistent within each concept [12].

There is no established and validated questionnaire specifically tailored to assess security concerns within the context of AVs. Security, is a multifaceted construct, including aspects of anxiety, threat perception, risk assessment, trust, and perceived control [278]. To address these dimensions, we incorporated these constructs alongside state anxiety, representing the corresponding emotional response associated with feelings of in/security. We used five self-constructed items to gain further insights into participants’ perceived security and to evaluate attitudes towards SAVs using a 7-point Likert scale ranging from “strongly disagree” to “strongly agree”: “I feel threatened by other passengers on the automated shuttle bus.” (threat), “I trust the automated shuttle bus.” (trust), “I feel like I am in control of the situation when I am riding on an automated shuttle bus.” (control), “I think it is risky to ride on an automated shuttle bus.” (risk), “I do not feel secure sharing an automated shuttle bus with other

passengers.” (security). To assess the state of anxiety within the presented scenarios we used a validated 6-item short version of the State-Trait Anxiety Inventory State Measure (STAI-S) questionnaire [357], which we provided in the respective languages German, Spanish, and Korean.

Additionally, we used the standardized User Experience Questionnaire Short Versions (UEQ-s) [282] in German, Korean, and Spanish [358] to evaluate the UX of each of the concepts, as we expected that security and UX are intertwined, e.g. a feeling of insecurity will influence the UX in a negative way. After being presented with all three concepts, the participants were asked which one they liked the best and why. The questionnaire was provided in German, Korean, and Spanish.

Procedure

The questionnaire included a briefing, a consent form, and an introduction into the topic of SAVs. Next, the participants were asked about their nationality [12]. This question was asked at the beginning as based on this, the participant was later shown the Asian, European, or Hispanic-looking version of the HDC (“James”, “Bruno”, “Roberto”). The participants watched the three videos (one video for each concept: baseline, RDC, HDC) showing all scenarios in one row. We opted against showing each scenario-DC combination (baseline, RDC, HDC) separately, as our participants would have had to fill out the main part of the questionnaire nine times leading to cognitive overload and excessive time consumption. Still, with three variations of the situations we aimed to make our results more stable. After the videos, the participants filled out the STAI-S, the five self-constructed items regarding the attitude towards SAVs, and the UEQ-s. Subsequently, participants indicated their preferred and unpreferred concept [12].

The questionnaire ended with demographic questions. As the level of a person’s anxiety influences the perceived security [278], we included six items on trait anxiety from a validated short version of the State-Trait Anxiety Inventory Trait Measure (STAI-T) [354]. Since current research is not conclusive on whether having experienced any sort of crime has an influence on perceived security [255], we did not consider this aspect. An overview of the study design can be seen in Figure 7.5.

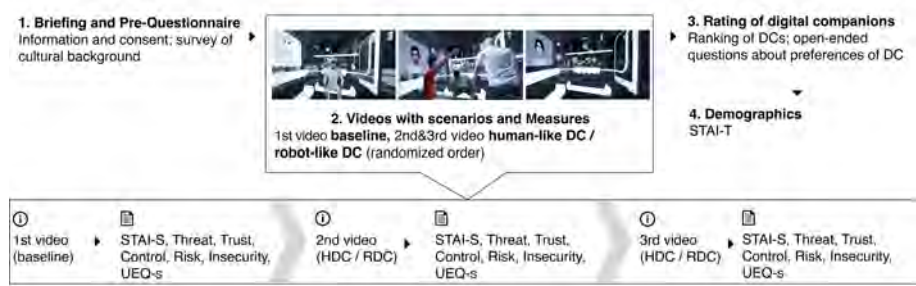


Figure 7.5: Study procedure (top) and sequence of videos and conditions (bottom).

7.2 Results

For the quantitative findings, both descriptive and inferential statistics were computed using JASP 0.16 [291], and mixed ANOVAs were carried out. Outcomes are considered significant if $p < 0.05$. As per Shapiro-Wilk’s Test, the metrics displayed a deviation from a normal distribution. Due to the absence of a suitable non-parametric examination for the study’s framework, a mixed ANOVA was utilized, despite its parametric nature. In this context, Blanca et al. [294] provide empirical backing for the resilience of the F-test to non-normality across diverse scenarios. Furthermore, Levene’s test of homogeneity of variances indicated a violation of the equality of error variances assumption, with $p = .05$. Mauchly’s test of sphericity revealed significant findings the state anxiety, threat, trust, control, risk, security, and UX, with $p = .05$, and we applied a Greenhouse-Geisser correction. In the following we will report significant Bonferroni corrected p values from our post-hoc tests.

First, we report the results for anxiety, then for threat, trust, risk, control, and security, and the overall UX. We finish with the digital companion preferences from the open-ended questionas at the end of the questionnaire. A more comprehensive examination of the resulting scale means, along with medians and standard deviations, is depicted in table 7.1 and descriptive plots including 95% confidence intervals of the results are shown in figure 7.6.

7.2.1 Anxiety

Regarding the state anxiety values it is important to note that raw test values were utilized, ranging from 10 (low anxiety) to 80 (high anxiety).

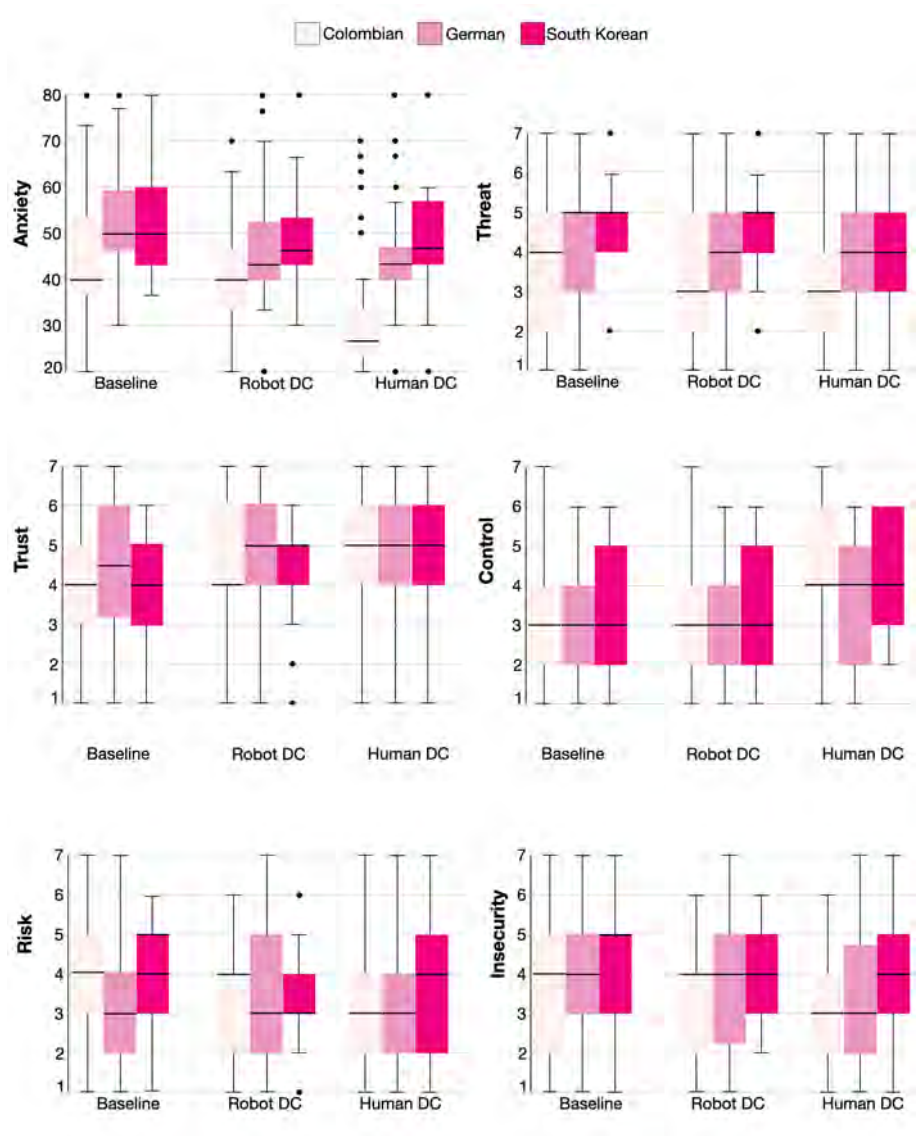


Figure 7.6: Boxplots of dimensions anxiety, threat, risk, trust, control, and insecurity for the three study conditions (baseline (BL), robot-like companion (RDC) and the human-like companion (HDC) and the between-subjects factor culture.

The mean scores of scenarios featuring RDC and HDC display decreased anxiety levels compared to the baseline scenarios. Post-hoc analyses unveiled noteworthy disparities in the comparison between the baseline and RDC, $t(df) = 4.33, p < .001, d = 0.36$, baseline and HDC, $t(df) = 8.75, p < .001, d = 0.73$, and RDC and HDC, $t(df) = 4.42, p < .001, d = 0.37$, with the HDC receiving better security scores than baseline and RDC. Interestingly, no significant differences in the preferences of the baseline or DCs were found between Germany and Korea, but between Colombia and Germany, $t(df) = -5.19, p < .001, d = -0.85$, and between Colombia and Korea, $t(df) = -5.14, p < .001, d = -0.99$. While all three countries feel the least anxiety with the HDC, this effect is higher in Colombia than in Germany and Korea.

7.2.2 Threat, Trust, Control, Risk, and Insecurity

Regarding the attitudes toward SAVs, it is necessary to highlight that low values are considered favorable for the dimensions threat, risk, and insecurity, whereas high values are considered positive for trust and control.

Threat from other passengers in the SAV decreased with the inclusion of either DC compared to rides without DC. Significant differences were seen between baseline and HDC, $t(df) = 5.41, p < .001, d = 0.42$, baseline and RDC, $t(df) = 2.87, p = .013, d = 0.22$, and RDC and HDC, $t(df) = 2.54, p = .035, d = 0.19$. Again, we found significant differences between Colombia and Germany, $t(df) = -2.77, p = .019, d = -0.47$, and Colombia and Korea, $t(df) = -2.72, p = .022, d = -0.54$, while Germany and Korea did not show any significant differences. The preference of a human companion is more pronounced among Colombians than among Germans or Koreans.

Trust was statistically significantly higher for the RDC, $t(df) = -3.17, p = .005, d = -0.23$, and the HDC, $t(df) = -5.88, p < .001, d = -0.43$, compared to the baseline and between the RDC and the HDC, $t(df) = -2.72, p = .021, d = -0.20$. While Germans and Colombians rated trust higher for the HDC, Koreans preferred the RDC over the human one. However, we found no statistical differences between culture for the dimension of trust.

The dimension control of the situation was statistically significantly higher for both the RDC, $t(df) = -5.82, p < .001, d = -0.50$, and the HDC, $t(df) = -7.27, p < .001, d = -0.63$ in comparison to the baseline. We did not find significant differences between the two companions. Colombian and Korean participants felt more in control with the human companion while Germans rated the robot higher.

The feeling of risk was statistically significantly higher in the baseline condition when compared with both, the RDC, $t(df) = 2.59, p = .030, d = 0.22$, and HDC, $t(df) = 3.04, p = .008, d = 0.25$. However, no significant difference was found between the two companions and between cultures. Yet, Koreans felt higher risk with the HDC than with the RDC.

Regarding feelings of insecurity, we found a tendency towards lower ratings for scenarios involving DC compared to those without but only the comparison between the baseline and the HDC, $t(df) = 3.72, p < .001, d = 0.31$, revealed statistically significant. Germans and Colombians considered the HDC as more secure than the RDC, and Germans considered the RDC as insecure as the baseline. Koreans felt similarly secure with both companions.

Table 7.1: Descriptive Statistics: Median (Mdn), Mean (M), and Standard Deviation (SD) for anxiety, threat, trust, control, risk, security for Colombian (COL), German (DE), and South Korean (KOR) participants.

	COL	DE	KOR	COL	DE	KOR	COL	DE	KOR
anxiety_baseline			anxiety_robot			anxiety_human			
M	44.737	52.867	52.644	40.409	47.733	49.195	30.409	45.000	48.736
Mdn	40.000	50.000	50.000	40.000	43.333	46.667	26.667	43.333	46.667
SD	14.127	11.857	11.697	11.548	11.536	9.581	12.053	10.822	11.492
threat_baseline			threat_robot			threat_human			
M	3.947	4.420	4.690	3.474	4.180	4.345	3.035	4.060	3.966
Mdn	4.000	5.000	5.000	3.000	4.000	5.000	3.000	4.000	4.000
SD	1.767	1.642	1.285	1.681	1.561	1.370	1.581	1.557	1.401
trust_baseline			trust_robot			trust_human			
M	3.772	4.540	4.103	4.368	4.620	4.517	5.053	4.940	4.448
Mdn	4.000	4.500	4.000	4.000	5.000	5.000	5.000	5.000	5.000
SD	1.701	1.555	1.448	1.644	1.713	1.184	1.381	1.596	1.549
control_baseline			control_robot			control_human			
M	3.351	2.940	3.138	4.053	3.900	3.862	4.561	3.780	4.069
Mdn	3.000	3.000	3.000	4.000	4.000	4.000	4.000	4.000	4.000
SD	1.695	1.504	1.642	1.619	1.555	1.302	1.500	1.645	1.646
risk_baseline			risk_robot			risk_human			
M	3.912	3.520	3.862	3.351	3.500	3.448	3.228	3.280	3.621
Mdn	4.000	3.000	4.000	4.000	3.000	3.000	3.000	3.000	4.000
SD	1.640	1.542	1.329	1.529	1.555	1.183	1.615	1.539	1.498
insecurity_baseline			insecurity_robot			insecurity_human			
M	3.684	4.040	4.276	3.368	4.040	3.931	3.105	3.540	3.897
Mdn	4.000	4.000	5.000	4.000	4.000	4.000	3.000	3.000	4.000
SD	1.605	1.678	1.688	1.508	1.690	1.223	1.460	1.555	1.372

7.2.3 User Experience and Overall Preference

The UX of both DCs achieved higher scores than the baseline concerning pragmatic, hedonic, and overall quality aspects (see Figure 7.7).

We found significant differences for pragmatic quality between baseline and RDC, $t(df) = -2.25, p = .016, d = -0.19$, baseline and HDC, $t(df) = -5.92, p < .001, d = -0.42$, and RDC and HDC, $t(df) = -3.12, p = .006, d = -0.22$. The HDC received the highest scores. The differences between Colombia and Korea were significant, $t(df) = 2.50, p = .040, d = 0.50$, whereas there were no significant differences between Colombia and Germany and Korea and Germany.

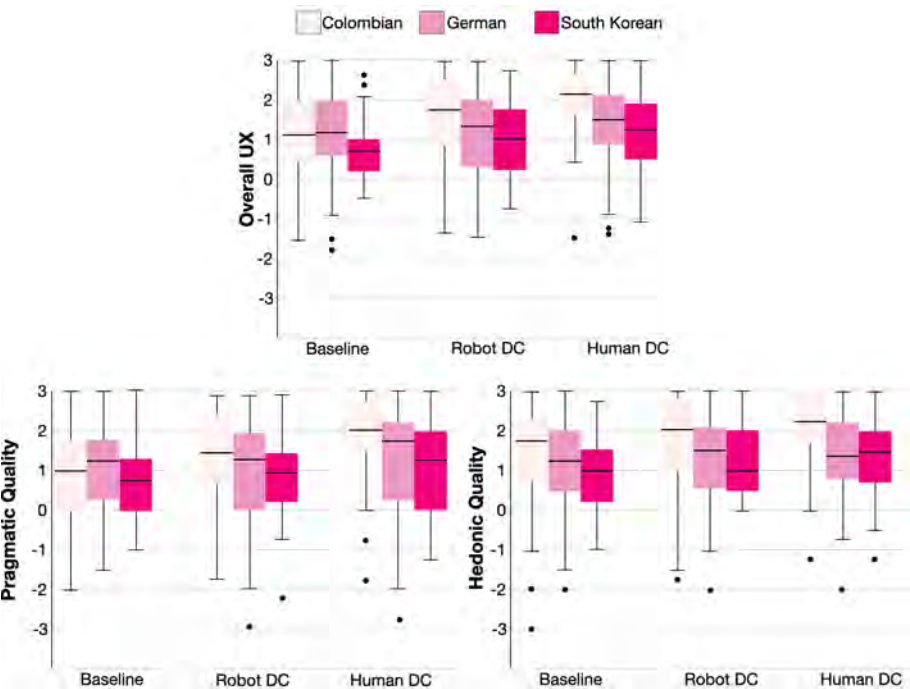


Figure 7.7: Boxplots of UEQ-s scale: overall UX, pragmatic UX, and hedonic UX (-3 = low; 3 = high) for the three conditions (baseline (BL), robot-like companion (RDC) and the human-like companion (HDC) and the between-subjects factor culture.

Regarding hedonic quality differences between baseline and RDC, $t(df) = -3.14, p = .006, d = -0.24$, and baseline and HDC, $t(df) = -5.21, p < .001, d = -0.39$, were significant. The companions were evaluated more positively than the baseline but their differences were not significant. However, Colombia

showed significant differences in comparison with Germany, $t(df) = 2.58, p = .033, d = 0.44$, and Korea, $t(df) = 2.86, p = .015, d = 0.57$, as their more positive rating of the HDC had a bigger effect. No differences were found between Germany and Korea.

As a result the overall quality of UX was perceived as significantly different between baseline and RDC, $t(df) = 3.53, p = .001, d = -0.24$, baseline and HDC, $t(df) = -6.63, p < .001, d = -0.46$, and RDC and HDC, $t(df) = -3.09, p = .006, d = -0.21$, with the HDC receiving the best ratings. Germany did not show differences with Korea and Colombia but we found significant differences among Colombia and Korea, $t(df) = 2.96, p = .011, d = 0.60$.

72.1% of all participants liked the SAV with the HDC best compared to 16.9% who chose the RDC and only 11.0% who would rather have no companion on board (see Table 7.2), which is in line with the findings from our previous dimensions. Interestingly, 27.6% Koreans liked the RDC best (see Table 7.3) which reflects part of our findings from the pre-study as well as their lower risk and higher trust and security ratings of the RDC. Germans were indifferent in their preference of baseline over RDC, and Colombians and Koreans seem to prefer having either a RDC or HDC over the baseline concept. Here the gap among Koreans is the largest with only 6.9% choosing to have no companion.

Table 7.2: Descriptive Statistics: Preferences for digital companions across cultures

DC	Frequency	Percent
BL	15	11.0
RDC	23	16.9
HDC	98	72.1

Table 7.3: Descriptive Statistics: Preferences for digital companions between cultures

DC	Colombian		German		Korean	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
BL	6	10.5%	7	14.0%	2	6.9%
RDC	8	14.0%	7	14.0%	8	27.6%
HDC	43	75.5%	36	72.0%	19	65.5%

7.2.4 Understanding Digital Companion Preferences

Below, we present the synthesized analysis of the open-ended question concerning participants' preferred DC version. Topics are outlined alongside their respective frequency (n) and the number of mentions by Colombian, German, and Korean participants. All quotations have been translated from their original languages into English. The primary rationale for favoring the HDC was its human likeness (27, 14 Colombians, 9 Germans, 4 Koreans) as it provided security (21, 14 Colombians, 4 Germans, 3 Koreans) and trust (16, 7 Colombians, 6 Germans, 3 Koreans): *"It generates the sensation of accompaniment and being watched by a person, giving security and confidence."*, [Colombian participant]. Participants felt that the human version would be able to provide quick and adequate help (16, 7 Colombians, 7 Germans, 2 Koreans) in case of emergency. Participants indicated that they would feel more comfortable (8, 1 Colombians, 3 Germans, 4 Koreans) and monitored (8, 4 Colombians, 3 Germans, 1 Koreans) with a HDC.

In contrast, participants found the RDC cute (5, 2 Colombians, 1 Germans, 2 Koreans) and less personal (2, 1 German, 1 Korean), with some perceiving it as more neutral and less artificial. One German participant favored the RDC for its perceived authenticity, while another felt the HDC was overly lifelike.

Participants who favored the SAV without a DC expressed varied rationales. One Korean participant noted that non-human companions would not match the experience of real companionship. Another German participant preferred solitude during bus rides while a third doubted the ability of digital companions to manage perilous situations and found both options unsettling.

7.3 Discussion and Implications

In our discussions of the results, we first address RQ2., evaluating the efficacy of DCs in enhancing security within SAVs. Subsequently, we delve into RQ3. exploring cross-cultural preferences for the human-like and robot-like DCs. Finally, we conclude by presenting recommendations for security measures that we derived from our study's findings.

7.3.1 Enhanced Ride Experience with Digital Companions, Human Digital Companions are Preferred Over Robots in Self-Driving Vehicles

In general, our results demonstrate notable improvements compared to the baseline when employing a DC. A DC inside the vehicle significantly reduces feelings of anxiety, threat, and risk while elevating trust, control, overall UX, as well as pragmatic and hedonic qualities. Specifically regarding security, significant effects were observed only with the HDC in contrast to the baseline.

Altogether, participants showed a preference for the HDC over the RDC, though statistically significant effects were established for anxiety, threat, trust, pragmatic UX, and overall UX. This inclination towards the HDC contrasts with the prior workshop findings, contradicting the anticipated preference for robots among Korean participants. Several factors may explain this contradiction between the main study and workshop outcomes. Primarily, research suggests that the appearance of DCs should align with their designated roles [327, 328], emphasizing the contextual relevance in their design. Our main study participants were presented with visualized SAV scenarios implemented in VR, enabling a better grasp of contextual situations compared to our workshop participants who solely relied on imaginative scenarios. The different contextual perceptions might have influenced the envisioned appearance of the DC. For instance, individual feedback highlighted a preference for the HDC due to its perceived authority. Workshop participants might not have considered this characteristic, given the absence of situations requiring authority. In contrast, our main study participants encountered a scenario where the DC demonstrated authority (scenario 2). This aligns with Johal et al.'s findings [328], suggesting that a cute appearance in robots might hinder acceptance in roles requiring authority.

Given the nuanced perceptions influenced by contextual experiences, future DC designs should account for the roles they undertake. Incorporating contextual scenarios or simulations could offer a more holistic understanding of the DC's potential functionalities and appearances. Furthermore, designing DCs with adaptable appearances or behaviors that align with varied situations may enhance their acceptability across diverse cultural preferences. A balance between perceived authority and approachability is crucial, suggesting a need for multifaceted designs that exude both competence and warmth. Integrating these findings into future co-design workshops or participatory design sessions may yield more comprehensive insights into DC preferences and enhance their acceptance in diverse cultural contexts.

7.3.2 Implications for Digital Companions Including Cultural Differences

The workshop results suggest a consensus between Koreans and Germans regarding the desired traits of a DC for SAV—both cultures value a friendly and sympathetic one. However, distinctions emerge in their preferences concerning the hierarchical position of the DC in relation to humans: Koreans lean towards a DC that displays obedience to humans, whereas Germans favor a supportive, reliable, and serious DC. This contrast could stem from cultural differences delineated by Hofstede [186], where Korea tends to uphold a slightly hierarchical societal structure while Germany gravitates towards lower power distances as discussed in Chapters 2.3.2 and 7. The inclination in Korean society towards hierarchy may underlie the preference for a DC subordinate to humans which aligns with the findings of Lee and Sabanović [349] asserting Koreans' preference for submissive robots. Conversely, Germany's pursuit of egalitarianism may manifest in a DC perceived as an equal, existing to support humans. Moreover, Germany's emphasis on punctuality and discipline [359] may drive the desire for a reliable and serious DC.

Although Koreans displayed a preference for the HDC, they expressed greater openness and trust toward robots compared to Colombia and Germany. Noteworthy differences emerged in anxiety, perceived threat, and hedonic quality, with significant differences between Colombia and Germany, as well as Colombia and Korea, but not between Germany and Korea. Differences were also significant between Colombia and Korea concerning the pragmatic and overall UX. Hofstede's cultural dimensions [186] suggest a closer alignment between Colombia and Korea than either between Colombia and Germany or Korea and Germany. Surprisingly, Colombians favored the RDC less than both Germans and Koreans when compared to a human-like DC. This preference might be attributed to Colombia's high power distance, potentially leading to the perception of the HDC as more authoritarian than the RDC. Conversely, the qualitative interviews preceding our main study and related research suggest that human drivers might not be viewed as equally trustworthy in Colombia as they are, for instance, in Germany, potentially influencing their preference for the RDC over the HDC.

This contrast becomes more intriguing when considering Colombia's apparent lesser openness to technologies, potentially influencing participants to opt for a concept closer to today's PT. This finding gains significance when contemplating more abstract and disembodied forms of a DC prompting inquiries about the potential relationship between the level of anthropomorphization and Colombians' acceptance of a system accommodating human drivers. Furthermore, it raises questions about whether Koreans might be more inclined toward adopting object-like solutions. Contrarily, qualitative insights under-

score that the preference for the robot-like version aligns with the futuristic essence of self-driving shuttle buses, suggesting that as time progresses, robots may amass more trust among users.

These findings suggest that the design of a DC should consider cultural nuances and should aim for a balance between familiarity and futuristic elements to cater to varying cultural predispositions. One solution could be adaptable interfaces allowing users to personalize their DC's appearance and interaction style. For instance, a modular design could offer varying levels of anthropomorphism, allowing users from different cultures to choose between human-like or abstract representations and interfaces could allow users to adjust facial features or choose between humanoid or abstract avatars. The DC behaviors and dialogue scripts should be adaptable and align with specific cultural preferences and language variations, gestures, and conversational styles could be tailored to each culture. The DC's responses and mannerisms could be adjusted to match the cultural norms of respect and authority in high power distance cultures, while maintaining a friendly demeanor.

Despite that, we recommend to implement gradual familiarization strategies for the introduction of futuristic elements. For example, the DC could start with more familiar attributes, such as resembling a kiosk or a familiar object, gradually integrating humanoid traits as users grow more accustomed to automation. We propose to design the DCs with adaptive learning capabilities to understand user preferences over time. These companions could evolve their behavior and appearance based on user interactions and feedback, gradually gaining trust and acceptance. An example might include a DC learning user preferences for safety announcements or personal assistance.

7.3.3 Comprehensive Security Measures Beyond User Interfaces in Shared Automated Vehicles

While prioritizing functionalities for security and comfort in DCs is essential, it is crucial to note that some participants emphasized limitations. For instance, despite suggestions to include emergency buttons and interactive screens for security updates, a subset of participants expressed concerns that a user interface alone might not suffice in critical situations or emergencies. Their feedback underlines the need for multifaceted solutions that extend beyond interface design, possibly including physical emergency mechanisms or direct communication channels with emergency services integrated into the vehicle itself as proposed in Chapter 4.3.2. This insight highlights the importance of integrating diverse safety measures and ensuring redundancy in emergency protocols, going beyond interface-based solutions to enhance real-time response capabilities. Thus, physical emergency mechanisms need to be integrated within the

SAV itself, such as easily accessible emergency stop buttons or handles that directly alert the vehicle's control center or emergency services. The SAVs should be equipped with integrated communication systems allowing passengers to directly contact emergency services or the vehicle's control center in urgent situations, ensuring swift response and assistance. These features could be supplemented by sensor-based technologies within the vehicle that can detect anomalies or distress signals among passengers, triggering automated alerts for immediate attention. Automated protocols within the SAVs could respond to specific emergency situations, such as automatic rerouting to a safe location or activating emergency lighting and audio signals to attract attention. We argue that Integrating a combination of these measures alongside UI functionalities ensures a robust security ecosystem within SAVs, addressing the participants' concerns and enhancing overall emergency preparedness and response capabilities.

7.4 Limitations and Future Work

Our main study was conducted using VR scenario videos, which offered a good understanding of the situations but cannot fully replicate real-world interactions. Participants' preferences might differ when they actually engage with the DCs in real-life situations. All participants in the main study experienced one RDC and one HDC, so preferences might be influenced not only by the robot-like or human-like nature but also by individual preferences for the specific DCs they encountered. While our main focus was on cultural differences in DC preferences, we did not explicitly consider gender differences, which could play a significant role, especially within different cultural contexts. We had 136 participants across three cultural groups and the statistical significance of our findings is limited. Future studies should aim to include a broader range of age groups, encompassing children and older adults.

This work draws upon our previous research from Chapters 4.3.4 and 6.3.3 where a (human) teleoperator on a screen was proposed to account for security issues that might arise due to the absence of a driver in SAVs. We deliberately stayed with the term *digital companion* during the co-design workshops as we wanted to investigate how this particular form of a UI for SAVs should look like from our participants' perspective. While this term directed participants towards an embodied representation, using a more technical term like "system" might have steered towards an abstract concept of a DC. Echoing related studies emphasizing anthropomorphization in designing caring conversational agents (CAs) [327], we contend that these traits hold particular importance in addressing security needs. However, research such as that by [360], which utilized a peripheral robotic object, suggests that more open approaches in

co-designing DCs for SAVs could yield equally promising yet abstract designs. This presents an avenue worth exploring in future research endeavors.

Although Colombians were not part of the workshops, our interviews provided valuable insights for DC conceptualization, suggesting that our work contributes to understanding preferences and requirements for DC appearance. The evolving landscape of mobility, particularly with SAVs, lacks concrete solutions, indicating a significant necessity for more research in this area. Moreover, a cross-cultural approach remains vital to cater to diverse needs in future mobility solutions as discussed in Chapter 2.3.

7.5 Conclusion

This Chapter delves into the design aspects of a CA, a digital companion intended to enhance security and UX for passengers using SAVs, focusing on the diverse cultural contexts of Colombia, Germany, and Korea. Through interviews and co-design workshops with participants from these cultures, we established specific requirements for the implementation of these digital companions within the realm of automated shuttle buses. Two distinct concepts emerged from these discussions: a human-like (HDC) and a robot-like companion (RDC).

These concepts were implemented into prototypical designs, resulting in three culturally adapted versions of a HDC (“Roberto”, “Bruno”, and “James”) and one RDC. These designs were evaluated in a comprehensive main study (N = 136) employing an online questionnaire that featured VR scenarios presented as videos. The findings suggest that the presence of a DC notably enhances the sense of security and overall UX for Korean and German passengers traveling in SAVs. Interestingly, Colombians, Germans, and Koreans exhibited particularly positive perceptions of the human-like companion, with Colombians explicitly favoring it and Koreans demonstrating the highest openness towards the robot-like version.

Our study contributes at the intersection of SAV security, digital companions’ role in enhancing security, and cross-cultural preferences for such companions. Based on our findings we advocate for the human-like companions as a promising design approach to elevate perceived security within SAVs, ultimately augmenting experiences. Additionally, these companions hold the potential to address challenges associated with the absence of a human driver in these vehicles. At the same time it is central to consider hierarchical structures and cultural nuances, as demonstrated by differences in preferences between cultures when designing DCs. The hierarchical nature of certain societies, as observed in Ko-

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rea, possibly influenced preferences for more obedient companions. Conversely, societies valuing equality and reliability, like Germany, may prefer companions as equals. These distinctions highlight the importance of tailoring companion designs to align with diverse cultural perspectives, emphasizing the significance of cultural adaptation in creating universally effective DCs for SAVs. ed designs and implementations for DCs within the context of SAVs.

8 ‘Baymax’ or ‘RoboCop’ ? Exploring Different Feminine Avatar Personalities for Shared Automated Vehicles

In Chapter 7, our study revealed a clear preference among participants for a human-like version of a digital companion (DC) within shared automated vehicles (SAVs). Building upon these insights, the studies in this chapter aim to delve deeper into the crucial aspect of personality in shaping user interactions with such companions. While the visual representation of the companion garnered significant attention, it is equally important to understand how its personality traits influence user experience and perceived security within SAVs. By exploring various personality dimensions and their impacts on user perceptions, we endeavor to refine our understanding of how to design digital companions that not only resonate visually but also engage users effectively on a personal and emotional level, thereby fostering a sense of trust and security in shared automated transportation environments.

The exploration of personality traits in DCs within SAVs resonates with the broader landscape of artificial agents, commonly known as companion technologies, which have permeated various domains such as hospitality, care, education, and even as travel assistants [328, 361]. These technologies, ranging from robots for cleaning to pet companions and chatbots facilitating transactions, underscore the growing importance of emotional artificial agents in user interactions [362, 363, 364]. Emotional artificial agents play a pivotal role in user interactions, eliciting positive responses and empathy [361]. Designing these companions involves focusing on emotions and empathy, emulating human interaction and actively contributing to shared objectives [347, 361]. As these technologies emulate human-like traits, they possess the potential to become social entities influencing behavior, evolving from mere authority figures to complex social counterparts [328, 365]. Designing human-machine interfaces (HMIs), particularly within shared PT, holds significant importance in facilitating the shift toward automated mobility [330]. As technology increasingly integrates into our social sphere, computers have evolved from objects to

resembling assistants or companions [365]. Thus, understanding this interplay becomes central in shaping the design framework within the context of SAVs.

How a technology looks shapes our perception and the roles we assign to it. The intended function of a companion technology is crucial in its design, with various situations dictating specific requirements for its effectiveness [347]. For instance, if a companion technology is meant to assert authority but appears too diminutive or endearing, its acceptance might diminish [328]. In order to scrutinize the ideal appearance of a companion for SAVs, we found it imperative to comprehend its designated role and its position within the social hierarchy relative to humans—whether it should embody an authoritarian presence or not. For this purpose, we applied the design framework put forth by Bouquet et al. [366] to explore the various facets and dimensions essential for shaping the technology’s visual identity and interaction dynamics. In their work, the authors conducted an analysis of 40 diverse games, showcasing a wide array of approaches to augment enjoyment. They proposed a design framework for companions in video games, outlining the key elements contributing to a successful companion. This framework comprises seven primary categories—appearance, sentience, individuality, behavior, communication capabilities, relation to the player, and significance—each defined by specific characteristics [13]. These facets intricately intersect and influence one another, making them interdependent and challenging to isolate. Their exploration aligns with Emmerich et al.’s [367] definition of companions as non-player characters (NPCs), whether human or not, accompanying the player throughout substantial portions in the game, often serving as sidekicks or allies. NPCs in games can assume various roles, from providing objectives and information to acting as allies or friends accompanying the player on their adventures [368, 369].

Bouquet et al. present their design space as a “supporting tool for companion design”, intended to offer varied perspectives on companion design. Unlike human drivers, DCs for SAVs will most probably not physically occupy the vehicle but will serve as companions for passengers during their journey. We speculate that their role might align with NPCs and thus, we integrated Bouquet et al.’s design space into the development of our DCs. Søndergaard and Hansen argue that the personality and functions of DC of digital personal assistants (DPAs) are gendered and thus gender issues need to be considered for their design and acceptance [370]. Typically, voice agents are defaulted to have a feminine gender [371, 372] and they are portrayed as the “stereotypical young female secretary” [370]. Research indicates that gender stereotypes extend to companion technologies such as voice agents, with feminine voices being perceived as more competent and intimate, while masculine voices are still favored in safety-critical contexts [373]. In contrast, the findings from [374] reveal no distinct preference between a masculine or feminine voice for in-vehicle voice assistants. Lopatovska et al. [340] examined whether cultural gender stereotypes are carried into the domain of conversational agents (CAs), and examined

user reactions to feminine, masculine, and gender-ambiguous voices in the context of stressful and non-stressful interactions. They found a preference for contextually dependent voice or stated a preference for an ideal agent with a gender-ambiguous voice, though this agent received the lowest scores during experimental interactions.

Scanlon et al. [375] investigated the effect of the narrator’s gender in the game “The Stanley Parable” on the perceived traits, authority and player experience [13]. Their results suggest that players were more inclined to comply with instructions when the gender of the narrator matched their own self-identified gender, indicating an attribute similarity effect. However, not only gender but also factors such as perceived trustworthiness and assertiveness of the narrators played a role in influencing decisions. Interestingly, as presented in Chapter 6.2.3 in our online questionnaire we found a clear preference of a DC that lies in between the female-male dichotomy. To supplement the previous Chapter 7, in the next study we will particularly delve into the significance of the gender aspect in the design of the DC, considering its potential influence on users’ perceptions and preferences. This analysis aligns with our exploration of cultural variances and the impact of societal hierarchies on the preferences for human-like versus robot-like companions in different cultures. In this Chapter we aim to 1) identify scenarios that provoke perceived insecurity in SAVs, 2) establish the diverse design requirements for DCs across various situations and user perspectives, 3) investigate gender considerations in DC design, and 4) evaluate the developed concepts within a prototype VR environment. Embracing the Feminist HCI approaches referenced in [74, 77, 370, 376], we started conducting a co-design workshop [13]. This collaborative endeavor allowed us to generate initial design concepts for DCs in the context of SAVs, drawing from insights gleaned from the workshop. Subsequently, we translated these insights into two feminine digital companion concepts (‘Baymax’ and ‘RoboCop’), implementing them in prototype form and subjecting them to evaluation through a VR study.

8.1 Material and Methods

Following the HCD process and its urge to engage users in the early stages of design, a co-design workshop was conducted including six participants (4 men, 2 women, 0 diverse, 0 n/a; from 22 to 57 years; $M = 35.3$; $SD = 16.1$; $Mdn = 27$ years). The participants were recruited via word-of-mouth and represented varied backgrounds, including students in social work and user experience design, an assistant tax consultant, individuals from industrial production, and a homemaker. While we aimed to diversify participants by age and profession, gender representation was imbalanced and no transgender or non-binary indi-

viduals were recruited. Approximately half of the participants self-identified as “gamers”. The workshop’s objective was to gain insights from participants regarding the design of a DC for enhancing security perceptions in SAVs, without constraints imposed by current technological limitations. Additionally, the session aimed to uncover situations perceived as potentially insecure by the participants [13].

8.1.1 Pre-Study: Co-Design Workshop

The workshop was conducted online via Zoom and we used a digital whiteboard (Miro) for the collection of ideas. Our participants worked in groups of two and brainstormed on concepts for DCs that they gathered on sticky-notes on the digital whiteboard. As an inspiration we provided pictures representing the “sense of security” taken from the internet and our participants were free to use them and create moodboards. We alternated group activities and presentations of the concepts with discussion sessions. Then, we presented 6 situations known from using public transportation that might evoke discomfort, insecurity, or stress, and discussed with our participants how a DC could support them in these situations. The scenarios included unexpected nighttime route alterations, discomfort from sharing a vehicle with strangers, nighttime rides with unfamiliar passengers, group rides, and encounters with unpleasant individuals [13].

The workshop ended with a final discussion and wrap-up. In total, the workshop lasted 180 minutes. The study was conducted in accordance with the ethical guidelines stated in the Declaration of Helsinki [268]. Participants took part voluntarily, were obliged to provide their written informed consent, and had the opportunity to abort the study at any time without stating reasons [13].

Findings from the Co-Design Workshop

The visuals, dialogues, and discussions generated in the co-design workshop were analyzed and categorized through affinity diagrams. To synthesize the results, we organized ideas from all three groups, focusing on common threads or themes arising from the discussions and responses to guiding questions. For this, the input from each team was transcribed onto individual sticky notes, cataloging each detail. The notes were color-coded to distinguish ideas originating from each team. In the following we will present the synthesized outcomes derived from the workshop sessions and clustered into the categories appear-

ance, communication, traits, roles, tasks, and abilities, and emergencies. The results of these workshops have been partly published by Röhr [13].

Appearance The digital companion’s visual representation lacked specific details in the consolidated outcomes. Two teams imagined a “human-like” avatar without diving into gender specifications, with the exception of one team, who characterized their companion as a feminine android. Two teams envisioned the companion to be “human-sized.” Additionally, two teams proposed to integrate a smartphone app into their digital companion, suggesting a size similar to a mobile device. Two teams preferred “light” or “soft colors”, with one team proposing colors like orange or yellow, and excluding darker shades such as black or grey. Another team offered more specific color choices, mentioning blue, red, or green, linked to the uniforms of various emergency services in Germany [13].

Communication The teams reached a consensus that the digital companion should interact with all passengers collectively and—if needed— individually within the vehicle. They preferred employing “natural speech” for communication. Additionally, two teams highlighted the need for visual support through in-vehicle displays, mainly for travel information [13].

Traits, Roles, Tasks and Abilities All teams emphasized the need for the digital companion to embody a “friendly” appearance and demeanor. Additionally, two teams highlighted the importance of “empathy” towards passengers while also acknowledging the companion’s potential to assert “authority” when required. This finding emphasizes once more the results from Chapter 7.1.1.1. This intriguing dichotomy between being amiable yet authoritative was evident in the ideas presented by two teams, which labeled the DCs as ‘Baymax’ and ‘RoboCop’ personality, respectively. The roles envisioned for the companion were varied, yet all groups proposed a role focused on calming passengers. Tasks and abilities outlined by two teams emphasized communication, considering it as an essential aspect. To guarantee safety and security of passengers were paramount among the discussed tasks and abilities. Observing the vehicle’s interior, passengers, their behavior, and consistently assessing the situation were consensus points across all teams. Finally, two teams explicitly mentioned the potential for automated intervention by the companion if needed [13].

Emergencies The teams presented diverse ideas for emergencies, focusing on a broad spectrum including car accidents. Two teams reiterated the need for the companion to identify emergencies and subsequently protect passengers.

All three teams highlighted the importance of automatic notification of the police or SAV service in emergency scenarios, aligning with Mirnig et al.’s recommendation [154] and emphasizing the necessity of communication with a remote operator during prolonged interruptions.

Moreover, two teams proposed that either the digital companion or passengers should have authority over initiating an emergency stop. This is in line with findings from Mirnig et al. [154] and our own findings from Chapter 4.3.2. Furthermore, two teams proposed the companion should “restrain passengers” who pose a threat, preventing them from causing harm. In extreme cases, they suggested the companion might employ tools such as a taser or martial arts, to handle such situations. [13].

In summary, our findings are in line with the results from Chapter 7.2 and strongly advocate for a human-like appearance of the companion, emphasizing its representation as a teleoperator featured on an in-vehicle screen. Notably, the results underscore the diverse range of tasks the companion should undertake, spanning from providing general information to handling specific emergency situations. Participants emphasized the necessity for the companion’s personality to balance both sensitivity and authority, especially in interactions with passengers. These revelations align with the power dynamics category identified by Bouquet et al. [366], leading us to label these distinct personas as ‘Baymax’, inspired by the nurturing demeanor of the character from Walt Disney Animation Studio’s movie “Big Hero 6” [377], and ‘RoboCop’, embodying the authoritative traits from the movie [378]. In terms of scenarios, unexpected nighttime route changes, sharing rides with uncomfortable co-passengers, and facing verbal aggression from another passenger were deemed the most distressing. Interestingly, while participants suggested the ‘Baymax’ personality for dealing with unexpected route changes, they favored the ‘RoboCop’ personality for the latter scenarios, where the companion’s portrayal of power and strength was deemed crucial [13].

8.1.2 Conceptualization of the Digital Companions

For the conceptualization of the companion, we leaned on our findings from the co-design workshop, advocating for a human-like appearance and representation as a teleoperator on an in-vehicle screen, as well as echoing the need for the companion’s persona to strike a balance between sensitivity and authority in interactions with passengers. Moreover, in an attempt to diverge from the stereotypical depiction of a man in a traditional “bodyguard” or authoritative role [370], we consciously created two feminine avatars for our main study. To shape these avatars, we sought inspiration from feminine hero characters commonly found in gaming. These characters, drawn from popular games such

as League of Legends, StarCraft, Overwatch, or My Time at Sandrock (see image 8.1), were aligned with the characteristics emblematic of ‘RoboCop’ and ‘Baymax’ personas [13].

The portrayal of these feminine avatars was aligned with the traits identified in our study. For instance, the warm and approachable attributes associated with the ‘Baymax’ persona were reflected in features such as light attire, soft facial characteristics, and gentle hair styling. In contrast, the depiction of the ‘RoboCop’ persona was marked by darker attire and hair, rigid facial features, and more stringent hair styles. This conceptualization of the companion was a direct manifestation of our insights derived from participant preferences and expectations [13].

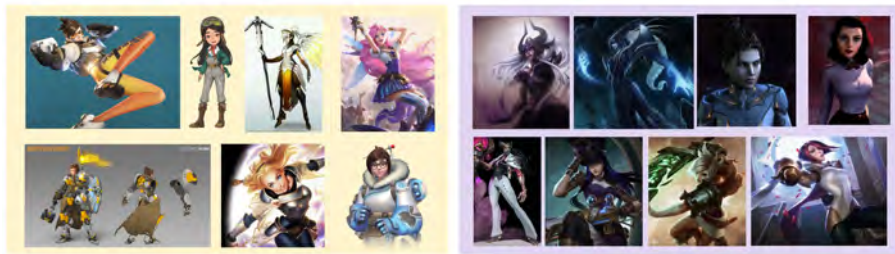


Figure 8.1: Feminine gaming characters: ‘Baymax’ personalities (left), ‘RoboCop’ personalities (right). ‘Baymax’ personality (from left to right and from top to bottom): Tracer (Overwatch), Mi-An (My Time at Sandrock), Mercy (Overwatch), Seraphine (League of Legends), Brigitte (Overwatch), Lux (League of Legends), Mei (Overwatach). ‘RoboCop’ personality (from left to right and from top to bottom): Syndra (League of Legends), Sarah Kerrigan (StarCraft), Elizabeth (BioShock), Renata Glasc (League of Legends), Riven (League of Legends), Fiora (League of Legends). Also see [13].

When refining the final designs for the companions, we adhered to the companion design framework proposed by Bouquet et al. [366]. Their framework delves into personality traits as integral aspects of character individuality, shaping interactions, visual appearance, and behavior. The ‘Baymax’ personality exudes a gentle, affable appearance, characterized by a caring, informal demeanor, fostering a relationship with passengers on eye level. In contrast, the ‘RoboCop’ personality embodies authority, maintaining a professional, reserved approach, assuming a more distant, superior stance in passenger interactions. The companions were designed using Ready Player Me [13, 351].

In our main study, our aim was to explore the potential increase of security in SAVs through DCs and to the preference between ‘Baymax’ and ‘RoboCop’ personalities. Moreover, we sought to investigate whether this preference is situation-dependent. Consequently, we pose the following research questions:

RQ8.1. Does the presence of a digital companion enhance the perceived security in an SAV?

RQ8.2. Which personality type of a digital companion is preferred for rides in SAVs?

RQ8.3. Does the preference of a digital companion depend on the situation?

As SAVs are not fully employed in Germany yet and to answer these questions, we conducted a study in virtual reality (VR) which allowed us to simulate experiences analogous to SAVs. This enabled participants to immerse themselves in the ride and encounter two specific discomforting scenarios we identified from our preliminary study. Among these scenarios, we implemented two deemed particularly uncomfortable, each lasting approximately two minutes in the VR setting. These scenarios were implemented in VR:

Scenario 1: Unpleasant passenger The participant encounters a challenging situation where they share a ride with an uncomfortable stranger, who directs verbally provocative remarks toward the service providers of public transportation and the SAV service. However, considering ethical considerations, we opted against having the stranger verbally attack the participant, as virtual characters exhibiting confrontational behavior in VR could pose ethical concerns [379]. Instead, the scenario was less severe to avoid triggering traumatic flashbacks or provoking a traumatising experience itself [13].

Scenario 2: Unforeseen event The scenario depicts an unexpected event with the participant as the sole passenger inside the SAV. Since each participant experienced this scenario with both DCs and without a companion (baseline), we required three distinct variations to maintain unpredictability. Consequently, we incorporated: a) an unplanned stop due to an obstacle, b) an unforeseen interference triggering an alarm, and c) a malfunction of the vehicle’s door [13].

All scenarios were implemented using Unity and the immersive VR simulator for automated driving by Riegler et al. [380]. The characters and animations were downloaded from *Adobe Mixamo* [381] and we animated the DCs using *Animaze* [352]. Figure 8.2 shows the final companion avatars ‘Baymax’ and ‘RoboCop’, the positioning of the display inside the vehicle from the participants perspective, and the environment of scenario 1 [13].

The order of the conditions (baseline, ‘Baymax’, ‘RoboCop’) was randomized within the scenarios. Additionally, half of the participants started with scenario group 1 and the other half with scenario group 2. For scenario group 2 the



Figure 8.2: Final companion avatars: ‘Baymax’ (left), ‘RoboCop’ (middle), scenario 1 with ‘RoboCop’ (right). Also see [13]

combination of the form of the scenario (a) obstacle, b) unknown error, c) door malfunction) and the conditions (baseline, ‘Baymax’, ‘RoboCop’) were also randomized across all participants. The different forms of scenario group 2 are comparable, as each scenario represents a new unknown situation. All participants experienced both scenarios in the baseline, ‘Baymax’, ‘RoboCop’ conditions [13].

8.1.3 Participants

We used a within-subjects design with 23 participants (13 men, 10 women, 0 diverse, 0 n/a; from 18 to 77 years; $M = 35.7$; $SD = 18.9$; $Mdn = 26$ years) with each participant experiencing each scenario with a baseline condition without a companion and the DCs ‘Baymax’ and ‘RoboCop’. Participants were recruited through social media, word-of-mouth, and university mailing-lists. All participated voluntarily and without any recompensation [13]. We used the State-Trait Anxiety Inventory State Measure (STAI-S) [270] to assess participants’ propensity to perceive situations as threatening or to respond with increased feelings of anxiety [13].

8.1.4 Procedure and Measurements

We used a mixed-method approach [272] and triangulated quantitative data collected during and between rides with qualitative interview data.

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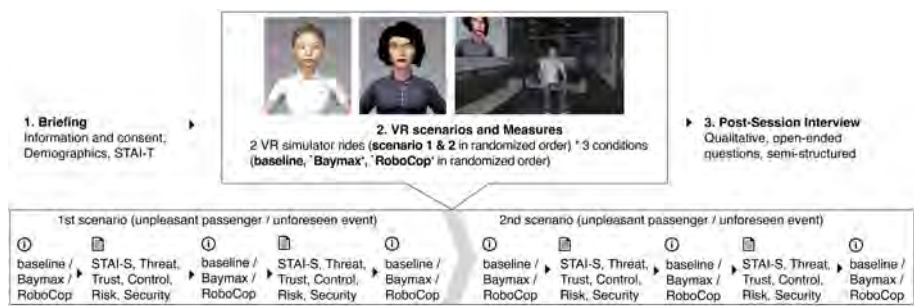


Figure 8.3: Study procedure (top) and sequence of scenarios and conditions (bottom).

Briefing and Pre-Questionnaire

After receiving a briefing comprising general information about the study goal and the procedure, participants were informed about VR usage, and signed an exclusion of liability, a declaration of consent, and a demographic pre-questionnaire. As the level of a person’s anxiety influences the perceived security [278], we also included the State-Trait Anxiety Inventory Trait Measure (STAI-T) [354] in our pre-questionnaire. Since current research is not conclusive on whether having experienced any sort of crime has an influence on perceived security [255], we left this aspect out [13].

Scenarios in Virtual Reality and Measures

Participants filled out a 6-item short version of the State-Trait Anxiety Inventory State Measure (STAI-S) questionnaire [357] during each ride. State-anxiety represents a momentary state marked by tension, nervousness, and apprehension about future events [13].

As discussed in Chapter (see 7.1.5), there is no established and validated questionnaire specifically tailored to assess security concerns within the context of AVs. Security, is a multifaceted construct, including aspects of anxiety, threat perception, risk assessment, trust, and perceived control [278]. To address these dimensions, we incorporated these constructs alongside state anxiety, representing the corresponding emotional response associated with feelings of in/security. Five self-constructed items evaluating attitudes towards SAVs were included using a 7-point Likert scale ranging from “strongly disagree” to “strongly agree”: “I feel threatened by other passengers on the automated shuttle bus.” (threat), “I trust the automated shuttle bus.” (trust), “I feel like I am in control of the situation when I am riding on an automated shuttle bus.” (control), “I

think it is risky to ride on an automated shuttle bus.” (risk), “I do not feel secure sharing an automated shuttle bus with other passengers.” (security). As the dimensions threat and security specifically focus on scenarios involving interactions with other passengers [138, 278], they were exclusively included in scenario 1 (unpleasant passenger). In total, participants filled out these questions six times, with the conditions baseline, ‘Baymax’, and ‘RoboCop’ for both scenarios [13].

Post-Session Interview

After all rides and to assess the quality and immersion of the simulated environment, we incorporated measurements of participants’ presence within the virtual environment using the igroup presence questionnaire (IPQ) [290]. Finally, we conducted a semi-structured post-session interview with each participant. We asked open-ended questions about participants’ preferences for the DCs, their ratings of the situations, and how the situations influenced the preference of one DC over another. The session concluded with a wrap-up, and participants were offered sweets as a token of appreciation for their time. With the consent of participants, audio captures of all post-session interviews were recorded for an in-depth post hoc analysis [13].

8.2 Results

The results from the experiment have been partly published by Röhr [13]. For the quantitative results, descriptive and inferential statistics were calculated using JASP 0.16 [291]. The audio-recorded post-session interviews were transcribed verbatim and analyzed applying qualitative content analysis [232, 233] with MAXQDA [234]. Session notes and anecdotal evidence during the study complemented the data collection. In the following, we report on descriptive and inferential statistics for a comparison of the study conditions in terms of our dependent variables, as well as for an assessment of the simulated setup by having a look at participants’ presence perception [13].

The prerequisites for various statistical methods are deemed met unless an explicit violation is indicated. A significance level of $\alpha = .05$ was set for this investigation. Data was analyzed via standard distribution using the Shapiro-Wilk-Test. The trait and state anxiety did not show significance in the Shapiro-Wilk-Test, suggesting they followed a normal distribution. Conversely, the majority of variables related to anxiety, security, risk, control, and trust showed significance in the Shapiro-Wilk-Test, indicating to not be normally distributed [13].

8.2.1 Anxiety

Regarding the state anxiety values it is important to note that raw test values were utilized, ranging from 10 (low anxiety) to 80 (high anxiety).

Surprisingly, scenario 2 (unpredictable event) yielded higher state anxiety ratings compared to scenario 1 (unpleasant passenger), yet both scenarios exhibited reduced state anxiety levels in the presence of a companion. The state anxiety decreased from 37.09 (baseline) to 35.39 with the ‘RoboCop’ companion and to 34.74 with the ‘Baymax’ companion in scenario 1. Meanwhile, in scenario 2, it decreased from 40.17 (baseline) to 35.96 with ‘RoboCop’ and to 34.91 with ‘Baymax’ [13].

All participants experienced both scenarios across all conditions (baseline, ‘Baymax’, ‘RoboCop’), we conducted a two-way repeated ANOVA examine within-subject effects. Sphericity assumptions were satisfied based on the Mauchly-test. However, the analysis of scenario*companion did not yield a statistically significant result, $F(2, 44) = 0.67, p = .604$. Likewise, no significant main effects were observed for scenario, $F(1, 22) = 0.28, p = .604$, or companion, $F(2, 44) = 2.65, p = .082$ [13].

Furthermore, a one-way repeated measures ANOVA was conducted separately for both scenarios. For scenario 1, the assumption of sphericity was not met. Consequently, the results adjusted with Huyuh-Feldt Epsilon (.834) were utilized, given that the Greenhouse Geisser Epsilon exceeded 0.75. In this case, the difference between the means of state anxiety did not reach statistical significance, $F(1.668, 36.695) = 0.71, p = .476$. Regarding Scenario 2, Mauchly’s test confirmed no breach of sphericity, leading to the use of results assuming sphericity. The within-subjects effects test for scenario 2 similarly demonstrated no significance, $F(2, 44) = 2.78, p = .073$ [13].

A more comprehensive examination of the resulting scale means, along with medians and standard deviations, is depicted in table 8.1 and descriptive plots of the results are shown in figure 8.4.

8.2.2 Threat, Security, Trust, Control, and Risk

We used Likert-scales from 1 (“strongly agree”) to 7 (“strongly disagree”) for the dimensions thread, security, trust, control, and risk. Since threat, security, and risk are formulated negatively and aim for high values, and trust and control are formulated positively and aim for low values, we inverted the results for the negatively formulated items. For an easier interpretation of the

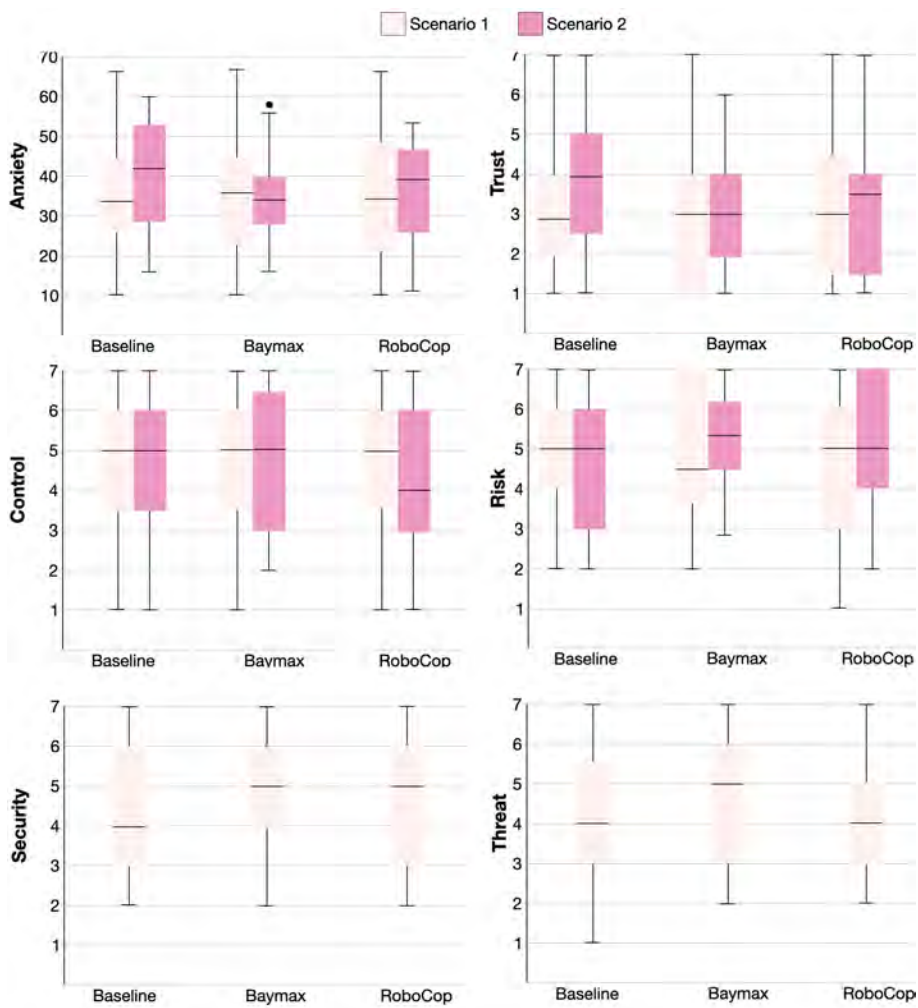


Figure 8.4: Boxplots of dimensions trust, control, risk, security, and threat for the three study conditions (baseline, 'Baymax', and 'RoboCop' and scenarios.

8 ‘Baymax’ or ‘RoboCop’? Exploring Different Feminine Avatar Personalities for Shared Automated Vehicles

Table 8.1: Descriptive Statistics for All Factors and Scenarios. The table shows the mean values, Median, and standard deviation for anxiety, threat, security, trust, control, and risk for the respective scenarios and companions.

anxiety								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	37.087	34.739	35.391	40.174	34.913	35.957	38.630	35.674
Mdn	33.000	36.000	34.000	41.000	34.000	39.000	36.500	38.500
SD	15.805	15.702	16.678	12.569	10.967	13.030	14.205	14.801
trust								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	3.304	2.957	3.261	3.609	3.087	3.087	3.457	3.174
Mdn	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
SD	1.663	1.894	2.072	1.828	1.443	1.807	1.735	1.924
control								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	4.522	4.522	4.739	4.739	4.652	4.304	4.630	4.587
Mdn	5.000	5.000	5.000	5.000	5.000	4.000	5.000	5.000
SD	1.563	1.855	1.738	1.789	1.799	1.820	1.665	1.773
risk								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	4.783	4.696	4.609	4.739	4.957	5.043	4.761	4.826
Mdn	5.000	4.000	5.000	5.000	5.000	5.000	5.000	5.000
SD	1.858	2.010	1.877	1.815	1.665	1.846	1.816	1.829
security								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	4.348	4.913	4.565	N/D	N/D	N/D	N/D	N/D
Mdn	4.000	5.000	5.000	N/D	N/D	N/D	N/D	N/D
SD	1.641	1.345	1.754	N/D	N/D	N/D	N/D	N/D
threat								
	baseline	Scenario 1 ‘Baymax’	‘RoboCop’	baseline	Scenario 2 ‘Baymax’	‘RoboCop’	Scenario 1 & 2 ‘Baymax’	‘RoboCop’
M	3.870	4.565	4.217	N/D	N/D	N/D	N/D	N/D
Mdn	4.000	5.000	4.000	N/D	N/D	N/D	N/D	N/D
SD	1.660	1.619	1.622	N/D	N/D	N/D	N/D	N/D

results, all values > 4 represent positive expressions of the factor and values < 4 represent negative expressions [13]. An overview of the descriptive statistics is represented in table 8.1.

The dimensions trust, control and risk were rated for both scenarios. In scenario 1 trust was rated more positive with the ‘RoboCop’ ($M = 3.26$) than ‘Baymax’ while in scenario 2 they were rated equally ($M = 3.09$) and the baseline received the highest rating [13].

Control was evaluated equally for ‘Baymax’ and baseline in scenario 1 ($M = 4.52$) and the rating was highest with the ‘RoboCop’ companion ($M = 4.74$). However, in scenario 2 control was rated best without a companion ($M = 4.74$), followed by ‘Baymax’ ($M = 4.65$) [13].

The best results for risk were gained without a companion in scenario 1 ($M = 4.78$). However, in scenario 2 risk was rated best with the ‘RoboCop’ companion ($M = 5.04$), followed by the ‘Baymax’ companion ($M = 4.96$) [13].

The factors threat and security were only rated for scenario 1 (unpleasant passenger), as the formulation of the items implies the presence of other passengers inside the SAV [13]. Regarding security, ‘Baymax’ ($M = 4.91$) had a higher impact than the baseline $M = 4.35$) and ‘RoboCop’ ($M = 4.57$). The mean for threat was slightly improved for the ‘RoboCop’ ($M = 4.22$) and the ‘Baymax’ ($M = 4.57$) companion in comparison to the baseline ($M = 3.87$) [13].

As neither of these factors exhibited normality, Friedman’s ANOVA was separately conducted for each dimension in each scenario. The results did not reveal statistical significance for any of the factors, and the null hypothesis of an equal distribution of variables could not be rejected [13].

Despite the violation of normal distribution, we performed a two-factor repeated measures ANOVA for the factors risk, trust, and control, due to the absence of a suitable non-parametric test. For risk and control, Mauchly’s test did not indicate any violation of sphericity, thus the results assuming sphericity were utilized. However, for trust, the sphericity assumption was not met and we used results with Huynh-Feldt Epsilon (.811) correction, as the Greenhouse Geisser Epsilon was > 0.75 [13].

None of the effects for scenario*companion and main effects showed statistical significance [13].

8.2.3 Qualitative Content Analysis and Preference of Digital Companions

For our post-session interview analysis, we transcribed the audio recordings and conducted a qualitative content analysis [232, 233], using inductive coding techniques. Generally, participants highlighted the preference for a visual face for interaction, rather than a specific visual representation of the companion. The placement of the display on the vehicle’s left side (see Figure 8.2) was criticized by some participants for its intrusive and patronizing nature, given its size and persistent presence. In Scenario 1 (unpleasant passenger), participants found the companions’ reactions occasionally inappropriate, with expressions perceived as provocative, potentially drawing unnecessary attention. However, in Scenario 2 (unpredictable event), the companions’ presence was often seen as reassuring, providing a sense of immediate assistance [13].

Table 8.2: Descriptive Statistics: Preferences for Digital Companions (DC) Between Scenarios

DC	Senario 1		Senario 2	
	Frequency	Percent	Frequency	Percent
BL	5	22.0%	3	13.0%
‘Baymax’	10	43.48%	16	69.57%
‘RoboCop’	8	34.78%	4	17.39%

Participants perceived the two companions and their contrasting personalities differently. In general, the study’s findings indicate a preference for the ‘Baymax’ companion among the majority of participants. In the post-session interviews, the ‘Baymax’ companion was mainly described as “friendly, likeable” and “more pleasant”. Additionally, certain participants described perceiving the light colors and attire as “professional”. Furthermore, the appearance of ‘Baymax’ conveyed a sense of assurance, suggesting that the companion has control over the situation, and it was perceived as more helpful [13].

‘RoboCop’ was singled out for its projected authority and competence attributed to its mature appearance, though it was seen as stringent. The attire, characterized by darker colors, was criticized for being excessively somber, less attractive, and too informal. Additionally, the ‘RoboCop’s’ conduct received negative ratings, described as impolite, unsettling, and forceful [13].

‘Baymax’ was preferred by 43.48% of all participants in scenario 1 and 69.57% in scenario 2. While the ‘RoboCop’ companion had a considerable share in scenario 1 (34.78%), its preference dropped to 17.39% in scenario 2 (see Table 8.2). Participants rated the impact of each companion on their perceived security at the end of each scenario group, using a scale from 1 (much more secure) to 7 (not secure at all). In both scenarios, the ‘Baymax’ companion was rated higher for improving perceived safety compared to the ‘RoboCop’ companion [13].

8.2.4 Presence Perception and Experience of the Rides

The results of the IPQ indicate a medium presence and immersion of the participants which is also reflected in the medium to high ratings for the four IPQ scales (Realism ($M(SD) = 3.32(0.9)$), Involvement ($M(SD) = 4.12(0.6)$), Spatial Presence ($M(SD) = 4.52(1.3)$), and General ($M(SD) = 4.74(1.4)$). However, in the post-session interview, one participant pointed out that the VR experience differed significantly from reality, primarily noting the vehicle’s

driving behavior, as the speed felt notably slower and the vehicle's maneuvering around curves peculiar were found peculiar. Another participant effected a similar experience, describing the simulated environment as unnatural during the interview [13].

8.3 Discussion and Implications

8.3.1 Digital Companions Have a Positive Impact on Perceived Security

Our research underscores the positive influence of DCs on passengers' perceived security within SAVs. The presence of a DC notably improved state anxiety and feelings of security, as supported by post-session interviews. This highlights the potential for DCs to significantly enhance the overall perceived security within SAVs.

However, the breadth of this improvement across diverse scenarios and individual responses needs further exploration. Future research could delve deeper into understanding the nuanced interactions between passengers and DCs in various challenging situations. While statistical analysis did not reveal significant differences in mean state anxiety or related factors, it is essential to consider potential factors influencing these perceptions. Particularly in scenario 2 (unforeseen event), participants found the presence of a companion to be reassuring. However, perceptions of the DCs varied, as some behaviors and expressions were perceived as inappropriate, resulting in negative ratings for state anxiety. Nevertheless, participants expressed in interviews that they would prefer one of the DCs to accompany them in the situation over being alone with an uncomfortable passenger. This underlines the DCs' potential to improve the perceived security [13].

In summary, while our study highlights the promising role of DCs in bolstering perceived security within SAVs, future endeavors should explore the nuances of passenger-DC interactions across varied scenarios, genders, and real-world implementations to maximize their potential benefits.

8.3.2 The 'Baymax' Personality Is Preferred Across Situations

In general we observed a preference for the 'Baymax' companion across different scenarios, aligning with the expectations of companion technologies mirroring emotions and empathy [361]. Even in scenarios where security concerns were pronounced, such as the one involving an unpleasant passenger, participants consistently favored 'Baymax', emphasizing its role in instilling a sense of security and reducing anxiety levels within the vehicle. This finding underlines the significance of a compassionate digital companion, even in security-critical situations, shedding light on the need for empathy-driven technology to alleviate anxiety and enhance passenger well-being. This contradicts the findings from our pre-study as well as our assumption that security critical situations— particularly in the context of unpleasant co-passengers as depicted in scenarios 1 (unpleasant passenger)— require a more authoritarian companion in the SAV and thus, should be designed to assert this characteristic to be accepted by users [328]. This preference might stem from the perception of 'Baymax's' appearance as more professional, while 'RoboCop' was viewed as unprofessional, overly stern, and dark in demeanor. However, within scenario 1 involving an unpleasant passenger, preferences were more evenly split among different companions. This suggests potentially intricate needs or varied participant requirements based on factors like past experiences.

Despite a preference of the 'Baymax' companion, the 'RoboCop' companion receiving better ratings for the dimension trust and control in scenario 1 and for risk in scenario 2. Nevertheless, it is important to highlight that our study did not uncover a significant correlation between the preferred companion and the specific scenario, which contradicts initial indications from our preliminary studies suggesting a relationship between the scenario context and the preferred personality of a companion. Contrary to assumptions drawn from our previous results from Chapter 4, scenario 2 (unforeseen event) triggered the highest state anxiety means across all conditions. The perception of being alone during a vehicle malfunction appeared to evoke more insecurity compared to sharing the vehicle with an unpleasant passenger, indicating the nuanced impact of situations on perceived security levels.

Moreover, Bouquet et al.'s [366] framework addressing the power dynamics of companions in video games and their positioning hierarchically as either 'superior' or 'subordinate' the player provides insight into our findings. As such, participants leaned towards preferring companions placed hierarchically 'subordinate' to the user, leaning toward cooperative and supportive interactions. This aligns with our results indicating a preference for companions like 'Baymax,' characterized by approachability and friendliness.

In conclusion, our findings stress the essential role of DCs, particularly compassionate ones like ‘Baymax’, in enhancing perceived security and reducing anxiety within SAVs. These results emphasize the need for empathetic technology even in security-critical scenarios, warranting a deeper understanding of the interplay between situations, user perceptions, and companion types for effective integration of such technologies in future transportation systems.

8.3.3 Gender and Digital Companions

The findings from Chapters 6.2.3 and 7.3.1 highlighted a strong preference for human-like appearances, leading us to create human avatars for our digital companions, displayed as artificial teleoperators within the SAV. Participants often favored the ‘Baymax’ companion for its friendly facial expression, emphasizing the appeal of an amiable appearance. Thus, an overall affable demeanor seemed preferable. On the other hand, the ‘RoboCop’ personality, perceived as stringent and authoritative, evoked both positive and negative reactions. Reactions from both companions were occasionally perceived as inappropriate in scenario 1, making further research of the companions’ behavior and interactions necessary.

While our approach aimed to consider gender aspects from a Feminist HCI [74] perspective, resulting in the development of two feminine companions for the final study, it raises questions about whether digital companions require a specific gender representation or if a more abstract approach would be more inclusive. This approach could cater to various gender identifications, as well as encompass diverse characteristics such as race and ethnicity. This highlights the imperative need for more comprehensive investigations in future studies within this domain. Additionally, it is worth contemplating whether empathy, more so than the technology’s gender, holds a pivotal role in shaping the acceptability and usability of companion technologies. Advocating for neutral and abstract companion technologies might serve as a viable avenue for future design considerations.

8.4 Limitations and Future Work

We used VR simulations of two scenarios within SAVs to evaluate the two different DCs. Participants’ perceptions of the scenarios and companion behaviors are derived from these simulations, potentially differing from real-world contexts. Nonetheless, our findings serve as preliminary insights and a foundational framework for subsequent research in more realistic settings. Addressing

the fidelity of the virtual environment and introducing more intense scenarios might provide deeper insights into the impact of DCs on passenger security perceptions. Exploring the implementation of DCs in real-world SAVs could be the next step. This involves designing and testing DCs that adapt their responses and behavior based on real-time passenger reactions, fostering a more interactive and responsive environment. Moreover, investigating the potential influence of DCs on passenger behaviors during emergency situations could be crucial for enhancing overall safety in SAVs.

In our VR study, we deliberately curated a limited set of situations within the SAV to avoid causing significant discomfort or inducing panic among participants. Although simulated, these scenarios still constitute a “real experience” [382], capable of impacting participants’ emotional responses [379, 383].

Given our small sample size and exclusive focus on German participants, the outcomes lack generalizability. The results from Chapter 7.3.2 have indicated statistically significant differences in DC preferences among Asian, European, and Latin American participants, suggesting the need for wider participant diversity encompassing various gender identities, cultural backgrounds, and educational levels. Consequently, we advocate replicating this study with more diverse participant groups.

Future research should explore diverse implementation formats for DCs beyond our artificial teleoperator visualized on a large display inside the vehicle. Investigating private implementations, such as on personal devices like smartwatches or smartphones, presents an intriguing avenue. Regarding DC appearances, our study specifically adopted a human-like representation, yet alternative approaches, including non-human appearances, warrant exploration. Additionally, further investigations into DC behavior across a spectrum of SAV scenarios are vital. Understanding preferences and requirements across everyday situations, security-critical scenarios, and emergencies is crucial in meeting the needs of potential future passengers.

8.5 Conclusion

This Chapter delves into the realm of companions for SAVs. To initiate our exploration, we conducted a co-design workshop ($N = 6$) leading to the formulation of human-like avatar concepts for DCs. In line with Bouquet et al.’s design framework [366], we introduced two feminine avatars, ‘Baymax’ and ‘RoboCop’, as contrasting personalities, aiming to challenge gender stereotypes associated with the male security guard or hero archetypes. These concepts were rigorously evaluated through a VR study ($N = 23$), using two distinct uncom-

fortable scenarios (scenario 1: unpleasant passenger, scenario 2: unpredictable event). Our results demonstrate a preference for the ‘Baymax’ companion in both scenarios, highlighting no discernible correlation between companion and scenario.

While statistical significance was not established in the analysis of the companions’ impact on perceived security, descriptive data and qualitative insights suggest a positive influence of the DCs in general. In light of these observations, we ascertain that integrating DCs into SAVs can potentially bolster passengers’ sense of security within shared rides. This study serves as a foundational framework for further exploration, urging researchers to delve into varied designs and implementations for DCs within the context of SAVs.

9 Development of a Perceived Security Scale for Shared Automated Vehicles

As we have observed in the preceding chapters, the concern surrounding perceived security is deeply rooted in the apprehension of sharing rides with strangers in vehicles that operate without human drivers on board, posing a paramount challenge in the domain of SAV adoption [245, 53]. This challenge resonates deeply within the minds of potential users and must be addressed comprehensively and effectively to exploit the full potential of SAVs and ensure their successful integration into the broader transportation ecosystem [124].

While previous work underlines security as one of the main factors keeping future passengers from adopting SAVs, there is no consensus on how this perceived security should be measured by researchers. Sarriera et al. used two items (“*I am afraid to be paired with an unpleasant passenger*”, “*I cannot see the name, gender, and age of the other passenger*”) to measure the feeling of (in)security in the ride-hailing service Lyft [133]. Their study proves that ensuring security in dynamic ride-sharing is crucial, especially for women, who often report feeling insecure and uncomfortable, and prefer being matched with passengers of the same gender. Gerhold et al. [138] measured perceived security for public transportation in Germany with one item (“*I do not use public transportation as it is too insecure*”), leaving open to participants how they interpret the term *insecure*. Lavieri and Bhat [245] approached the issue of

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Note: both authors contributed equally to this paper.

travelers' willingness to share rides with strangers by examining the monetary value associated with the option of riding alone or with a stranger, factoring in the additional travel time required to pick up the stranger. However, the study focused on the perceived discomfort and privacy concerns that arise when sharing a vehicle with a stranger, rather than on issues of security. The concept of privacy may encompass some aspects of security, as Sanguinetti et al. [135] outline Sommer's personal space [384] to propose designs of the interior of SAVs. A study conducted by Zoellick et al. [385] focused on the reactions of riders of shared, automated "pods" on campuses, which followed predetermined routes. Among other dimensions, the researchers investigated how riders perceived the safety, trustworthiness, and fear with these modes of transportation. They assessed security with a single item ("*I would feel safe using automated vehicles*", also considering trust ("*I trust automated vehicles because they take my interests into account*", "*Automated vehicles are trustworthy*"), and risk ("*I believe that using automated vehicles is dangerous*"). The concepts of risk and trust are intertwined with security [278], with risk referring to situations where multiple outcomes are possible, and trust involving a willingness to make oneself vulnerable [27]. According to [386], also anxiety has an impact on trust. Kurani [278] adds uncertainty to these dimensions, which defines the extent to which outcomes and their probabilities are unknown. In general, there is little theoretical work on factors underlying perceived security.

Perceived security cannot be seen as a stable, enduring construct, as it depends on many personal, situational, and contextual factors [149]. Age [140] and gender [141] have been identified as two common factors, with older adults and women having a tendency towards higher fear of crime. Other theories of fear of crime and perceived security are based on prior knowledge. The subjective perceived sense of security is subject to individual and group differences and depends on experiences [139] which stands that culture has an influence, as well. SAVs will function as an automated form of public transportation (PT). While passengers are facing security challenges in today's PT systems all over the world [142], there are differences with regard to security in different countries. In Germany, for instance, PT is rather secure. However, there is a breach between actual and perceived security with many passengers not considering PT as secure as it is [138]. Contrarily, passengers in Latin America face various mobility challenges, with personal security and gender-based violence being the most important ones [142, 191]. Studies underline that users in Latin America feel unsafe while using transit services [191], where pick-pocketing and aggressive behavior in overcrowded buses is a growing problem for both users and operators. With a population of over 10 million people [387] and its rapid urbanization, Bogotá takes special measurements to assure for the mobility of its inhabitants. Today, mass public transportation in Bogotá is mainly supplied by the *Transmilenio*, with buses operating on designated bus routes and using separate lanes alongside the usual traffic lanes, the traditional buses, and illegal, unregulated transport services, the so-called *bicitaxis* [388]. At the same time,

Colombia faces several security issues in PT including gender-based violence, harassment, and high crime rates [389].

We expect that different experiences in today's PT systems will have an influence users' adoption of SAVs. The studies mentioned in the previous paragraphs have been conducted in Europe and Northern America. Based at a European institution, we wanted to gain insights from a broader, cross-cultural perspective on the perception of security in SAVs.

In this chapter, we aim to close the described research gaps and developed a questionnaire for perceived security in SAVs (PSSAV) and included participants from Colombia as representatives from countries with high (perceived) insecurity.

9.1 Material and Methods

The PSSAV was developed in an iterative way. First, we followed a data-driven and inductive approach and clustered items from statements of participants from our prior studies from Chapters 3, 5, and 6 that address security in SAVs. Second, based on related work, we categorized our 52 items into 6 dimensions (Security, Trust, Risk, Privacy, Anxiety, Control). Third, we validated these items in a pilot study with $N = 60$ participants following a data-driven approach and using an online questionnaire. Next, we conducted an exploratory factor analysis to gain an initial hypothesis on the factor structure underlying security and eliminate items based on item analysis, factor loadings, and redundancy, and subsequently validated the remaining questionnaire in another online study. To account for cross-cultural differences and ensure that the proposed questionnaire can be used in different cultural contexts, participants from Colombia ($N = 101$) and Germany ($N = 114$) were included in the validation study. Participants were randomly assigned either to the utopia or the dystopia group, and were accordingly presented either a video of a positive SAV ride (utopia) or a video of a negative SAV ride (dystopia) implemented in virtual reality (VR). we investigate the multifaceted dimension of perceived security in SAVs. By transcending geographical boundaries and embracing diverse cultural contexts, we aim to develop a more comprehensive understanding of the factors that shape security perceptions, ultimately contributing to the development of more robust security frameworks tailored to the unique needs of SAV users across the globe.

9.2 Pre-Studies

9.2.1 Item Generation

All the used items were derived from previous qualitative work with a total of 75 participants (67 Germans, 50 women, 17 men, 0 diverse, 0 n/a; from 18 to 82 years; $M = 44.93$; $SD = 20.5$; $Mdn = 36$ years; 8 Colombians, 4 women, 4 men, 0 diverse, 0 n/a; from 27 to 56 years; $M = 34.68$; $SD = 8.3$; $Mdn = 33$ years;) that were interviewed during co-creation workshops, in-depth and semi-structured interviews, and in lab experiments with regard to their perceived security in the context of sharing rides in SAVs with other passengers. This approach is in line with Morgado et al. who claim that items can be identified inductively through exploratory research using qualitative data [390]. Parts of these works have been already published (see [1, 2, 3, 5]). All statements regarding perceived security were clustered and discussed in an experts workshop with three researchers from the area of automated driving. Incorporating the results of the experts workshop, we formulated 52 indicator items (in the following referred to as items) for six latent constructs (also referred to as dimensions) with the three potential secondary factors: **Security** (10 items), **Trust** (8 items), **Risk** (8 items), **Privacy** (8 items), and **Anxiety** (7 items), and **Control** (11 items). However, at this stage of the development process we did not know whether these six factors would also be clearly identified by the statistical analyses in the data set collected during our pilot study.

9.2.2 Pilot Study

The initial questionnaire was evaluated in an online study for item and factor analysis. Through such pre-testing, the meaningfulness of the questionnaire can be ascertained before conducting larger validation experiments. Bad items can be eliminated in the early stages of the project [391]. Participants were asked about their general attitude towards perceived security in shared automated vehicles without any additional stimulus material.

Materials and Procedure

The study was performed as an online questionnaire and participants were explained the context and requested to fill the 52-item first version of the Perceived Security Scale (PSSAV). This was followed by questions on demographics, driving experience, and usual participation in road traffic (e.g., public

transport use). In total, participating in the online study took about 15 minutes.

Participants

The pilot study was conducted with a total of 60 participants (31 women, 29 men, 0 diverse, 0 n/a; from 18 to 70 years; $M = 31.3$; $SD = 13.4$; $Mdn = 29$ years;) from Germany.

Results

The retrieved data were used for an initial exploratory principal component analysis (PCA) to gain insights on the underlying factor structure [392], even though the sample size was not sufficient to draw final conclusions. Despite our a-priori ideation of dimensions affecting security, we decided to rely on a posterior data-driven approach in order to derive the actual factors from the given data. Based on the rather little theoretical work on factors underlying perceived security, we considered the posterior approach preferred to a confirmatory factor analysis, despite our efforts to hypothesize underlying dimensions a-priori [391]. Data analysis was performed using R [393]. Three items were excluded from the initial item set prior to PCA, as these were found to be highly redundant ($r > .8$). The remaining item set was found to be suitable for factor analysis, $KMO = .63$, Bartlett's test: $\chi^2(1485) = 3019.64$, $p < .001$. The recommended number of factors as retrieved from scree plot and parallel analysis was $n = 4$. PCA was chosen as the method of factor extraction, as there was no concrete hypothesis on communality [394], and PCA is considered efficient in terms of maximizing communality [395]. Further, PCA and maximum likelihood factor analysis tend to produce highly similar results with large matrices [396], making the reduced complexity PCA the suggested method for initial analysis. Also, maximum-likelihood estimation proposed the same factor structure and item-factor allocation for the present dataset. We therefore decided to rely on and report the lower-complexity PCA here. Varimax rotation was applied as a method of orthogonal rotation, as we were interested in retrieving independent factors. The resulting standardized pattern matrix of the PCA confirms that the four factor structure explains 57 % of the total variance, with each factor explaining more than 10 %. The a-priori structural assumptions (six dimensions) made based on the experts workshops were subsequently revised and re-interpreted following the structure proposed by the PCA, leading us to propose the final four subscales Security, Trust, Privacy, and Control.

Item analysis was performed after the factor analysis, as this way also the item factor loadings could be considered: Items loading on numerous subscales with less difference than .2 to their primary factor were removed from the item pool. We further regarded the criteria item difficulty, item-total correlation (corrected), and redundancy (high correlation with different items). Following the case-by-case item exclusion, there were 23 items left having fulfilled all requirements. Hereof, 11 items belonged to the Security subscale, 4 items to the Trust subscale, 4 items to the Privacy subscale, and 4 items to the Control subscale (Figure 9.2). Most items (eighteen) were negative-tone, with higher values indicating lower perceived security. The 23 items showed good internal consistency, Cronbach's $\alpha = .87$.

9.3 Validation experiment

A second online study was performed to confirm the initially observed factor structure as well as the new scale's validity and reliability. While the initial sample size in the pilot study was $N = 60$, it is generally recommended to use larger samples (e.g., 10 observations per variable, [397]) for factor extraction. Further, it is not possible to conclude on a scale's validity merely from the determination of its factorial structure. Following the known-groups validity approach [398], a scale's construct validity may be demonstrated by showing that it is sensitive to differences across two groups which are known to differ with regard to the construct at question. Experience with automated shuttles was therefore manipulated in a between-groups design experiment, with one group experiencing a secure drive (= utopic) in an automated shuttle and one experiencing an insecure drive (= dystopic). The newly designed scale should be sensitive to differences across these two groups if it is a valid measure of perceived security in the context of shared automated vehicles. Throughout the item brainstorming phase, participants from both Germany and Colombia were involved in the process. Also for the validation experiment, we therefore decided to invite participants from both Germany and Colombia. This way, on the one hand, we will be able to provide a validated questionnaire in both a German and a Spanish version. On the other hand, we thereby demonstrate that the scale is valid independent from its cultural context and may be able to report on first cultural differences in perceived security.

9.3.1 Materials and Procedure

The study was performed in a between-subjects design including the factors automated shuttle experience (utopic vs. dystopic) and cultural background

(Germany vs. Columbia). Between-subject designs are considered more robust, while within-subject designs are more prone to carryover or contrast effects. Participants were randomly assigned to either the utopic or the dystopic condition by the questionnaire platform. Upon engaging the online study, participants were explained the context and requested to file the 23-item Perceived Security Scale (PSSAV) prior to experiencing any stimulus materials. In the following, the participants were asked to watch a video and imagine that they were experiencing the depicted situation in an automated shuttle themselves. The videos were created using Unity and showed a first-person perspective on the interior of a shuttle bus with other passengers. The utopic and dystopic videos were equal regarding length, traffic environment (which was visible through the shuttle windows), and perspective.

Utopic condition: In the utopic condition, the passengers were a mother and her child. In the course of the played scene a dialogue arose between mother and child, in which the boy asked how long the trip would take and the mother answered that they were almost at the football square and promised they would have ice cream after the football game.

Dystopic condition: In the dystopic condition, a young man was the only other passenger. Throughout the course of the played scene, the passenger was complaining about the service provider in an angry and aggressive way and gesturing wildly. From an ethical point of view we decided that the co-passenger should not address participants directly on purpose, but assault the service provider instead, to avoid triggers and re-experiencing negative past experiences in participants.

For the German and Spanish versions of the questionnaires the videos were dubbed in German and Spanish respectively by native speakers. Figure 9.1 shows both scenarios inside the vehicle from the participants perspective.

After the video, the participants were asked to answer the PSSAV again. This was followed by questions on demographics, driving experience, and usual participation in road traffic (e.g., public transport use). In total, participating in the online study took about ten minutes.

The questionnaire's Spanish version was translated by one of the authors who is a sworn interpreter for Spanish.



Figure 9.1: Implementation of scenarios in Unity. The participant is sitting in driving direction and shares the ride with another passenger. Left: Utopic scenario with a mother and her son. Right: Dystopic scenario with aggressively behaving co-passenger.

9.3.2 Hypotheses

The two SAV experience groups are expected to differ with regard to perceived security after the video was presented with the utopic group rating their perceived security higher than the dystopic group if the suggested PSSAV is a valid measure of perceived security (following the known-groups validity approach, [398, 391, 399]). The cultural background of the participants will be included in the analysis as a second factor. It is recommended that scale items should be tested on heterogeneous samples, which we account for including participants with different cultural backgrounds [400].

H8.1: Following the known-groups validity approach, perceived security as measured by the PSSAV should be rated *higher* in the utopia group compared to the dystopia group.

H8.2: Based on the security levels in public transportation and on the assumption that this will affect the perception of SAVs as a form of public transportation, we expect participants from Colombia to have higher security concerns (i.e., lower perceived safety).

H8.3: We expect the PSSAV to be valid regardless of cultural context. No differences in sensitivity to group differences in automated shuttle experience are expected. Accordingly, we do not expect any interaction effects of automated shuttle experience and cultural background.

9.3.3 Participants

A total of $N = 215$ participants (109 women, 102 men, 1 diverse, 3 n/a; from 16 to 73 years; $M = 28.29$; $SD = 10.68$) took part in the validation online study. We had an almost evenly distributed sample of German ($n = 114$) and Colombian participants ($n = 101$) participants. German participants were aged between 18 and 73 years, $M = 26.63$; $SD = 9.77$ (46 women, 66 men 1 diverse, 1 n/a). Colombian participants were aged between 16 and 72 years, $M = 30.16$; $SD = 11.39$ (63 women, 36 men, 2 n/a). 63 % of our Colombian participants and 48 % of our German participants indicated to use PT at least once a week or more often, and 22 % of our Colombian participants and 30 % of our German participants indicated to use PT never or less than once a month. 68 % of our Colombian participants and 73 % of our German participants indicated to use their own cars at least once a week or more often, and 8 % of our Colombian participants and 14 % of our German participants indicated to use their own cars never or less than once a month.

9.3.4 Results

All statistical analyses were performed using R [393].

Factor analysis

As was preliminary stated, results from PCA and maximum-likelihood estimate (MLE) tend to coincide with large matrices, with both approached generally aiming at reducing dimensions. Kline [395] proposed that MLE would be especially suited for confirmatory analysis. Therefore, despite we again intend to perform an exploratory analysis in the first place, we decided to report the results for MLE here, as with MLE it is possible to report goodness of fit indices known from structural equation modeling or confirmatory analysis. Note that both PCA and MLE were performed initially, both indicating the same factor structure and item-factor allocations. A maximum-likelihood based factor analysis was performed on the 23 item version of the PSSAV using varimax rotation. The data was well suited for factor analysis, $KMO = .89$, Bartlett's test: $\chi^2(253) = 2800.90$, $p < .001$. The number of factors was determined $n = 4$ based on scree plot and parallel analysis, which is consistent with findings from the pilot study. The extracted factor structure overall confirmed the structure extracted from the pilot study, including the factors Security (eigenvalue = 4.40), Trust (eigenvalue = 2.86), Privacy (eigenvalue = 2.75), and Control (eigenvalue = 2.73). Factor loadings are presented in Table 9.1. Three items belonging to the former Security subscale were now found to load higher on

different factors, with the item “I want to know in advance who is sharing a shared automated vehicle with me” now loading highest on Control, “I would feel safer sharing a shared automated vehicle exclusively with people I know” now loading highest on Privacy, and “I would feel safe using a shared automated vehicle late at night/at night” now loading highest on Trust. The items were found to match well with the other items in their now highest loading factor. The items were therefore moved to the subscales suggested by the more robust larger sample results, leaving Security with 8 items, Control with 5, Privacy with 5, and Trust with 5 (Figure 9.2). The items in German, Spanish, and English versions are shown in Table 9.3 and Table 9.4 with their finally assigned factors.

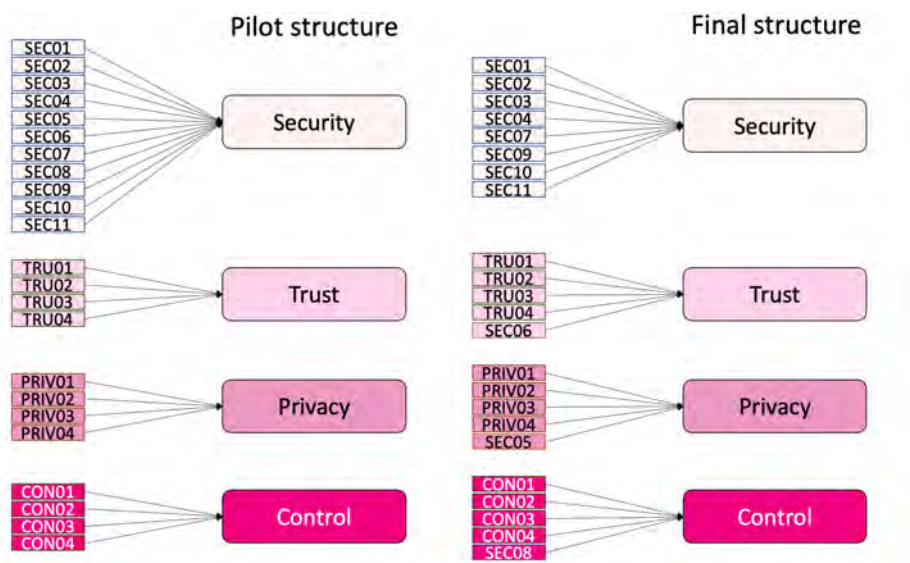


Figure 9.2: Factor structure as derived by the pilot and validation study.

Model fit

The extracted factor structure explained 55 % of the variance. Note that a slightly higher proportion of variance is explained according to the PCA solution (63 %). The goodness of fit criteria suggest a mediocre model fit, with root square of the residuals (RMSEA) = 0.065, $\chi^2(215) = 318.60$, $p < .001$, CFI = 0.94. TLI = 0.91. To allow an easier interpretation, we will provide the reader with information on the interpretation of these goodness of fit indices.

Table 9.1: Standardized pattern matrix for the factor analysis. Loadings < 0.3 are deemed irrelevant and were hence suppressed for this table, to allow for enhanced understandability. Stevens [401] recommends a sample-size dependent factor loading of ≥ 0.364 for sample sizes $N = 200$. h2 indicates communalities and u2 unique variance (for a better understanding, we recommend [394]). The com column indicates Hoffman's index of complexity (see documentation of the R package psych, [402]).

	Security	Control	Privacy	Trust	h2	u2	com
<i>SEC10</i>	0.78				0.73	0.27	1.4
<i>SEC11</i>	0.78		0.31		0.71	0.29	1.4
<i>SEC09</i>	0.74		0.38		0.70	0.30	1.5
<i>SEC07</i>	0.69			0.31	0.65	0.35	1.8
<i>SEC04</i>	0.64		0.56		0.76	0.24	2.2
<i>SEC03</i>	0.61			0.35	0.52	0.48	1.8
<i>SEC02</i>	0.56			0.38	0.50	0.50	2.0
<i>SEC01</i>	0.51		0.35		0.45	0.55	2.3
<i>CON03</i>		0.85			0.75	0.25	1.1
<i>CON04</i>		0.79			0.69	0.31	1.2
<i>CON02</i>		0.61			0.39	0.61	1.1
<i>SEC08</i>	0.31	0.59			0.52	0.48	2.0
<i>CON01</i>		0.51			0.33	0.67	1.5
<i>PRIV01</i>	0.45		0.74		0.76	0.24	1.7
<i>PRIV02</i>			0.63		0.52	0.48	1.6
<i>PRIV03</i>			0.56		0.45	0.55	1.9
<i>SEC05</i>		0.34	0.50		0.43	0.57	2.3
<i>PRIV04</i>	0.35	0.31	0.39		0.39	0.61	3.2
<i>TRU02</i>				0.77	0.76	0.24	1.6
<i>TRU03</i>				0.75	0.58	0.42	1.1
<i>TRU04</i>				0.70	0.57	0.43	1.3
<i>TRU01</i>				0.56	0.32	0.68	1.0
<i>SEC06</i>				0.50	0.29	0.71	1.3

An $RMSEA \leq 0.08$ indicates fair fit, while values ≤ 0.05 would indicate close fit [403], as cited by [391]. A non-significant Chi-square test would indicate a good model fit (which is not given for the present analysis). However, note that the chi-square test is known to be sensitive to sample size. For CFI and TLI, cutoff values close to 0.95 are recommended [404]. For reasons of space, we refrain from presenting the complete covariance matrices and residuals. Instead, we additionally provide the fit based upon off diagonal values as provided by the psych package [402], which is the sum of the squared residuals divided by the sum of squared correlations and may range from 0 to 1 [394]. Values > 0.95 are considered values of good fit [394; present model = 0.99).

Table 9.2: Cronbach’s alpha for PSSAV complete and the subscales Security, Trust, Privacy, and Control.

	Cronbach’s alpha
<i>PSSAV complete</i>	.91
<i>Security</i>	.91
<i>Trust</i>	.81
<i>Privacy</i>	.82
<i>Control</i>	.82

Reliability analysis

While the best way to estimate a scale’s reliability is usually to calculate its test-retest reliability, it is widely accepted to provide Cronbach’s alpha in scale development. Cronbach’s alpha was calculated for the complete PSSAV questionnaire as well as its four subscales, indicating good to excellent reliability (Table 9.2).

Hypothesis testing

Negative polar items were inverted prior to calculating questionnaire scores. A PSSAV main score was calculated averaging over all items included in the PSSAV. Subscale scores were calculated as averages of the items included in each subscale. The total score as well as the subscores were considered in 2×2 between-factors ANOVAs, including the factors automated shuttle experience (utopic vs. dystopic) and cultural background.(Germany vs. Colombia).

The analysis of the PSSAV total score indicated a significant main effect of the factor automated shuttle experience, $F(1,211) = 4.86, p = .029, \eta^2 = 0.02$, with the utopic group reporting to feel more secure compared to the dystopic group (Figure 9.3). There also was a significant main effect of cultural background, $F(1,211) = 19.51, p < .001, \eta^2 = 0.08$, with the German participants reporting a higher feeling of security than the Colombian participants (Figure 9.3). The interaction of automated shuttle experience and cultural background was not significant, $F(1,211) = 0.27, p = .606, \eta^2 = 0.00$.

For the Security subscale, there again were significant main effects of automated shuttle experience, $F(1,211) = 4.34, p = .039, \eta^2 = 0.02$, and cultural background, $F(1,221) = 21.54, p < .001, \eta^2 = 0.09$, with the utopic group reporting a higher feeling of security than the dystopia group and German participants reporting a higher feeling of security compared to the Colombian participants (Figure 9.3).

The interaction of automated shuttle experience and cultural background did not significantly affect security, $F(1,211) = 1.14$, $p = .287$, $\eta^2 = 0.01$.

Regarding the analysis of Trust, neither the main effect of automated shuttle experience, $F(1,211) = 3.08$, $p = .081$, $\eta^2 = 0.01$, nor the main effect of cultural experience, $F(1,211) = 0.07$, $p = .796$, $\eta^2 = 0.00$, nor the interaction of automated shuttle experience and cultural experience was significant, $F(1,211) = 0.86$, $p = .354$, $\eta^2 = 0.00$ (Figure 9.3).

For Privacy, again the main effects of automated shuttle experience, $F(1,211) = 4.72$, $p = .031$, $\eta^2 = 0.02$, and cultural background, $F(1,211) = 5.40$, $p = .021$, $\eta^2 = 0.02$, with the utopic group requiring less privacy than the dystopic group and German participants requiring less privacy (the items were inverted as a lower need for privacy indicates higher perceived security) compared to Colombian participants (Figure 9.3). The interaction of automated shuttle experience and cultural background was not significant, $F(1,211) = 0.30$, $p = .588$, $\eta^2 = 0.00$.

The analysis of the Control subscale indicated a significant main effect of cultural background, $F(1,211) = 29.88$, $p < .001$, $\eta^2 = 0.12$, with Colombian participants expressing a higher need for control compared to the German participants (Figure 9.3). Again, the items are inverted as a lower need for control indicates higher perceived security. The main effect of automated shuttle experience, $F(1,211) = 0.00$, $p = .987$, $\eta^2 = 0.00$, and the interaction of cultural background and automated shuttle experience, $F(1,211) = 0.28$, $p = .595$, $\eta^2 = 0.00$, were not significant.

9.4 Discussion and Implications

9.4.1 Perceived Security and Influencing Factors

The PSSAV was created specifically for measuring perceived security in the context of automated shuttle buses. The outcomes of the initial assessment, particularly the factor analysis, demonstrate empirical support for the construct of perceived security, providing evidence of the impact of trust, privacy, and control on perceived security. The proposed PSSAV represents a more advanced approach than previous efforts to measure security [138, 133, 385], as it moves away from general security measurement to a more nuanced perspective. Perceived security has already been shown to influence individuals' willingness to use automated shuttle buses [245, 133, 124], and our prior work in Chapters 3 through 8 suggests solutions to overcome security issues.

Table 9.3: Items of the PSSAV (Part 1 of 2): Security and Trust

	Item Wording <i>German</i>	<i>Spanish</i>	<i>English</i>
Security			
SEC01	Ich fühle mich nicht sicher, wenn ich ein gemeinsam genutztes automatisiertes Fahrzeug mit anderen Passagieren teile.	No me siento seguro/a compartiendo un vehículo automatizado con otros pasajeros.	I do not feel safe sharing a shared automated vehicle with other passengers.
SEC02	Ich fühle mich in einem gemeinsam genutzten automatisierten Fahrzeug nicht sicher, weil keine Fahrerin/kein Fahrer anwesend ist.	No me siento seguro/a en un vehículo automatizado compartido porque no hay conductor presente.	I do not feel safe in a shared automated vehicle because there is no driver present.
SEC03	Ich habe Sorge, dass die Türen des gemeinsam genutzten automatisierten Fahrzeugs verschlossen bleiben und ich darin gefangen bleibe.	Me preocupa que las puertas del vehículo automatizado compartido se queden cerradas y yo quede atrapado/a adentro.	I am concerned that the doors of the shared automated vehicle will remain locked and I will remain trapped inside.
SEC04	Ich würde mich unwohl fühlen, wenn ich in einem gemeinsam genutzten automatisierten Fahrzeug in der Nähe von Fremden sitzen würde.	Me sentiría incómodo/a al sentarme cerca de desconocidos en un vehículo automatizado compartido.	I would feel uncomfortable sitting near strangers in a shared automated vehicle.
SEC07	Ich denke, dass es riskant ist, in einem gemeinsam genutzten automatisierten Fahrzeug zu fahren.	Creo que es arriesgado conducir en un vehículo automatizado compartido.	I think it is risky to ride in a shared automated vehicle.
SEC09	Ich fühle mich von anderen Passagieren im gemeinsam genutzten automatisierten Fahrzeug bedroht.	Me siento amenazado/a por otros pasajeros del vehículo automatizado compartido.	I feel threatened by other passengers in the shared automated vehicle.
SEC10	Ich habe Sorge, dass fremde Passagiere im gemeinsam genutzten automatisierten Fahrzeug mit mir aussteigen.	Me preocupa que los desconocidos salgan conmigo en el vehículo automatizado compartido.	I am concerned about unfamiliar passengers exiting the shared automated vehicle with me.
SEC11	Ich hätte Angst, mit nur einer weiteren fremden Person in einem gemeinsam genutzten automatisierten Fahrzeug zu fahren.	Me daría miedo viajar en un vehículo automatizado compartido con otro desconocido.	I would be afraid to ride in a shared automated vehicle with just one other stranger.
Trust			
TRU01	Wenn ich tagsüber in einem gemeinsam genutzten automatisierten Fahrzeug fahre, habe ich das Gefühl, die Kontrolle über die Situation zu haben.	Cuando conduzco en un vehículo automatizado compartido durante el día, siento tener control sobre la situación.	When I ride in a shared automated vehicle during the day, I feel like I am in control.
TRU02	Ich vertraue gemeinsam genutzten automatisierten Fahrzeugen.	Confío en los vehículos automatizados compartidos.	I trust shared automated vehicles.
TRU03	Ich vertraue darauf, dass Hackerangriffe (Cyberattacken) auf gemeinsam genutzte Fahrzeuge aufgrund hoher Sicherheitsmaßnahmen nicht passieren.	Confío en que no se produzcan ataques de hacking (ciberataques) a los vehículos automatizados compartidos debido a las altas medidas de seguridad.	I trust that hacking attacks (cyberattacks) on shared vehicles will not happen due to high security measures.
TRU04	Wenn ich spät abends/-nachts in einem gemeinsam genutzten automatisierten Fahrzeug fahre, habe ich Vertrauen in die Situation.	Cuando conduzco en un vehículo automatizado compartido a última hora de la tarde/de noche, tengo confianza en la situación.	When I drive late at evening/night in a shared automated vehicle, I have confidence in the situation.
SEC06	Ich würde mich sicher fühlen, ein gemeinsam genutztes automatisiertes Fahrzeug spät abends/-nachts zu nutzen.	Me sentiría seguro/a utilizando un vehículo automatizado compartido a última hora de la tarde/noche.	I would feel safe using a shared automated vehicle late at evening/night.

Table 9.4: Items of the PSSAV (Part 2 of 2): Privacy and Control

Item Wording			
	German	Spanish	English
Privacy			
<i>PRIV01</i>	In einem gemeinsam genutzten automatisierten Fahrzeug würde ich mich durch andere Mitfahrende gestört fühlen.	En un vehículo automatizado compartido, me sentiría molesto/a por otros pasajeros.	In a shared automated vehicle, I would feel disturbed by other passengers.
<i>PRIV02</i>	Während der Fahrt bevorzuge ich es, ein Fahrzeug für mich alleine zu haben und es nicht mit anderen teilen zu müssen.	Prefiero tener un vehículo para mí y no tener que compartirlo con otros.	While driving, I prefer to have a vehicle to myself and not have to share it with others.
<i>PRIV03</i>	In einem gemeinsam genutzten Fahrzeug kann ich die Zeit nicht so gut nutzen, weil ich auf andere Mitfahrende Rücksicht nehmen muss.	En un vehículo compartido, no puedo aprovechar tan bien el tiempo porque tengo que ser considerado/a con los demás pasajeros.	In a shared vehicle, I cannot use the time as well because I have to be considerate of other passengers.
<i>PRIV04</i>	Für Fahrten zu Freizeitaktivitäten bietet das gemeinsam genutzte automatisierte Fahrzeug nicht die ausreichende Privatsphäre.	Para viajar a actividades de ocio, el vehículo automatizado compartido no ofrece suficiente privacidad.	For trips to recreational activities, the shared automated vehicle does not provide sufficient privacy.
<i>SEC05</i>	Ich würde mich sicherer fühlen, ein gemeinsam genutztes automatisiertes Fahrzeug ausschließlich mit Personen zu teilen, die ich kenne.	Me sentiría más seguro/a compartiendo un vehículo automatizado sólo con personas conocidas.	I would feel safer sharing a shared automated vehicle exclusively with people I know.
Control			
<i>CON01</i>	Ich möchte zu jeder Zeit die Möglichkeit haben, das gemeinsam genutzte automatisierte Fahrzeug anzuhalten und aussteigen zu können, falls ich mich unwohl fühle.	Quiero poder detener el vehículo automatizado compartido en cualquier momento y bajarme si me siento incómodo/a con otros pasajeros.	I want to be able to stop the shared automated vehicle at any time and get out if I feel uncomfortable.
<i>CON02</i>	Ich möchte vorher die Strecke wissen, die das gemeinsam genutzte automatisierte Fahrzeug fahren wird.	Quiero saber de antemano la ruta que seguirá el vehículo automatizado compartido.	I would like to know beforehand the route that the shared automated vehicle will take.
<i>CON03</i>	Ich möchte, dass andere Passagiere beim Service-Provider von gemeinsam genutzten automatisierten Fahrzeugen registriert sind.	Quiero que los demás pasajeros estén registrados en el proveedor de servicios de vehículos automatizado compartidos.	I want other passengers to be registered with the service provider of shared automated vehicles.
<i>CON04</i>	Ich möchte, dass andere Passagiere beim Einstieg in ein gemeinsam genutztes automatisiertes Fahrzeug auf ihre Identität geprüft werden.	Quiero que se compruebe la identidad de los demás pasajeros al subir a un vehículo automatizado compartido.	I would like other passengers to be checked for identity when boarding a shared automated vehicle.
<i>SEC08</i>	Ich möchte vorher wissen, wer mit mir ein gemeinsam genutztes automatisiertes Fahrzeug teilt.	Quiero saber de antemano quién comparte conmigo un vehículo automatizado compartido.	I want to know in advance who is sharing a shared automated vehicle with me.

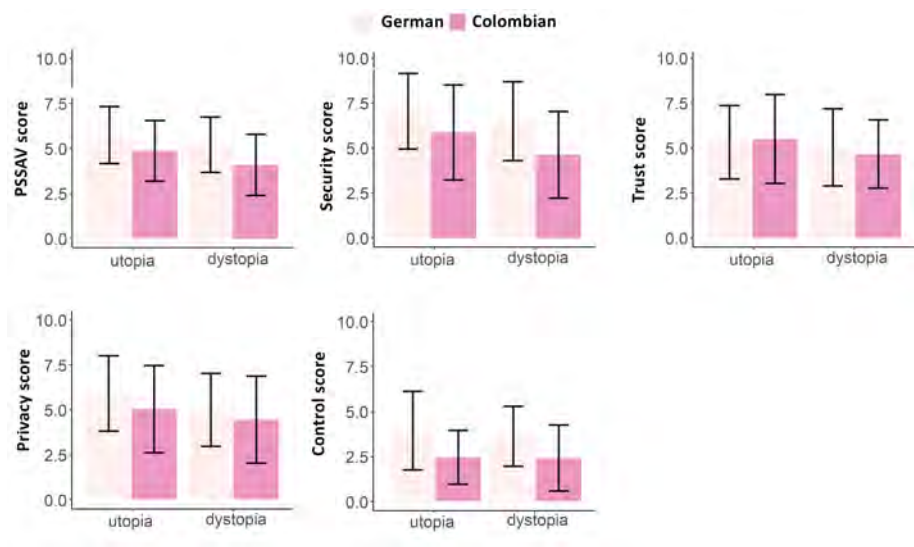


Figure 9.3: Average PSSAV scores and the subscales Security, Trust, Privacy, and Control depending on automated shuttle experience (utopic vs. dystopic) and cultural background (German vs. Spanish version). Error bars indicate standard deviations of the mean.

As a result, future research could employ the PSSAV to evaluate proposed design solutions, identify factors that increase perceived control or privacy within passengers, or determine what user interfaces or interactive systems foster trust and security. It could also help determine the extent to which security components such as trust, privacy, and control contribute to potential users’ overall attitude toward automated shuttle buses. The high reliability of the scale further supports its potential usefulness in future research.

9.4.2 Discussion of Exploratory and Validation Analyses

The factorial structure of the PSSAV was investigated in two online studies and concluded the same overall factorial structure, supporting the general robustness of the proposed solution. Perceived security was found to consist of the underlying factors Security, Trust, Privacy, and Control, which, taken together, explain a reasonable proportion of the total variance. Note that the model fit must be considered fair rather than optimal, and it would be preferable to conduct cross-validation, i.e., running a confirmatory analysis on another independent dataset. Due to the limited sample size, cross-validation was not possible with the available data. We encourage researchers interested in using the PSSAV to proceed with attempts to further validate the factorial structure

of the questionnaire. The reliability analysis using Cronbach's alpha showed that the PSSAV total and all of its subscales were sufficiently reliable. However, it should be noted that it is not without criticism to report Cronbach's alpha as proof of reliability, as it cannot replace a retest, which was beyond the scope of the present investigation.

The construct validity of the PSSAV was demonstrated by showing its sensitivity to differences between the utopia and the dystopia group [398]. It should be noted that the dystopia example was a moderately negative SAV experience for ethical reasons. The group difference was hence rather small, while the PSSAV was still sensitive. The subscales Trust and Control did not indicate any significant differences across the utopia and the dystopia groups, which may be due to the overall limited threat of the dystopia video. Overall, no interactions of automated shuttle experience and cultural background were reported. Accordingly, there is no evidence of differential sensitivity of the PSSAV for different cultural backgrounds, and we may assume the validity of both the German and the Spanish version of the PSSAV to measure perceived safety in shared automated vehicles. The authors also provide an English version, which was translated by the authors and re-translated by an English native speaker to ensure translation quality.

Overall, our data has a high standard deviation which suggests that there is a wide range of responses to the perceived security scale, which could be due to a variety of factors, such as, e.g. personal experiences, or to demographic factors.

9.4.3 Influence of Culture on Perceived Security

The comparison of our results show that, in general, German participants felt more secure than Colombian participants in both conditions. We hypothesize that this is due to the generally more negative experiences that public transportation users in Colombia have [142, 389]. Participants from Colombia showed a higher need for privacy than participants from Germany. This result contrasts Hofstede's framework of cultural differences [187], which defines Colombia as a highly collectivistic culture, as it is very important to belong to an in-group and align oneself with that group's opinion. Contrarily, Germany is an individualistic country and people are expected to take care only of themselves and their close families. Particularly public transportation in Bogotá has to deal with overcrowding [191] and we consider the need for privacy being a close consequence to this situation and would like to underline that the specific context of shared (automated) mobility must be considered in isolation.

Furthermore, our Colombian participants showed a higher need for control. According to Hofstede's framework [187], uncertainty avoidance implies a society's risk-averse attitude resulting in rigid codes of belief and behavior and intolerance towards unconventional behaviors and ideas. Both, Colombia and Germany show high mean scores of uncertainty avoidance with Colombia showing a higher score (80) than Germany (65). Again, we argue that the higher need for control in SAVs that resulted in our study is highly influenced by participants' experiences in shared public transportation. For the future development of SAVs the status quo of public transportation systems of the respective countries has to be considered to account for special requirements due to past experiences.

9.5 Limitations and Future Work

The study had some limitations, and it is recommended that future evaluations should be conducted in more realistic environments, such as simulations, to ensure the PSSAV's reliability under various conditions. Although the study produced significant results between the dystopic and utopic conditions, there was no formal test-retest reliability evaluation conducted for this scale during the initial study, as all videos were viewed within a short, single session in an online questionnaire. To ensure consistency, it is suggested that future studies should evaluate the retest reliability of the PSSAV. As a strong theoretical basis for perceived security and the underlying constructs was missing, we followed a data-driven approach and the relationship between security, trust, and privacy can be seen as ambiguous. However, given the specific context and the basis of our previous qualitative work, we believe that the PSSAV presents a compelling scale. Currently, a couple of pilot projects of automated shuttle buses are operating in Germany. However, as seen in Chapter 6, these vehicles operate with slow speed and with an operator on board as a back-up. In Colombia, the introduction of automated public shuttle buses is currently not in sight. In a few decades, when automated buses might have become an integral part of our daily life and road traffic, the scale should be used in more realistic contexts to investigate if participants with higher security scores are adopting and using automated shuttle buses significantly more than respondents with lower ratings on security. The presented questionnaire is specifically tailored towards SAVs and in its current version is not suitable for other automated mobility systems. We hypothesize that trust, privacy, and control are likely to influence security in the context of other forms of mobility, and thus, the scale could be adapted. Our findings represent the collective attitudes of people from Germany and Colombia at present. In the future, the questionnaire study should be re-conducted with participants from other countries and continents, e.g., from places where automated shuttle buses already operate in a more

advanced way, such as USA. However, the authors believe that this scale can be used for the evaluation of concepts for security in projects involving SAVs in the future.

9.6 Conclusion

In this Chapter, we have argued that due to the complexity of the construct perceived security, a consensus is necessary to measure security and influencing factors in the context of shared automated vehicles and shuttle buses. Our prior qualitative work conducted in Germany and Colombia offered us a solid base for the initial, data-driven development of the Perceived Security Scale in Shared Automated Vehicles (PSSAV) with 52 items. By building upon our prior qualitative work and related work, we categorized these items into 6 initial dimensions (Security, Trust, Risk, Privacy, Anxiety, and Control) and evaluated the scale in a pilot study with participants from Germany ($N = 60$). The scale was reduced based on item quality and the results of the factor analysis, proposing a final 23 item version loading on the four factors Security, Trust, Privacy, and Control. The final version of the PSSAV was evaluated in a subsequent main study with participants from Germany ($N = 114$) and Colombia ($N = 101$). The results indicated that the PSSAV is sensitive to differences in perceived security, showing its construct validity, and was sufficiently reliable both considering the total score and the PSSAV subscales. The factor structure, with Security, Trust, Privacy, and Control being the underlying constructs, was confirmed in two separate investigations. We propose the PSSAV as a promising and more nuanced approach that can be used to evaluate new concepts designed to address the security needs of future SAV passengers.

10 Discussion and Conclusion

This chapter starts with a summary (Section 10.1) and an outline of its contributions (Section 10.2). Following this, we offer insights into our main research questions concerning the influence of distinct needs and preferences of individuals representing diverse gender, age, and cultural profiles (RQ1) and the optimization and design of Human-Machine Interfaces (HMIs) within these vehicles to elevate users' perceived security and enhance trust and acceptance (RQ2), specifically within the in-vehicle context of human-AV interactions (Section 10.3). Finally, we conclude this thesis by outlining limitations and potential avenues for future research (Section 10.4).

10.1 Summary

As researchers we occupy a central position entrusted with the development of groundbreaking technologies capable of shaping our societal landscape. This profound responsibility urges us to weigh the potential consequences of our work carefully. As architects of the future, we possess the capability to pave the way for either utopian or dystopian scenarios, as illustrated in Chapter 1. The rapid evolution of technology, particularly within the domains of AVs and HCI, has opened an area of new possibilities and challenges. Amidst this transformative journey, it becomes imperative to forge technologies that genuinely contribute to societal improvement. Mere innovation is insufficient; our creations must also embody beneficial, ethical, and equitable qualities.

Chapter 1 introduced the central aspects of the dissertation, exploring the contrasting landscapes of utopias and dystopias associated with AVs. Emphasizing the motivation behind this thesis, we introduced SAVs as a transformative element in our future, designed with the aim of improving our daily lives. These vehicles, distinct from private AVs, operate as publicly accessible transportation, potentially reducing individual vehicle ownership, traffic congestion, and environmental pollutants. The chapter provided a comprehensive background on shared mobility, encompassing public transit and shared automated mobility. After an overview on vehicle automation it proceeded with a discussion on the pervasive issue of data biases within technological systems under-

scoring the importance of addressing them, as they may perpetuate inequities and undermine the ethical underpinnings of technological advancements. This section highlighted the significance of rectifying biases in technology, particularly in AVs, to ensure equitable impact and functionality. Furthermore, the chapter emphasized the significance of human-AV interaction development in addressing user concerns. Emphasizing the necessity to account for them early on, the chapter underlined the important role of including a diverse group of potential users in the research process to enable the design of human-AV interactions tailored to decrease potential user insecurities, and, thus facilitating successful and widespread AV adoption. To address this thesis' motivation, rooted in addressing societal and environmental benefits, we used the qualities of feminist HCI [74] and applied the HCD process [29], steering SAVs towards a future that embodies progress, equity, and societal betterment.

With **Chapter 2**, we situated this research among related work and gave an overview of the potentials of SAVs and how these vehicles are perceived by potential users. We explored critical factors impacting the adoption of SAVs. Notably, social acceptance [107, 108] and psychological needs [117] play pivotal roles in driving adoption rates. Significantly important for this thesis was the revelation that perceived security emerges as a substantial deterrent to SAV adoption which is due to the security concerns inherent in today's public transportation and reinforced by the absence of a human driver—who typically is a source of reassurance for passengers—in SAVs of the future.

Further, our research identified distinct user characteristics that formed the foundation of our inclusive research approach. Understanding gender, age, and cultural dimensions, such as those elucidated by Hofstede [186], were instrumental in framing the diverse cultural contexts within this thesis. This comprehensive background on user characteristics guided our efforts to foster inclusivity and diversity within our research endeavors.

Central to our methodology is the HCD process described in ISO 9241 [29], which advocates for early and continuous user involvement in the design and development phases. This approach underscores the imperative of user participation in shaping technologies. Additionally, the feminist HCI [74] framework functions as a critical paradigm in our pursuit of diversity, equity, and inclusivity in technological research and development of SAVs. By integrating these methodologies, our groundwork in related work serves as the solid base upon which we start to address the research questions, propelling our research into the realm of practical application and solutions.

In **Chapters 3** through **9** we presented our empirical research. In **Chapters 3** and **4**, we examined different implementation scenarios of AVs and specific needs, particularly expressed by women in relation to SAVs. Firstly, there is a desire for information about co-passengers, although this poses a challenge due

to the inherent privacy versus security dilemma. While having details about fellow passengers is deemed important, our data highlighted significant privacy concerns regarding the disclosure of private addresses to others. Despite these concerns, we sought to empirically evaluate the solution of providing information on co-passengers in **Chapter 5** using video-based prototyping and a simulated environment. Secondly, the concept of a digital companion within SAVs emerged as a potential solution to mitigate security concerns in SAVs. Exploring various ideas such as holograms, tele-assistants, ear pods, and chatbots, this exploration continued in **Chapter 6**, where we evaluated different concepts for the digital companion and identified the tasks it would need to assume. Crucially, we integrated context into this investigation through in-the-field studies. In **Chapters 7 and 8**, we delved deeper into the implementation of the digital companion, proposing and evaluating different approaches. We compared different appearances of such DCs (human-like and robot-like) and personalities (a caring ‘Baymax’ and an authoritarian ‘RoboCop’) and evaluated them. In **Chapter 9**, we introduced the Perceived Security Scale for SAVs (PSSAV), a central development stemming from our research in **Chapters 3 through 8**. Our exploration during these chapters revealed a significant gap: the absence of a validated universal measurement or model to effectively measure perceived security within SAVs. The following sections provide further details about each chapter.

Chapters 3 and 4 started with an extensive exploratory research, aiming to figure out whether users prefer private or shared AVs and the underlying reasons for their decisions. In our investigation, a prominent revelation emerged: security, particularly concerning women, stood out as a significant concern inhibiting the adoption of SAVs. Driven by these findings, our research focused towards addressing the security needs of women in the context of SAVs. For this, a series of qualitative user studies were conducted, focusing explicitly on understanding the nuanced security requirements of women as passengers within SAVs. Importantly, these studies were not just observational but engaged women from different age groups as co-designers. Our study uncovered the criticality of security within the realm of automated mobility services, emphasizing the significance of a holistic approach to safeguarding passengers’ well-being throughout their journey. We derived tangible security-enhancing features tailored for SAVs, encompassing a comprehensive perspective that spans from booking to arrival, providing insights into shared automated mobility solutions. Additionally, we have formulated concrete propositions for user interfaces across different stages of the ride and introduced concepts for a digital companion—building the basis for the research in Chapter 5 and 6—further enriching the landscape of secure, user-centric, and inclusive SAV experiences.

The insights from **Chapters 3** and **4**, as well as from prior research by König et al. [169] indicated the potential of providing information about fellow travelers to alleviate security apprehensions among SAV passengers. Our study in **Chapter 5** investigated this approach in an exploratory within-subjects user investigation involving 24 participants. We used a TV-based and immersive-video simulator in combination with the the spatial mock-up we used for the user enactment study in **Chapters 3** to increase immersion within the simulated environment. To create a social context, we chose to virtually represent co-passengers through auditory cues (such as sounds of passengers entering and leaving the vehicle) and visual displays on the passenger information system.

Building on the fact that the time of the day is central in the context of SAVs and the night is perceived as more critical in terms of security, we evaluated participants' experiences across both daytime and nighttime scenarios. These rides offered varying degrees of information about fellow passengers, aligning with our research question. Interestingly, our findings revealed a positive impact of information provision—particularly photos of fellow travelers—during nighttime rides, enhancing both the attractiveness of the SAV and passengers' overall ride experience. However, contrasting results emerged during daytime scenarios, with the provided information being deemed unnecessary.

Interestingly, participants, irrespective of their gender, expressed a preference for sharing rides with women as co-passengers. While instances with information on fellow passengers were generally perceived as less risky compared to scenarios without such details, concerns regarding privacy were raised during our post-session interviews. This tension between competing factors—security and privacy—poses a significant challenge for the future design of successful SAVs systems.

Chapter 6 focuses on the current landscape of automated shuttle buses in Germany, aiming to summarize the roles performed by on-board operators and to evaluate the designs of digital companions from Chapter 4. We used a mixed-method user study combining the collection of qualitative and quantitative data as well as the perspectives of both operators and passengers regarding SAVs. For this, we conducted in-the-field observations in two German cities operating automated shuttle buses, conducted in-depth interviews with operators ($N = 5$) and participants with experience ($N = 25$) and without experience ($N = 15$) using SAVs, and used online-questionnaires ($N = 40$).

Despite the depiction of automated shuttle buses as fully automated vehicles, operational pilot projects currently employ human operators onboard. Our study explores the existing challenges in accepting these automated buses from the standpoint of passengers, operators, and other road users.

Additionally, we defined the diverse and multifaceted roles undertaken by these operators, essential information as these roles would eventually be assumed by the automated systems.

We evaluated proposed concepts for digital companions intended for these automated shuttle buses, pinpointing the human tele-assistant and holographic interfaces as the preferred solutions. Building on these insights, we formulated additional design requirements for such companions and that form the foundation of the research we conducted in **Chapters 7** and **8**.

In essence, the study underscores numerous unresolved issues that demand attention before automated road vehicles can seamlessly integrate into the transport infrastructure. Beyond technical hurdles and legal regulations, the study elucidates challenges in individual and social acceptance that necessitate thorough exploration in early developmental phases and continued assessment through pilot projects. Successfully navigating these challenges could pave the way for a technology embraced by society, potentially revolutionizing public transportation and offering substantial benefits to the populace in the years ahead.

Chapters 7 and **8** constitute a comprehensive exploration of digital companions (DCs) intended to enhance security and UX within SAVs. The chapter encompasses two distinct studies, both grounded in HCD principles and involving users in the design process and evaluation of the resultant concepts.

Chapter 7, our focus was on the cultural nuances of Colombia, Germany, and Korea, aiming to design DCs to diverse cultural contexts. Through interviews and co-design workshops, specific requirements were identified, leading to the emergence of two distinct concepts: a human-like (HDC) and a robot-like companion (RDC). Prototypical designs, including culturally adapted versions of the HDC and an RDC, were crafted and evaluated through a comprehensive main study ($N = 136$) using an online questionnaire with scenarios implemented in VR and presented to participants as videos. The findings uncover a significant increase in the sense of security and overall UX of participants. Intriguingly, while all cultures exhibited positive perceptions, Colombians, Germans, and Koreans displayed particular preferences for the human-like companion, with Colombians explicitly favoring it and Koreans showcasing the highest openness towards the robot-like version. The chapter study contributes significantly to the understanding of SAV security and the role of digital companions in enhancing security, emphasizing cross-cultural preferences for such companions. The findings advocate for human-like companions as a promising design approach to elevate perceived security within SAVs, considering the challenges posed by the absence of a human driver.

Building on these results, in **Chapter 8**, a co-design workshop initiated the creation of human-like avatar concepts for DCs, resulting in two contrasting feminine avatars, 'Baymax' and 'RoboCop'. These were evaluated through a study ($N = 23$) with two distinct uncomfortable scenarios that we implemented in VR. The results surprisingly demonstrated a prevalent preference for the 'Baymax' companion across both scenarios, resulting in no direct correlation between the preferred companion and specific scenarios. Although statistical significance regarding the companions' impact on perceived security was not established, descriptive data and qualitative insights suggested a positive influence of the DCs in general. The study indicates that integrating DCs into SAVs could potentially bolster passengers' sense of security within shared rides, laying the groundwork for further exploration and encouraging varied designs and implementations for DCs in SAV contexts.

In **Chapter 9** we underscore the need for consensus in assessing perceived security within the intricate context of SAVs. Our qualitative groundwork in Chapters 3 through 8, as well as interviews conducted in Colombia provided a robust foundation for formulating the first version of the Perceived Security Scale for Shared Automated Vehicles (PSSAV), comprising 52 items. Drawing from our prior qualitative research and related studies, we organized these items into six initial dimensions (Security, Trust, Risk, Privacy, Anxiety, and Control), which underwent evaluation in a pilot study in Germany $N = 60$. This initial scale underwent refinement based on item quality and factor analysis, resulting in a concise 23-item version loaded on four key factors: Security, Trust, Privacy, and Control.

The subsequent validation of the final PSSAV version involved a main study ($N = 215$) with 114 participants from Germany and 101 from Colombia. The results indicated the scale's sensitivity to differences in perceived security, affirming its construct validity and demonstrating reliability for both the overall score and its subscales. Across two distinct investigations, the factor structure supporting Security, Trust, Privacy, and Control as foundational constructs was consistently confirmed making the PSSAV a promising and nuanced instrument that can effectively evaluate novel concepts aimed to mitigate the security requirements of passengers in future SAVs.

10.2 Contributions

Despite encountering technological challenges, the widespread acceptance and perceived security of SAVs remain significant hurdles that demand resolution for successful integration. At the same time, it is imperative to account for potential biases that might exclude and/or discriminate groups of people. To address this, our research aimed to include a diverse range of people with different characteristics under consideration of age, gender, and cultural background enhancing the reliability and inclusivity of our findings. This goal is encapsulated in our first research question (RQ1). Additionally, women, senior citizens, and people hailing from regions with unreliable public transportation systems are prone to perceiving SAVs as lacking in security. This perception serves as a significant barrier to their widespread acceptance. In response, we developed HMIs specifically tailored to address these concerns. These interfaces were designed to enhance the perceived security of SAVs for user groups, striving to bridge the gap and alleviate their apprehensions about using this mode of transportation, addressing our second research question (RQ2). Tables 10.1 and 10.2 serve as comprehensive summaries, outlining our contributions toward these research questions, categorized by their respective types of contribution.

10.3 Answers to Research Questions

Drawing from our insights (Chapters 3 to 9) and contributions (Section 10.2), we formulate answers to RQ1 and RQ2. These encompass actionable design suggestions, along with considerations of diverse user requirements.

10.3.1 RQ1.: Needs and preferences of individuals representing diverse gender, age, and cultural profiles and their influence on the requirements of SAVs

Data biases within technology development and research can result in discriminatory outcomes when implementing new technologies. As women constitute half of the global population and represent a substantial demographic often overlooked in research and development, we aimed to integrate them from the outset of our research to prevent acceptance issues. By taking intersectionality into account we also considered age and cultural background. Drawing from our research, empirical findings, and practical insights, we present the following overarching recommendations as responses to RQ1.

Table 10.1: Overview of contributions to RQ1: How do the needs and preferences of individuals representing diverse gender, age, and cultural profiles influence the requirements of shared automated vehicles, and how can these vehicles be tailored and adapted to ensure broader acceptance?

Type	Contribution	Chapter [Ref.]
Theoretical	Literature-based overview of discriminated user groups and applicable methods and concepts to account for diversity, equity, and inclusion in HCI research.	2
Practical, Empirical	Collection of requirements for SAVs under consideration of age and gender through a qualitative user studies($N = 12$ and $N = 21$) and design recommendations Catalog with concrete system features for mitigation of women's perceived security in SAVs under a holistic view on the ride with shared automated mobility solutions (booking to arrival) derived from a qualitative user study ($N = 21$)	3, [1, 2, 3] 3, [3]
Theoretical	Literature-based overview cultural background and its relevance for HCI research.	2, 7, [under review]
Practical, Empirical	Collection of requirements for SAVs under consideration of cultural background (Colombia, Germany, Korea) through a qualitative user study ($N = 27$) and design recommendations for digital companions Assessment of perceived security in SAVs under consideration of cultural background (Colombia, Germany) through a quantitative user study ($N = 215$) and implications for SAVs	7, [under review] 9, [6]

Early Engagement of Women through HCD and Feminist HCI to Address Acceptance Challenges

It is pivotal to involve women right from the early phases of development, especially considering the prevalent data biases that often result in products that are either underused by or lack usability for women [405]. We contend that participatory design techniques [210, 220] serve as a fitting approach to achieve this goal. Initially, particularly the elderly women in our studies hesitated to engage, citing their lack of knowledge about SAVs and technology in general. However, upon persuasion, their participation notably empowered them during group sessions, enabling them to vocalize their needs as passengers.

Table 10.2: Overview of contributions to RQ2: How can Human-Machine Interfaces (HMIs) be optimized and designed within shared automated vehicles to effectively increase users' perceived security, fostering greater trust and acceptance of this technology among diverse user groups?

Type	Contribution	Chapter [Ref.]
Theoretical	Literature-based overview of acceptance challenges and psychological needs in the context of SAVs.	2, [1]
	Literature-based overview of perceived security in public transportation	2, [3]
Practical, Empirical	Design recommendations for SAVs based on an empirical study ($N = 24$) on passengers' information demands in terms of information on co-passengers during day and night rides.	5, [4]
	Categorization of the roles of operators and design recommendations for HMIs to assume these roles from in-the-field observations, expert interviews ($N = 5$), interviews ($N = 40$), and an online questionnaire ($N = 40$)	6, [5]
	Evaluation of proposed concepts for digital companions for SAVs from interviews ($N = 40$) and an online questionnaire ($N = 40$)	6, [5]
	Development, implementation, and evaluation of HMIs in form of digital companions in SAV under consideration of cultural background (Colombia, Germany, Korea); design recommendations based on an empirical study ($N = 136$) on preferences of human-like or robot-like appearances under consideration of cultural background (Colombia, Germany, Korea).	7, [under review]
	Development, implementation, and evaluation of HMIs in form of digital companions in SAV under consideration of gender; design recommendations based on an empirical VR study ($N = 21$) on preferences of different personalities of digital companions in different security levels.	8, [under review]
Methodological	Development of a validated Perceived Security Scale for Shared Automated Vehicles (PSSAV) and its validation in Germany and Colombia ($N = 215$).	9, [6]

This empowerment aligns with the principles of feminist HCI, emphasizing participation and advocacy. An iterative process, such as HCD, plays a central role in crafting appropriate HMIs. In our journey, the feminist HCI framework provided crucial guidance, facilitating the inclusion of diverse user groups. It allowed us to consider intersectionality and adopt a methodological mix, effec-

tively balancing qualitative approaches for understanding and specifying the context of use, specifying user requirements, and creating design solutions, alongside quantitative methods for evaluating the design solutions and making the data more generalizable, objective, and allowing comparison between groups.

Employing Feminist HCI to include women presented its challenges. While it facilitated discussions about results and aided in participant and method selection, its application was occasionally challenging due to its vagueness. Despite being extensively referenced within HCI research, the foundation of feminist HCI relies on a CHI paper [74], leading to its frequent citation but limited practical application [76]. This aspect occasionally introduced ambiguity. However, despite these challenges, the use of feminist HCI provided valuable insights. It encouraged a critical lens, fostering discussions about inclusivity and diverse perspectives within technological design. Additionally, it prompted a deeper examination of power structures and social contexts, allowing for a more comprehensive understanding of user needs and experiences.

Allow for Flexibility and Diverse Requirements

To achieve SAVs as the preferred transportation mode, it is crucial to design them flexibly for diverse user needs. This entails providing customization options like flexible pick-up and drop-off, multiple seat reservations, and the ability to pick up passengers en route, addressing complex scenarios with scheduled, recurring, and on-demand services, and allowing for precise planning rather than solely on-demand availability.

Participants stressed the significance of privacy to be able to work during the ride, or to engage in social relations with friends and family. Interior designs ought to support privacy through compartmentalization while also allowing interactions with other passengers. This highlights the varying needs influenced by specific contexts—time of travel, companionship, duration, and destination. This complexity underscores the importance of offering passengers flexibility within these vehicles.

Furthermore, flexibility is reflected by participants demand for comprehensive booking options for trip planning in advance, demanding adaptability en route, including the ability to alter routes and stops and control the disclosure of destinations to fellow passengers. However, while flexibility is crucial for individual needs, accommodating various desires in a multi-passenger setting could challenge predictability for both passengers and the service. Yet, solutions like seat adjustments, temperature controls at the seat, and personalized booking processes might cater to these needs.

Moreover, accommodating complex situations such as traveling with children or ensuring the ability to disembark when feeling uncomfortable is especially crucial for vulnerable groups. Nevertheless, we believe that implementing such adaptable features will benefit everyone by fostering a more inclusive, comfortable, and user-friendly transportation system that caters to diverse needs, ultimately enhancing the overall travel experience for all passengers.

Reimagining Security in Shared Transportation: Advocacy, Privacy, and Inclusivity

Security concerns, particularly gender-based, emerged prominently among participants—women expressed heightened anxiety, especially during evening or nighttime shared mobility. Women advocated for safety measures like human support during rides with strangers or surveillance cameras, aligning with existing studies. Yet, their suggestions extended to diverse options, including information on co-passengers' demographics, altering destinations mid-trip, or opting for only-women rides, emphasizing security through shared location details with relatives. While primarily expressed by women, these options may extend security for other groups, such as children, senior citizens, or discriminated groups.

Prior studies on seat reservation [238] found seat choice significant to people, aligning with women's desire for pre-ride information about co-passengers for added security. However, this need poses a privacy versus security dilemma, as revealing personal details raised considerable privacy concerns. Achieving a balance between increased security and privacy is essential, especially considering potential societal segregation based on personal characteristics.

Discussing a rating system, concerns arise regarding potential discrimination, exemplified by experiences in ride-sharing apps. Advocating for inclusive solutions, we propose an anonymous booking system for shared automated and traditional transportation, without excluding people on the basis of demographic characteristics.

Approaching this from a feminist HCI standpoint, we caution against exclusive solutions like women-only vehicles due to potential exclusion and conflicts with non-binary individuals. Instead, research should focus on enhancing women's security without disregarding other groups.

Tailoring Digital Companions for Shared Automated Vehicles and Embrace Cultural Nuances

Findings from our preliminary studies revealed shared preferences among both Koreans and Germans for a friendly and empathetic digital companion for SAVs. However, cultural differences emerged in their desires for the DC's hierarchical position, reflecting distinctions in societal structures outlined by Hofstede's cultural dimensions. Colombians displayed less openness to technological changes but differed from Koreans and Germans in their preference for a more human-like DC over a robot-like one. Simultaneously, Koreans showed the highest openness towards robot-like DCs. The system could offer customizable options for the appearance and behavior of the DC, including different facial expressions, gestures, and speech patterns to make the DC appear more human-like and relatable to users in Colombia. On the other hand, for Korean users the system could provide options for a more robotic appearance and behavior, catering to their preferences. The system could employ modular designs for the interface, allowing for flexibility and customization based on cultural preferences. Users could choose from different interface layouts, colors, and fonts that resonate with their cultural backgrounds. This adaptation ensures that the interface feels familiar and comfortable for users across different cultures. The interface in the SAVs should account for different cultural contexts, including multilingual support and customizing the language used by the DC to match the user's preferred language and dialect, enhancing the overall user experience. Furthermore, the DC could be equipped with behavior adaptation and learning capabilities to evolve and match user preferences over time. By analyzing user interactions and feedback, the DC can continuously improve its responses and adapt to cultural nuances, fostering a more personalized and engaging user experience.

Cultural Adaptability in HMI Design for Shared Automated Vehicle

The comparison highlights that German participants felt more secure than Colombians in shared vehicle scenarios, potentially linked to Colombia's negative public transportation experiences. Surprisingly, Colombians expressed a higher need for privacy, contrary to collectivist cultural norms, likely linked to Bogotá's overcrowded transport systems. Additionally, Colombians showed a stronger desire for control, possibly influenced by their societal risk-averse attitude. These findings stress the need to isolate shared mobility contexts for tailored development in different countries, considering past public transport experiences. These disparities advocate for culturally adaptive designs in SAVs and HMIs, catering to varied privacy expectations and the need for user control across different societal landscapes. In developing HMIs for SAVs, accommodating cultural diversity entails crafting interfaces that adjust based on

users' cultural preferences. For instance, interfaces should offer customization options, allowing users to personalize language settings or the appearance of digital companions according to their cultural inclinations. These HMIs should also provide contextual information tailored to specific cultural norms, ensuring that the displayed details resonate with users' expectations. Moreover, interaction styles and communication tones should adapt to different cultural norms, maintaining a balance between authority and friendliness as per specific cultural expectations. Gradual familiarization strategies and adaptive learning capabilities are vital, allowing users to ease into futuristic elements while evolving the interface based on user interactions and feedback. This ensures that the HMI aligns with various cultural norms and preferences, fostering greater acceptance and usability across diverse user groups.

10.3.2 RQ2: How can Human-Machine Interfaces (HMIs) be optimized and designed within SAVs?

Traveling in an SAV without a human driver can evoke discomfort among passengers, leaving them reliant on the software system for perceptions, decisions, and actions. HMIs serve as the sole means for passengers to communicate and engage with driverless vehicles. Hence, these interfaces must address the resulting gap in service and information, alleviating user apprehensions to enhance acceptance and encourage the adoption of this technology. Our insights are organized below into four key recommendations.

Tailored Travel Information for SAV Journeys

Offering a blend of familiar travel information and functions alongside specific requirements and demands for SAV rides, these features cater to users' expectations while addressing distinct needs in the automated vehicle environment.

While integrating familiar functionalities from present transportation systems, such as profile authentication for first-time users, constant updates on precise arrival times, route and stop details, arrival displays, and stop notifications during the journey, novel elements should be tailored to enhance the travel experience.

Virtual stops and flexible vehicle stop options enable passengers to specify their destinations flexibly without needing predefined physical stops. Additionally, the system should offer various options for vehicle stops, allowing passengers to choose convenient locations based on their preferences and needs.

The system should allow to share information with trusted contacts, such as real-time updates on traffic conditions, route changes, and arrival times. Our findings suggest a personalized buddy systems involving matching passengers with compatible travel companions based on their preferences, interests, and travel habits to foster a sense of companionship and security during the journey, especially for solo travelers or those with specific needs. Additionally, the inclusion of in-vehicle security systems would enhance passenger safety and security during the journey. This may include features such as surveillance cameras, panic buttons, and automatic emergency response systems to address potential threats or emergencies effectively. Providing passengers with the capability to report discomfort or dissatisfaction during the journey allows for immediate resolution of issues and concerns. This feedback mechanism enables service providers to address passenger needs promptly, improving overall satisfaction and comfort. These features should be supported by the implementation of security checks upon arrival and by offering last-mile assistance through the security system and by providing additional support and guidance to passengers as they reach their final destinations. This may include escort services, navigation assistance, and ensuring safe drop-offs, particularly in unfamiliar or high-risk areas. Collectively, these innovations aim to redefine public transportation, fostering acceptance, and adapting to evolving travel needs.

Nuanced Solutions for SAVs Balancing Passenger Security and Privacy

In SAV settings, HMIs play a critical role in compensating for the absence of a human driver to address passengers' safety concerns, especially related to potential assaults. Transparent system information is crucial, and participants wished to have details about fellow passengers. Our findings, particularly from Chapter 5, highlight increased information needs during night-time AV rides. Passengers express a sense of security when provided with co-traveler details like names, ages, genders, pictures, and destinations. However, participants displayed hesitancy in both receiving and sharing such personal information due to privacy concerns. This tension between security needs and privacy demands underscores the complexity of future system designs, requiring a careful balance in determining necessary and beneficial information for heightened security while ensuring passenger comfort in information sharing.

Implementing these solutions could potentially lead to discrimination, echoing the challenges seen in blocking and ranking systems. Taking a feminist perspective, the implementation of such features requires careful consideration. We recommend these solutions to be more pertinent during night-time travel when enhanced security is crucial, understanding that during daytime, their relevance is less important. A nuanced approach is needed here and solutions might involve offering selective information sharing options, enabling opt-in se-

curity features for specific times like night travels, creating anonymous profiles, providing customizable privacy settings, establishing trusted networks, implementing real-time monitoring tools, and introducing third-party verification services. These solutions aim to balance passengers' security needs with their privacy preferences, allowing them to control the information shared based on their comfort and travel circumstances.

Operator Roles in Shared Automated Vehicles and Their Significance for HMI Development

Uncovering the abundant roles of operators was crucial to address potential challenges arising from automation in SAVs and the absence of a driver. Our findings highlight people's perception of the key roles of informants and supervisors for operators. However, our observations and operator interviews revealed a broader spectrum of responsibilities, notably in managing emotions like trust and discomfort. Participants expressed the necessity of operator presence while simultaneously expecting fully automated vehicles without onboard personnel, indicating a tension. Despite this, recognizing the multitude of onboard duties emphasizes the need to consider all roles, especially those involving emotional aspects, and the question whether these can be covered by a DC. These insights pave the way to address these roles effectively through the development of HMIs and technological solutions that can assume driver roles.

Enhancing Security in Shared Automated Vehicles with Digital Companions as Human-Machine Interfaces

Incorporating a DC as an HMI within SAVs could potentially resolve the complex issues that security measures often introduce, including privacy concerns and the risk of inadvertently discriminating against individuals by restricting their access. Our findings strongly indicate that integrating a DC contributes significantly to enhancing passengers' perceived security (Chapters 7 and 8).

Human-like appearances for DCs emerged as a preferred choice (Chapters 6 and 7), influencing our creation of human avatars as digital companions. The 'Baymax' companion, notably recognized for its friendly facial expression, resonated well due to its amiable demeanor. Conversely, reactions to the 'RoboCop' persona, perceived as strict and authoritative, evoked mixed responses, aligning with the expectation that companion technologies mirror emotions and empathy [361]. Even in scenarios with heightened security concerns, such as those involving unpleasant passengers, 'Baymax' stood out. Participants consistently highlighted its role in fostering security and reducing anxiety levels within the

vehicle. This underscores the crucial role of an empathetic digital companion, emphasizing the need for technology driven by empathy to alleviate anxiety and bolster passenger well-being, even in security-sensitive situations.

Redesign the Emergency Button to Increase Security

While we have observed solutions enhancing perceived security through HMIs, such as DCs, it is equally central to address tangible security measures within this context, as we must avoid situations where passengers perceive security due to the presence of an avatar but might face attacks without real assistance available. Thus, augmenting companions with further security measures becomes crucial. Our findings emphasize the need to reconceptualize the emergency button within SAVs. Security, a multifaceted construct, often involves uncomfortable situations that are not easily categorized as purely secure or insecure. Acknowledging this complexity is crucial to address real-world scenarios beyond binary notions.

Rather than a simplistic emergency button on smartphones, our suggestion is to integrate an easily accessible emergency mechanism within the vehicle itself. Placing such buttons in close proximity, like beneath the seats, allows for a more nuanced response to varying degrees of emergencies, diverging from traditional public transportation systems.

Our proposed three-stage emergency system (red, yellow, green) is designed to accommodate these complexities. The “green” phase, tailored for mildly uncomfortable situations, involves notifying trusted contacts and offering an alternative vehicle nearby, empowering passengers to exit discomfiting scenarios—a factor positively impacting perceived security. For situations of discomfort (the “yellow” phase), activating the mechanism initiates interior video recording and alerts a central authority while notifying fellow passengers, aiming to deter escalations. In cases of clear emergencies or severe harm (the “red” phase), immediate alerts are sent to the police or the vehicle’s central control.

This adaptable emergency system could be readily integrated into current PT, allowing for field evaluations. Passengers would not only benefit in potentially threatening scenarios but also in situations requiring assistance or medical aid, enhancing overall passenger safety and well-being.

Evaluation of Solutions for SAVs with the Validated PSSAV

No validated questionnaire existed to assess perceived security in SAVs until our research, where we successfully closed this research gap. Our exploration of the Perceived Security Scale for Automated Vehicles (PSSAV) presents a critical tool for evaluating solutions to foster security within SAV contexts, such as, e.g. HMIs. The factorial structure of the Perceived Security Scale for Automated Vehicles (PSSAV) was examined in two online studies, confirming its robustness and comprising factors like Security, Trust, Privacy, and Control—dimensions that were not previously clearly defined until the development and validation of the PSSAV. Demonstrating construct validity, the PSSAV exhibited sensitivity in distinguishing between the utopia and dystopia groups, despite a moderately negative experience represented by the dystopia scenario.

Despite the wide range of responses observed in the data, influenced by various factors like personal experiences or demographics, our qualitative ground-work suggests the PSSAV is a compelling scale specifically designed for the SAV context. This nuanced approach provides a valuable tool provided in English, German, and Spanish, for practitioners and researchers to evaluate design proposals, identify factors enhancing control or privacy for passengers, and determine user interfaces or systems that foster trust and security.

10.4 Limitations and Future Work

In the foreseeable future, AVs will become increasingly integrated into our daily lives, prompting the necessity to establish effective and inclusive interaction methods with these vehicles. Our work aims to contribute to shaping inclusive human-AV interactions, primarily by integrating a variety of people into our desing and research process. We contend that taking feminist HCI, intersectionality, and HCD into account during the development of SAVs should be adopted. This methodology helps define requirements, address acceptance and security issues, and evaluate potential design solutions. Additionally, it is important to acknowledge that our work has limitations, which present opportunities for future research and which we will address in the following sections.

10.4.1 Expanding User Representation

In our research, we intentionally included different user groups and focused on diverse demographics to enhance the comprehensiveness of our findings and to comply with the feminist HCI approach. We emphasized age diversity and

prioritized gender-inclusive perspectives, aligning with the concept of intersectionality. Furthermore, we focused on different cultural backgrounds, encompassing Colombian, German, and Korean participants in our research. Through this inclusive approach, we uncovered nuanced distinctions in HMI perceptions across cultures (Chapters 7 and 9). However, despite these efforts, further diversity in user representation is necessary. To achieve a more comprehensive understanding of HMI perceptions and interactions, future research should focus on even broader and more diverse user groups, for example, by including perspectives of individuals with disabilities or those using assistive technologies, as well as considering participants from rural, suburban, and urban settings to capture the differences in perceptions based on geographical environments. We recommend exploring the impact of diverse gender identities and sexual orientations such as LGBTQIA+ communities on HMI designs. This approach will significantly enrich the understanding of how different demographics perceive SAVs.

10.4.2 Enhancing User Security and Privacy in SAVs and Mitigating Discriminatory Side-Effects

In Chapter 3 participants proposed receiving information about co-passengers in SAVs and in Chapter 5 we investigated whether this solution indeed mitigated security concerns. The findings indicated that revealing personal details about fellow passengers could reduce perceived risk and improve the overall user experience, especially during nighttime trips. However, participants expressed concerns regarding their own privacy when sharing personal data. Moreover, it is crucial to acknowledge that these solutions include the possibility of inadvertently discriminating against certain user groups. Applying the feminist HCI approach is essential to mitigate any potential biases or discriminatory elements within these solutions, ensuring that the proposed measures are inclusive and equitable for all passengers. Future research should aim to strike a balance between security and privacy concerns, as well as keeping in mind negative side-effects that solutions might bring. This entails exploring strategies to heighten passengers' sense of security and control, possibly incorporating human support options before, during, and after rides.

10.4.3 Cultural Considerations in the Development of Digital Companions

Findings from our research in Chapter 7 underscore the importance of cultural considerations in designing DCs. Our results suggest that DC design should carefully navigate cultural nuances, aiming for a balance between familiarity

and futuristic elements to accommodate diverse cultural predispositions. One potential avenue for future research involves conducting extensive cultural analyses to identify specific communication preferences, gestures, and visual representations across diverse cultures, informing the creation of more tailored DC interfaces. User trials involving individuals from various cultural backgrounds should be implemented to assess adaptability and acceptance of different interface designs, particularly focusing on personalization options like varying anthropomorphism levels and customizable features. Exploring generative AI customization methods that dynamically adjust DC behaviors and conversation scripts to align with cultural norms could be another direction, employing machine learning algorithms to adapt to diverse cultural settings.

However, there are notable limitations in this endeavor. Adapting DC interfaces to diverse cultural norms may present significant complexities due to a wide array of preferences, languages, and communication styles. Technical challenges might arise in developing adaptable systems seamlessly adjusting behaviors to align with different cultural norms. Additionally, designing avatars or interfaces that cater to multiple cultures without reinforcing stereotypes or biases requires careful consideration and sensitivity. Further, considering the limitations of cultural representation within a single interface raises questions about cultural accuracy and the risk of inadvertently perpetuating cultural stereotypes. A potential solution could involve exploring a disembodied approach for DC avatars, allowing for more inclusive cultural representations. Addressing these limitations will be crucial for designing culturally inclusive and widely accepted DC interfaces.

10.4.4 Challenges and Opportunities in Applying Feminist HCI to Automotive User Interfaces

Applying feminist HCI in the context of automotive user interfaces presented distinct challenges. While it facilitated robust discussions and contributed to methodological choices, its practical implementation faced difficulties due to inherent vagueness and limited practical guidelines. Despite its frequent citation in HCI, feminist HCI's primary foundation lies within one CHI paper [74], resulting in widespread referencing yet limited practicality [76], leading to occasional ambiguities. However, despite these obstacles, the application of feminist HCI offered invaluable insights, and fostered critical discussions on inclusivity and diverse perspectives in design processes. It prompted an in-depth exploration of power dynamics and social contexts, enabling a richer comprehension of user experiences and needs. It is worth noting that while feminist HCI finds frequent usage among social scientists, automotive user interface communities predominantly rely on conventional research methods such as quantitative lab studies using. In future interdisciplinary collaborations, there is potential to

blend insights from feminist HCI's critical perspectives with the methodological rigor of established automotive user interface research. These collaborations can help bridge the gap between disciplines, offering a more nuanced understanding of user experiences and needs in automotive design, and putting a high focus on diverse user groups. Moreover, defining and establishing clearer guidelines for the application of feminist HCI within specific contexts, such as automotive user interfaces, would enhance its practicality and effectiveness.

10.4.5 Longitudinal Studies to Explore the Evolution of Perceived Security

In our research, we employed a mixed-methods approach that actively engaged users during the early developmental phases. Through a combination of co-design workshops, user enactments, simulator and VR studies, and comprehensive questionnaire studies, we sought to comprehensively understand user perspectives. Furthermore, we conducted on-site field visits and visited two pilot projects introducing shared automated shuttle buses to the public. However, our study faces certain limitations, mainly the absence of long-term studies. Perceived security in shared automated shuttle buses is subject to change over time due to several factors. Firstly, as users become more familiar with the service and its operations, their comfort levels and perceptions of security may naturally evolve. Familiarity often increases confidence, potentially enhancing perceived security as users acclimate to the system's functionalities and operational reliability. Moreover, long-term exposure and repeated use tend to influence how individuals perceive security in public transport. However, the absence of commuters or regular users at this stage poses a unique challenge. As the passengers in Germany mainly consists of tourists or first-time participants, the absence of a consistent user group may hinder the development of entrenched perceptions of security. The lack of regular users limits the scope for longitudinal studies, making it challenging to observe and analyze changes in perceived security over extended periods. Consequently, the evolution of perceived security might be slower or less pronounced without regular users to evaluate these shifts comprehensively. To improve the external validity of our research, future work might focus on establishing long-term and in-the-field studies involving regular commuters or residents. These longitudinal studies could assess how perceived security in SAVs changes over longer periods, providing deeper insights into user experiences and evolving needs. Despite these limitations, our work and methodologies remain vital and suitable at this stage of development, highlighting the importance of continued research in this domain.

10.5 Final Remarks

In conclusion, the advent of SAVs promises of advantages for society, yet our research has revealed security concerns accompanying their implementation. This thesis underscores the central role of inclusive design and user empowerment to ensure that these advancements lead to a utopia rather than reinforcing the exclusion of user groups. Embracing diverse perspectives and empowering users within the design process stand as cornerstones in shaping a future where SAVs embody inclusivity, security, and progress. To put it in Donna Haraway's words:

“The machine is not an it to be animated, worshipped, and dominated. The machine is us, our processes, an aspect of our embodiment. We can be responsible for machines; they do not dominate or threaten us. We are responsible for boundaries; we are they.”
[406].

This principle underscores our commitment to fostering a future where technology is harnessed for the collective benefit and well-being of all.

Bibliography

- [1] M. Schuß, P. Wintersberger, and A. Riener, “Let’s share a ride into the future: A qualitative study comparing hypothetical implementation scenarios of automated vehicles,” in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, ser. CHI ’21. New York, NY, USA: Association for Computing Machinery, 2021. [Online]. Available: <https://doi.org/10.1145/3411764.3445609>
- [2] M. Schuß, P. Wintersberger, and A. Riener, “Security issues in shared automated mobility systems: A feminist HCI perspective,” *Multimodal Technologies and Interaction*, vol. 5, no. 8, 2021. [Online]. Available: <https://www.mdpi.com/2414-4088/5/8/43>
- [3] M. Schuß, C. Manger, A. Löcken, and A. Riener, “You’ll never ride alone: Insights into women’s security needs in shared automated vehicles,” in *Proceedings of the 14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’22. New York, NY, USA: Association for Computing Machinery, 2022, pp. 13–23. [Online]. Available: <https://doi.org/10.1145/3543174.3546848>
- [4] L. A. Flohr, M. Schuß, D. P. Wallach, A. Krüger, and A. Riener, “Designing for passengers’ information needs on fellow travelers: A comparison of day and night rides in shared automated vehicles,” *Applied Ergonomics*, vol. 116, p. 104198, 2024. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0003687023002363>
- [5] M. Schuß, A. Rollwagen, and A. Riener, “Understanding operator influence in automated urban shuttle buses and recommendations for future development,” *Multimodal Technologies and Interaction*, vol. 6, no. 12, 2022. [Online]. Available: <https://www.mdpi.com/2414-4088/6/12/109>
- [6] M. Schuß, C. Himmels, and A. Riener, “Development of a Perceived Security Scale for Shared Automated Vehicles (PSSAV) and its validation in colombia and germany,” in *Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’23. New York, NY, USA:

- Association for Computing Machinery, 2023, pp. 52–62. [Online]. Available: <https://doi.org/10.1145/3580585.3607177>
- [7] J. M. Beuthel, M.-M. Schaper, M. Schuß, E. Márquez Segura, C. Núñez Pacheco, and A. Riener, “Exploring and materialising bodily experiences of security through lenses of feminist hci practices,” in *Adjunct Proceedings of the 2022 Nordic Human-Computer Interaction Conference*, ser. NordiCHI ’22. New York, NY, USA: Association for Computing Machinery, 2022. [Online]. Available: <https://doi.org/10.1145/3547522.3547696>
- [8] A. Rollwagen, M. Schuß, and A. Riener, “Enhancing accessibility for diverse user groups in automated shuttle buses: Implications from a user enactment study,” in *Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 77–82. [Online]. Available: <https://doi.org/10.1145/3581961.3609876>
- [9] J. Dong, C. Nadri, I. Alvarez, C. Diels, M. Lee, J. Li, P. H. Liao, C. Manger, S. Sadeghian, M. Schuß, B. N. Walker, F. Walker, Y. Wang, and M. Jeon, ““play your anger”: A report on the empathic in-vehicle interface workshop,” in *Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 168–173. [Online]. Available: <https://doi.org/10.1145/3581961.3609865>
- [10] K. Stojmenova Pečečnik, S. C. Lee, S. Hong, M. Schuß, H. Sahin Ippoliti, A. R. Patel, A. Löcken, D. Dey, A. Riener, A. G. Mirnig, and M. Jeon, “How to ensure diversity and inclusion at conferences? a workshop for general chairs, program committee members, reviewers and authors: A workshop for general chairs, program committee members, reviewers and authors,” in *Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 241–244. [Online]. Available: <https://doi.org/10.1145/3581961.3609838>
- [11] M. Schuß and A. Riener, ““give me the keys, i’ll drive!”: Results from an exploratory interview study to assess public’s desires and concerns on automated valet parking,” in *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’20. New York, NY, USA: Association

- for Computing Machinery, 2020, pp. 16–18. [Online]. Available: <https://doi.org/10.1145/3409251.3411712>
- [12] L. Pizzoni, “Conceptualization of a digital companion for shared automated vehicles,” Ingolstadt, pp. 47, XXXI, 2022. [Online]. Available: <http://nbn-resolving.de/urn:nbn:de:bvb:573-35676>
- [13] T. Röhr, “Digital companion,” Ingolstadt, pp. 56, XXXIII, 2022. [Online]. Available: <http://nbn-resolving.de/urn:nbn:de:bvb:573-35827>
- [14] P. Norton, *Autonorama: the illusory promise of high-tech driving*. Island Press, 2021.
- [15] F. Kröger, “Automated driving in its social, historical and cultural contexts,” in *Autonomous Driving*. Springer, 2016, pp. 41–68.
- [16] Waymo, “On the road to fully self-driving: Waymo safety report,” 2017.
- [17] The Guardian, “San Francisco to get round-the-clock robo taxis after controversial vote,” <https://www.theguardian.com/us-news/2023/aug/10/san-francisco-self-driving-car-autonomous-regulation-google-gm>, July 2023, last accessed April 2024.
- [18] S. Kelheim, “Autonomes Fahren in Kelheim,” <https://www.kelheim.de/leben/umwelt-energie-mobilitaet/autonomes-fahren/>, last accessed April 2024.
- [19] E. Papa and A. Ferreira, “Sustainable accessibility and the implementation of automated vehicles: Identifying critical decisions,” *Urban Science*, vol. 2, no. 1, p. 5, 2018.
- [20] M. Wilson, “People keep attacking Waymo’s autonomous cars,” Fast Company, <https://www.fastcompany.com/90281114/people-keep-attacking-waymos-autonomous-cars>, December 2018, last accessed April 2024.
- [21] R. Unseld, “Trap the cap,” pp. 3–3, 2023. [Online]. Available: <https://doi.org/10.1007/s38314-023-1532-y>
- [22] Cruise, “Driverless is here,” <https://getcruise.com>, last accessed April 2024.
- [23] Reuters, “GM cruise unit suspends all driverless operations after California ban,” <https://www.reuters.com/business/autos-transportation/us->

- auto-safety-agency-investigating-two-new-gm-cruise-crash-reports-2023-10-26/, October 2023, last accessed April 2024.
- [24] J. Himmelreich, “Never mind the trolley: The ethics of autonomous vehicles in mundane situations,” *Ethical Theory and Moral Practice*, vol. 21, no. 3, pp. 669–684, 2018. [Online]. Available: <https://doi.org/10.1007/s10677-018-9896-4>
- [25] P. Wintersberger, A.-K. Frison, and A. Riener, “Man vs. machine: Comparing a fully automated bus shuttle with a manually driven group taxi in a field study,” in *Adjunct Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’18. New York, NY, USA: Association for Computing Machinery, 2018, pp. 215–220. [Online]. Available: <https://doi.org/10.1145/3239092.3265969>
- [26] G. Lyons, “Driverless cars— a great opportunity for society?Final report of the driverless cars emulsion initiative,” Tech. Rep., 2020. [Online]. Available: <https://uwe-repository.worktribe.com/output/5859439>
- [27] P. Wintersberger and A. Riener, “Trust in technology as a safety aspect in highly automated driving,” *i-com*, vol. 15, no. 3, pp. 297–310, 2016. [Online]. Available: <https://doi.org/10.1515/icom-2016-0034>
- [28] B. P. S. G. Henrik Detjen, Sarah Faltaous and S. Schneegass, “How to increase automated vehicles’ acceptance through in-vehicle interaction design: A review,” *International Journal of Human-Computer Interaction*, vol. 37, no. 4, pp. 308–330, 2021. [Online]. Available: <https://doi.org/10.1080/10447318.2020.1860517>
- [29] ISO, “ISO 9241-210 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems (ISO 9241-210:2020),” Tech. Rep., March 2020. [Online]. Available: <https://www.dinmedia.de/de/norm/din-en-iso-9241-210/313017070>
- [30] S. Bardzell and J. Bardzell, “Towards a feminist HCI methodology: Social science, feminism, and HCI,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI ’11. New York, NY, USA: Association for Computing Machinery, 2011, pp. 675–684. [Online]. Available: <https://doi.org/10.1145/1978942.1979041>
- [31] S. Harding, *Whose science? Whose knowledge?: Thinking from women’s lives*. Cornell University Press, 1991.
- [32] English Oxford Learner’s Dictionaries, “public transport,”

- <https://www.oxfordlearnersdictionaries.com/>, last accessed April 2024.
- [33] A. Stocker and S. Shaheen, “Shared automated mobility: Early exploration and potential impacts,” in *Road Vehicle Automation 4*, G. Meyer and S. Beiker, Eds. Cham: Springer International Publishing, 2018, pp. 125–139.
 - [34] J. Lazarus, S. Shaheen, S. E. Young, D. Fagnant, T. Voegelé, W. Baumgardner, J. Fishelson, and J. Sam Lott, “Shared automated mobility and public transport,” in *Road Vehicle Automation 4*, G. Meyer and S. Beiker, Eds. Cham: Springer International Publishing, 2018, pp. 141–161.
 - [35] M. Aboulela, A. Tirachini, E. Chaniotakis, and C. Antoniou, “Characterizing the adoption and frequency of use of a pooled rides service,” *Transportation Research Part C: Emerging Technologies*, vol. 138, p. 103632, 2022. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0968090X22000754>
 - [36] Uber, “Uber,” <https://www.uber.com>, last accessed April 2024.
 - [37] MOIA, “Uber,” <https://www.moia.io/de-DE>, 2023, last accessed April 2024.
 - [38] V. Miklos, “Nuclear-powered vehicle concepts from the mid-20th century,” Gizmodo, <https://bit.ly/2UpPPKe>, August 2013, last accessed April 2024.
 - [39] A. Cooke, “From the archive, 20 July 1955: Nuclear energy for the american home,” The Guardian, <https://bit.ly/2Z3McYT>, July 2015, last accessed April 2024.
 - [40] M. Kamali, L. A. Dennis, O. McAree, M. Fisher, and S. M. Veres, “Formal verification of autonomous vehicle platooning,” *Science of Computer Programming*, vol. 148, pp. 88–106, 2017, special issue on Automated Verification of Critical Systems (AVoCS 2015). [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0167642317301168>
 - [41] Z. Chong, B. Qin, T. Bandyopadhyay, T. Wongpiromsarn, E. Rankin, M. Ang, E. Frazzoli, D. Rus, D. Hsu, and K. Low, “Autonomous personal vehicle for the first-and last-mile transportation services,” in *2011 IEEE 5th International Conference on Cybernetics and Intelligent Systems (CIS)*. IEEE, Sep. 2011, pp. 253–260. [Online]. Available: <https://ieeexplore.ieee.org/document/6070337>

- [42] W. J. Horrey, M. F. Lesch, A. Garabet, L. Simmons, and R. Maikala, “Distraction and task engagement: How interesting and boring information impact driving performance and subjective and physiological responses,” *Applied Ergonomics*, vol. 58, pp. 342–348, 2017. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0003687016301429>
- [43] T.-C. Au, S. Zhang, and P. Stone, “Autonomous intersection management for semi-autonomous vehicles,” *Handbook of transportation*, vol. 15, no. 07, pp. 88–104, 2015. [Online]. Available: <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=7a0846007737ca74f18e56148cb9a6c29788f7e4>
- [44] D. Horowitz, “Self-driving homes could be the future of affordable housing,” *The Architects Newspaper*, <https://archpaper.com/2018/09/self-driving-homes/>, September 2018, last accessed April 2024.
- [45] S. Society of Automotive Engineers, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (J3016 Ground Vehicle Standard)*, June 2018. [Online]. Available: https://doi.org/10.4271/J3016{_ }201806
- [46] A. Riener, *Sensor-actuator supported implicit interaction in driver assistance systems*. Springer, 2010. [Online]. Available: <https://doi.org/10.1007/978-3-8348-9777-0>
- [47] D. J. Fagnant and K. M. Kockelman, “The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios,” *Transportation Research Part C: Emerging Technologies*, vol. 40, pp. 1–13, 2014. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0968090X13002581>
- [48] W. Zhang, S. Guhathakurta, J. Fang, and G. Zhang, “Exploring the impact of shared autonomous vehicles on urban parking demand: An agent-based simulation approach,” *Sustainable Cities and Society*, vol. 19, pp. 34–45, 2015. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S221067071530010X>
- [49] Z. J. Chong, B. Qin, T. Bandyopadhyay, T. Wongpiromsarn, E. S. Rankin, M. H. Ang, E. Frazzoli, D. Rus, D. Hsu, and K. H. Low, “Autonomous personal vehicle for the first- and last-mile transportation services,” in *2011 IEEE 5th International Conference on Cybernetics and Intelligent Systems (CIS)*, 2011, pp. 253–260.
- [50] G. Currie, “Lies, damned lies, avs, shared mobility, and urban

- transit futures,” *Journal of Public Transportation*, vol. 21, no. 1, p. 3, 2018. [Online]. Available: <https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1737&context=jpt>
- [51] W. H. Wong, *We, the data: Human rights in the digital age*. The MIT Press, 2023. [Online]. Available: <https://mitpress.mit.edu/9780262048576/we-the-data/>
- [52] R. Benjamin, *Race after technology: Abolitionist tools for the new Jim Code*. Oxford, England: John Wiley & Sons, 2019.
- [53] C. C. Perez, *Invisible Women: Exposing data bias in a world designed for men*. New York, NY: Abrams, 2019.
- [54] D. Danks and A. J. London, “Algorithmic bias in autonomous systems,” in *IJCAI*, 2017, pp. 4691–4697. [Online]. Available: <https://doi.org/10.24963/ijcai.2017/654>
- [55] J. Destin, “Amazon scraps secret AI recruiting tool that showed bias against women,” in *Ethics of data and analytics*. Auerbach Publications, 2022, pp. 296–299. [Online]. Available: <https://www.taylorfrancis.com/chapters/edit/10.1201/9781003278290-44/amazon-scraps-secret-ai-recruiting-tool-showed-bias-women-jeffrey-destin>
- [56] C. D’Ignazio and L. F. Klein, *Data feminism*. MIT press, 2023. [Online]. Available: <https://mitpressbookstore.mit.edu/book/9780262547185>
- [57] J. Buolamwini, “When the robot doesn’t see dark skin,” <https://www.nytimes.com/2018/06/21/opinion/facial-analysis-technology-bias.html>, 2018, last accessed April 2024.
- [58] H. Lloyd and M. Mey, “Gender differences in perceptions of workplace progression: an automotive industry case study,” *Southern African Business Review*, vol. 11, no. 3, pp. 95–120, 2007. [Online]. Available: <https://journals.co.za/doi/pdf/10.10520/EJC92860>
- [59] D. Balkmar and U. Mellström, “Masculinity and autonomous vehicles: A degendered or resegregated future system of automobility?” *Transfers*, vol. 8, no. 1, pp. 44–63, 2018. [Online]. Available: <https://www.berghahnjournals.com/view/journals/transfers/8/1/trans080105.xml>
- [60] J. Bajorek, “Voice recognition still has significant race and gender biases,” <https://hbr.org/2019/05/voice-recognition-still-has-significant-race-and-gender-biases>, May 2019, last accessed April 2024.

- [61] H. Paetz, *Gender and technology: the "female factor" in software design*. Munich: GRIN Verlag, 2015. [Online]. Available: <https://www.grin.com/document/296194>
- [62] G. Williams, "Are you sure your software is gender-neutral?" *Interactions*, vol. 21, no. 1, pp. 36–39, jan 2014. [Online]. Available: <https://doi.org/10.1145/2524808>
- [63] S. F. Vila, G. Miotto, and J. R. Rodríguez, "Cultural sustainability and the sdgs: Strategies and priorities in the european union countries," *European Journal of Sustainable Development*, vol. 10, no. 2, pp. 73–73, 2021. [Online]. Available: <http://www.ecsdev.org/ojs/index.php/ejsd/article/download/1211/1194&hl=de&sa=X&ei=p0onZpz1AsKBy9YPvdmEyA4&scisig=AFWwaeaXh8Cfo17n6zAO9rK4SEW5&oi=scholar>
- [64] The World Bank, "Female population," <https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS>, 2019, last accessed April 2024.
- [65] J. Butler, "Gender trouble," *Continental feminism reader*, pp. 29–56, 2003.
- [66] A.-J. Berg and M. Lie, "Feminism and constructivism: Do artifacts have gender?" *Science, Technology, & Human Values*, vol. 20, no. 3, pp. 332–351, 1995. [Online]. Available: <http://www.jstor.org/stable/690019>
- [67] D. Haraway, "Situated knowledges: The science question in feminism and the privilege of partial perspective," in *Space, gender, knowledge: Feminist readings*. Routledge, 2016, pp. 53–72.
- [68] K. Crenshaw, "Mapping the margins: Intersectionality, identity politics, and violence against women of color," *Stanford Law Review*, vol. 43, no. 6, pp. 1241–1299, 1991. [Online]. Available: <http://www.jstor.org/stable/1229039>
- [69] J. Lazar, J. H. Feng, and H. Hochheiser, *Research methods in Human-Computer Interaction*. Morgan Kaufmann, 2018. [Online]. Available: <https://www.sciencedirect.com/book/9780128053904/research-methods-in-human-computer-interaction>
- [70] L. Bannon, "Reimagining HCI: Toward a more human-centered perspective," *Interactions*, vol. 18, no. 4, pp. 50–57, jul 2011. [Online]. Available: <https://doi.org/10.1145/1978822.1978833>

- [71] S. Bødker, “When second wave HCI meets third wave challenges,” in *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles*, ser. NordiCHI '06. New York, NY, USA: Association for Computing Machinery, 2006, pp. 1–8. [Online]. Available: <https://doi.org/10.1145/1182475.1182476>
- [72] E. F. Duarte and M. C. C. Baranauskas, “Revisiting the three HCI waves: A preliminary discussion on philosophy of science and research paradigms,” in *Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems*, ser. IHC '16. New York, NY, USA: Association for Computing Machinery, 2016. [Online]. Available: <https://doi.org/10.1145/3033701.3033740>
- [73] R. Reich, M. Sahami, J. M. Weinstein, and H. Cohen, “Teaching computer ethics: A deeply multidisciplinary approach,” in *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, ser. SIGCSE '20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 296–302. [Online]. Available: <https://doi.org/10.1145/3328778.3366951>
- [74] S. Bardzell, “Feminist hci: taking stock and outlining an agenda for design,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '10. New York, NY, USA: Association for Computing Machinery, 2010, pp. 1301–1310. [Online]. Available: <https://doi.org/10.1145/1753326.1753521>
- [75] S. G. Harding, *The feminist standpoint theory reader: Intellectual and political controversies*. Psychology Press, 2004.
- [76] S. S. Chivukula and C. M. Gray, “Bardzell’s Feminist HCI legacy: Analyzing citational patterns,” in *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, ser. CHI EA '20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 1–8. [Online]. Available: <https://doi.org/10.1145/3334480.3382936>
- [77] S. S. Chivukula, “Feminisms through design: A practical guide to implement and extend feminism: Position,” *Interactions*, vol. 27, no. 6, pp. 36–39, nov 2020. [Online]. Available: <https://doi.org/10.1145/3427338>
- [78] M. Harris, “History and significance of the emic/etic distinction,” *Annual review of anthropology*, vol. 5, no. 1, pp. 329–350, 1976.
- [79] D. Gergle and D. S. Tan, “Experimental research in hci,” in *Ways of Knowing in HCI*, J. S. Olson and W. A. Kellogg, Eds. New

- York, NY: Springer New York, 2014, pp. 191–227. [Online]. Available: https://doi.org/10.1007/978-1-4939-0378-8_9
- [80] L. E. Monteagut, “Etic approach to qualitative research,” *The International Encyclopedia of Communication Research Methods*, pp. 1–2, 2017. [Online]. Available: <https://doi.org/10.1002/9781118901731.iecrm0092>
- [81] M. Pavone, “Autonomous mobility-on-demand systems for future urban mobility,” in *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte*, M. Maurer, J. C. Gerdes, B. Lenz, and H. Winner, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015, pp. 399–416. [Online]. Available: https://doi.org/10.1007/978-3-662-45854-9_19
- [82] S. de Groen and P. Kromhout, “Autonomous driving cars are key for mobility in 2030,” <https://www.compact.nl/articles/autonomous-driving-cars-are-key-for-mobility-in-2030/>, 2017, last accessed April 2024.
- [83] A. Riener, A. Appel, W. Dorner, T. Huber, J. C. Kolb, and H. Wagner, Eds., *Autonome Shuttlebusse im ÖPNV: Analysen und Bewertungen zum Fallbeispiel Bad Birnbach aus technischer, gesellschaftlicher und planerischer Sicht*, ser. Springer eBook Collection. Berlin, Heidelberg: Springer Nature, 2020.
- [84] F. Hunsicker, A. Knie, G. Lobenberg, D. Lohrmann, U. Meier, S. Nordhoff, and S. Pfeiffer, “Pilotbetrieb mit autonomen Shuttles auf dem Berliner EUREF-Campus. Erfahrungsbericht vom ersten Testfeld zur integrierten urbanen Mobilität der Zukunft,” 2017.
- [85] V. Distler, C. Lallemand, and T. Bellet, “Acceptability and acceptance of autonomous mobility on demand: The impact of an immersive experience,” in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ser. CHI '18. New York, NY, USA: Association for Computing Machinery, 2018, pp. 1–10. [Online]. Available: <https://doi.org/10.1145/3173574.3174186>
- [86] T. Litman, *Autonomous vehicle implementation predictions*. Canada: Victoria Transport Policy Institute Victoria, 2017. [Online]. Available: <https://trid.trb.org/view/1678741>
- [87] Y. Wiseman, “Driverless cars will make passenger rail obsolete [opinion],” *IEEE Technology and Society Magazine*, vol. 38, no. 2, pp. 22–27, 2019.
- [88] International Transport Forum, “Urban mobility system upgrade,” p. 36,

- <https://www.itf-oecd.org/urban-mobility-system-upgrade>, 2015, last accessed April 2024".
- [89] A. Henry, R. E. Barone, A. Pichardo, E. Roach, T. Keegan, D. Simons, E. Thenhaus, and B. Oldenburg, "New mobility autonomous vehicles and the region," *Regional Plan Association (RPA)*, New-York, <https://s3.us-east-1.amazonaws.com/rpa-org/pdfs/RPA-New-Mobility-Autonomous-Vehicles-and-the-Region.pdf>, 2017, last accessed April 2024.
- [90] B. McKenzie and M. Rapino, "Commuting in the United States: 2009," <https://www2.census.gov/library/publications/2011/acs/acs-15.pdf>, 2009, last accessed April 2024.
- [91] K. Spieser, K. Treleaven, R. Zhang, E. Frazzoli, D. Morton, and M. Pavone, *Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems: A Case Study in Singapore*. Cham: Springer International Publishing, 2014, pp. 229–245. [Online]. Available: https://doi.org/10.1007/978-3-319-05990-7_20
- [92] N. Thomopoulos and M. Givoni, "The autonomous car—a blessing or a curse for the future of low carbon mobility? An exploration of likely vs. desirable outcomes," *European Journal of Futures Research*, vol. 3, no. 1, p. 14, 2015. [Online]. Available: <https://doi.org/10.1007/s40309-015-0071-z>
- [93] S. Feigon and C. Murphy, *Shared mobility and the transformation of public transit*, <https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf>, 2016, last accessed April 2024, no. Project J-11, Task 21.
- [94] Nuro, "Next-generation vehicle | Nuro," <https://www.nuro.ai/vehicle>, last accessed April 2024.
- [95] K. Korosec, "Cruise can now give passengers rides in driverless cars in california," *TechCrunch*, <https://techcrunch.com/2021/06/04/cruise-can-now-give-passengers-rides-in-driverless-cars-in-california/>, November 2022, last accessed April 2024.
- [96] NAVYA, "Moving people - navya," <https://navya.tech/en/solutions/moving-people/>, November 2022, last accessed April 2024.
- [97] Baidu Research, "Robotics and autonomous driving," <http://research.baidu.com>, last accessed April 2024.

- [98] R. Bellan, “Baidu to operate fully driverless commercial robotaxi in Wuhan and Chongqing,” *TechCrunch*, <https://techcrunch.com/2022/08/07/baidu-to-operate-fully-driverless-commercial-robotaxi-in-wuhan-and-chongqing/>, August 2022, last accessed April 2024.
- [99] Transdev, “First Latin American autonomous vehicle project in Chile was a great success,” <http://research.baidu.com>, 2021, last accessed April 2024.
- [100] Verband Deutscher Verkehrsunternehmen (VDV), “Autonome Busse in Deutschland: Liste und Details der Projekte | VDV - Die Verkehrsunternehmen,” <https://www.vdv.de/liste-autonome-shuttle-bus-projekte.aspx>, last accessed April 2024.
- [101] SMO - Shuttle-Modellregion Oberfranken, “Kronach - SMO - Shuttle Modellregion Oberfranken,” <https://www.shuttle-modellregion-oberfranken.de/strecken-smo/kronach-smo>, July 2022, last accessed April 2024.
- [102] KelRide Wheeler - Proof Smart Shuttle, “KelRide Wheeler-Proof Smart Shuttle,” <https://kelride.com/>, March 2022, last accessed 2024.
- [103] DB Regio Bus Bayern, “Erste autonome Buslinie Deutschlands in Bad Birnbach,” <https://www.dbregiobus-bayern.de/angebot/Autonomes-Fahren-/autonomer-bus>, last accessed April 2024.
- [104] EVAShuttle, “EVA-Shuttle,” <http://www.eva-shuttle.de/>, May 2022, last accessed April 2024.
- [105] Verkehrsgesellschaft Frankfurt am Main, “Autonomer Bus: VGF und Continental richten Testbetrieb ein,” <https://www.vgf-ffm.de/de/aktuellpresse/news/einzelansicht/autonomer-bus-vgf-und-continental-richten-testbetrieb-ein/>, August 2022, last accessed 2024.
- [106] W. Rudschies and T. Kroher, “Autonomes Fahren: So fahren wir in Zukunft,” <https://www.vgf-ffm.de/de/aktuellpresse/news/einzelansicht/autonomer-bus-vgf-und-continental-richten-testbetrieb-ein/>, December 2019, last accessed 2024.
- [107] F. D. Davis, “User acceptance of information technology: system characteristics, user perceptions and behavioral impacts,” *International Journal of Man-Machine Studies*, vol. 38, no. 3, pp. 475–487, 1993.

- [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0020737383710229>
- [108] G. Eden, B. Nanchen, R. Ramseyer, and F. Evéquoz, “Expectation and experience: Passenger acceptance of autonomous public transportation vehicles,” in *Human-Computer Interaction – INTERACT 2017*, R. Bernhaupt, G. Dalvi, A. Joshi, D. K. Balkrishan, J. O’Neill, and M. Winckler, Eds. Cham: Springer International Publishing, 2017, pp. 360–363.
 - [109] J. Schade and B. Schlag, “Acceptability of urban transport pricing strategies,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 6, no. 1, pp. 45–61, 2003. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1369847802000463>
 - [110] G. Schuitema, L. Steg, and S. Forward, “Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in stockholm,” *Transportation Research Part A: Policy and Practice*, vol. 44, no. 2, pp. 99–109, 2010. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856409001256>
 - [111] M. Kyriakidis, R. Happee, and J. de Winter, “Public opinion on automated driving: Results of an international questionnaire among 5000 respondents,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 32, pp. 127–140, 2015. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1369847815000777>
 - [112] B. Schoettle and M. Sivak, “A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia,” University of Michigan, Ann Arbor, Transportation Research Institute, Tech. Rep., <https://deepblue.lib.umich.edu/handle/2027.42/108384>, 2014, last accessed April 2024.
 - [113] S. Nordhoff, B. van Arem, and R. Happee, “Conceptual model to explain, predict, and improve user acceptance of driverless podlike vehicles,” *Transportation Research Record*, vol. 2602, no. 1, pp. 60–67, 2016. [Online]. Available: <https://doi.org/10.3141/2602-08>
 - [114] F. Becker and K. W. Axhausen, “Literature review on surveys investigating the acceptance of automated vehicles,” *Transportation*, vol. 44, no. 6, pp. 1293–1306, 2017. [Online]. Available: <https://doi.org/10.1007/s11116-017-9808-9>
 - [115] C. Rödel, S. Stadler, A. Meschtscherjakov, and M. Tscheligi, “Towards autonomous cars: The effect of autonomy levels on acceptance and user experience,” in *Proceedings of the 6th International*

- Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '14. New York, NY, USA: Association for Computing Machinery, 2014, pp. 1–8. [Online]. Available: <https://doi.org/10.1145/2667317.2667330>
- [116] S. Nordhoff, J. de Winter, W. Payre, B. van Arem, and Riender, “What impressions do users have after a ride in an automated shuttle? An interview study,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 63, pp. 252–269, 2019. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S1369847818304327>
- [117] M. Hassenzahl, S. Diefenbach, and A. Göritz, “Needs, affect, and interactive products — facets of user experience,” *Interacting with Computers*, vol. 22, no. 5, pp. 353–362, 2010, modelling user experience - An agenda for research and practice. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0953543810000366>
- [118] A.-K. Frison, P. Wintersberger, T. Liu, and A. Riener, “Why Do You like to Drive Automated? A context-dependent analysis of highly automated driving to elaborate requirements for intelligent user interfaces,” in *Proceedings of the 24th International Conference on Intelligent User Interfaces*, ser. IUI '19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 528–537. [Online]. Available: <https://doi.org/10.1145/3301275.3302331>
- [119] A. Shariff, J.-F. Bonnefon, and I. Rahwan, “Psychological roadblocks to the adoption of self-driving vehicles,” *Nature Human Behaviour*, vol. 1, no. 10, pp. 694–696, 2017. [Online]. Available: <https://doi.org/10.1038/s41562-017-0202-6>
- [120] M. Lundquist, “Autonomous bus passenger experience,” p. 109, 2018.
- [121] T. Brell, H. Biermann, R. Philipsen, and M. Ziefle, “Conditional privacy: Users’ perception of data privacy in autonomous driving,” in *Proceedings of the 5th International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS '19)*, no. VEHITS, 2019, pp. 352–359. [Online]. Available: <https://www.scitepress.org/Papers/2019/76938/76938.pdf>
- [122] A.-K. Frison, P. Wintersberger, A. Riener, and C. Schartmüller, “Driving hotzenplotz: A hybrid interface for vehicle control aiming to maximize pleasure in highway driving,” in *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '17. New York, NY, USA: Association

- for Computing Machinery, 2017, pp. 236–244. [Online]. Available: <https://doi.org/10.1145/3122986.3123016>
- [123] K. Kaur and G. Rampersad, “Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars,” *Journal of Engineering and Technology Management*, vol. 48, pp. 87–96, 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0923474817304253>
- [124] A. O. Salonen and N. Haavisto, “Towards autonomous transportation. passengers’ experiences, perceptions and feelings in a driverless shuttle bus in finland,” *Sustainability*, vol. 11, no. 3, 2019. [Online]. Available: <https://www.mdpi.com/2071-1050/11/3/588>
- [125] S. De Capitani Di Vimercati, S. Foresti, G. Livraga, and P. Samarati, “Data privacy: Definitions and techniques,” *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, vol. 20, no. 06, pp. 793–817, 2012. [Online]. Available: <https://doi.org/10.1142/S0218488512400247>
- [126] Lyft, “Lyft,” <https://www.lyft.com>, 2013, last accessed April 2024.
- [127] Y. Ge, C. R. Knittel, D. MacKenzie, and S. Zoepf, “Racial and gender discrimination in transportation network companies,” National Bureau of Economic Research, Tech. Rep., 2016. [Online]. Available: <https://ssrn.com/abstract=2861708>
- [128] A. O. Salonen, “Passenger’s subjective traffic safety, in-vehicle security and emergency management in the driverless shuttle bus in finland,” *Transport Policy*, vol. 61, pp. 106–110, 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0967070X1730286X>
- [129] T. Fleischer, M. Puhe, and J. Schippl, “Autonomes Fahren und soziale Akzeptanz: konzeptionelle überlegungen und empirische Einsichten,” *Journal für Mobilität und Verkehr*, vol. 12, pp. 9–23, 2022, 46.24.01; LK 01.
- [130] Aral, “Würden sie ein autonom fahrendes Auto nutzen?” <https://de.statista.com/statistik/daten/studie/270596/umfrage/interesse-an-autonomen-fahrzeugen/>, August 2021, last accessed April 2024.
- [131] M. Wicki and T. Bernauer, “Public Opinion on Route 12 Interim report on the first survey on the pilot experiment of an automated bus service in Neuhausen am Rheinfall,” 08 2018.
- [132] R. Krueger, T. H. Rashidi, and J. M. Rose, “Preferences for shared

- autonomous vehicles,” *Transportation Research Part C: Emerging Technologies*, vol. 69, pp. 343–355, 2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0968090X16300870>
- [133] J. M. Sarriera, G. E. Álvarez, K. Blynn, A. Alesbury, T. Scully, and J. Zhao, “To share or not to share: Investigating the social aspects of dynamic ridesharing,” *Transportation Research Record*, vol. 2605, no. 1, pp. 109–117, 2017. [Online]. Available: <https://doi.org/10.3141/2605-11>
- [134] J. Piao, M. McDonald, N. Hounsell, M. Graindorge, T. Graindorge, and N. Mallhene, “Public views towards implementation of automated vehicles in urban areas,” *Transportation Research Procedia*, vol. 14, pp. 2168–2177, 2016, transport Research Arena TRA2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352146516302356>
- [135] A. Sanguinetti, K. Kurani, and B. Ferguson, “Is it ok to get in a car with a stranger? Risks and benefits of ride-pooling in shared automated vehicles,” 2019. [Online]. Available: <https://escholarship.org/uc/item/1cb6n6r9>
- [136] A. H. Maslow, “A theory of human motivation,” *Psychological Review*, vol. 50, no. 4, pp. 370–396, 1943.
- [137] D. T. Kenrick, V. Griskevicius, S. L. Neuberg, and M. Schaller, “Renovating the pyramid of needs: Contemporary extensions built upon ancient foundations,” *Perspectives on Psychological Science*, vol. 5, no. 3, pp. 292–314, 2010. [Online]. Available: <https://doi.org/10.1177/1745691610369469>
- [138] L. Gerhold, “Sicherheitsempfinden, Sicherheitskommunikation und Sicherheitsmaßnahmen,” 2020.
- [139] O. Zotova and L. Karapetyan, “Psychological security as the foundation of personal psychological wellbeing (analytical review),” *Psychology in Russia: State of the Art*, vol. 11, no. 2, pp. 100–113, 2018. [Online]. Available: <https://doi.org/10.11621/pir.2018.0208>
- [140] J. Ditton, “Crime and the City,” *The British Journal of Criminology*, vol. 40, no. 4, pp. 692–709, Sep. 2000. [Online]. Available: <https://academic.oup.com/bjc/article-pdf/40/4/692/1374135/400692.pdf>
- [141] D. C. May, N. E. Rader, and S. Goodrum, “A gendered assessment of the “threat of victimization”: Examining gender differences in fear of crime, perceived risk, avoidance, and defensive behaviors,” *Criminal*

- Justice Review*, vol. 35, no. 2, pp. 159–182, 2010. [Online]. Available: <https://doi.org/10.1177/0734016809349166>
- [142] International Transport Forum, “Women’s safety and security - A public transport priority,” <https://www.itf-oecd.org/womens-safety-security>, 2018, last accessed April 2024.
- [143] N. Karusala and N. Kumar, “Women’s Safety in Public Spaces: Examining the Efficacy of Panic Buttons in New Delhi,” in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ser. CHI ’17. New York, NY, USA: Association for Computing Machinery, 2017, pp. 3340–3351. [Online]. Available: <https://doi.org/10.1145/3025453.3025532>
- [144] J. S. Cossman and N. E. Rader, “Fear of crime and personal vulnerability: Examining self-reported health,” *Sociological Spectrum*, vol. 31, no. 2, pp. 141–162, 2011. [Online]. Available: <https://doi.org/10.1080/02732173.2011.541339>
- [145] D. L. Bissler, *Fear of crime and social networks: A community study of two local public housing complexes*. United States: North Carolina State University, 2003. [Online]. Available: <http://www.lib.ncsu.edu/resolver/1840.16/3100>
- [146] C. J. Vilalta, “Fear of crime in public transport: Research in Mexico City,” *Crime prevention and community safety*, vol. 13, no. 3, pp. 171–186, 2011. [Online]. Available: <https://doi.org/10.1057/cpcs.2011.4>
- [147] M. Killias and C. Clerici, “Different Measures of Vulnerability in their Relation to Different Dimensions of Fear of Crime,” *The British Journal of Criminology*, vol. 40, no. 3, pp. 437–450, Jun. 2000. [Online]. Available: <https://academic.oup.com/bjc/article-pdf/40/3/437/1211316/400437.pdf>
- [148] M. Paydar, A. Kamani-Fard, and R. Etminani-Ghasrodashti, “Perceived security of women in relation to their path choice toward sustainable neighborhood in Santiago, Chile,” *Cities*, vol. 60, pp. 289–300, 2017. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0264275116302098>
- [149] O. Newman, “Creating defensible space,” 1996.
- [150] V. Ceccato, “Moving safely: crime and perceived safety in Stockholm’s subway stations,” 2013.

- [151] J. Blom, D. Viswanathan, M. Spasojevic, J. Go, K. Acharya, and R. Ahonius, "Fear and the city: Role of mobile services in harnessing safety and security in urban use contexts," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '10. New York, NY, USA: Association for Computing Machinery, 2010, pp. 1841–1850. [Online]. Available: <https://doi.org/10.1145/1753326.1753602>
- [152] B. Hillier, "Space is the machine: A configurational theory of architecture," 2007.
- [153] T. Litman, "A new transit safety narrative," *Journal of Public Transportation*, vol. 17, no. 4, pp. 114–135, 2014. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1077291X22001837>
- [154] A. G. Mirnig, M. Gärtner, E. Füssl, K. Ausserer, A. Meschtscherjakov, V. Wallner, M. Kubesch, and M. Tscheligi, "Suppose your bus broke down and nobody came," pp. 1–16, 2020. [Online]. Available: <https://doi.org/10.1007/s00779-020-01454-8>
- [155] W. Clayton, D. Paddeu, G. Parkhurst, and J. Parkin, "Autonomous vehicles: who will use them, and will they share?" *Transportation Planning and Technology*, vol. 43, no. 4, pp. 343–364, 2020. [Online]. Available: <https://doi.org/10.1080/03081060.2020.1747200>
- [156] C. Pakusch, G. Stevens, A. Boden, and P. Bossauer, "Unintended effects of autonomous driving: A study on mobility preferences in the future," *Sustainability*, vol. 10, no. 7, 2018. [Online]. Available: <https://www.mdpi.com/2071-1050/10/7/2404>
- [157] P. S. Lavieri and C. R. Bhat, "Modeling individuals' willingness to share trips with strangers in an autonomous vehicle future," *Transportation Research Part A: Policy and Practice*, vol. 124, pp. 242–261, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856418309819>
- [158] H. Endleman, T. F. Wallace, D. Kao, and B. Wallace, "An Exploratory Review of the Societal Impacts of Automated and Connected Vehicles in Canada, with a focus on Women and Indigenous Peoples Carleton University," 2019. [Online]. Available: <http://www.sce.carleton.ca/~wally/2019%2010%2031b%20%20Transport%20Canada%20Report%20AVCV%20Indigenous%20and%20Women.pdf>
- [159] International Transport Forum, "Transport Innovation for Sustainable Development: A Gender Perspective," [https://www.itf-](https://www.itf-transport.org/en/publications/transport-innovation-for-sustainable-development-a-gender-perspective)

- oecd.org/transport-innovation-sustainable-development-gender-perspective, 2021, last accessed 2024.
- [160] C. Vanier and H. d. de Jubainville, "Feeling unsafe in public transportation: A profile analysis of female users in the Parisian region," *Crime prevention and community safety*, vol. 19, no. 3-4, pp. 251–263, 2017. [Online]. Available: <https://doi.org/10.1057/s41300-017-0030-7>
 - [161] A. Delatte, T. Baouni, R. Belwal, L. Daou, D. Gourram, R. Imam, M. S. Zitoun, and A. Smadi, "Understanding the needs of Mena public transport customers: culture of service and gender responsive recommendations," pp. 7–30, 2018. [Online]. Available: https://www.academia.edu/76244489/Understanding_the_needs_of_MENA_public_transport_customers_Culture_of_service_and_gender_responsive_recommendations?hb-sb-sw=81282247
 - [162] G. Ferrant and A. Thim, "Measuring women's economic empowerment," no. 16, <https://www.oecd-ilibrary.org/content/paper/02e538fc-en>, 2019, last accessed April 2024.
 - [163] V. Ceccato, "Women's victimisation and safety in transit environments," *Crime prevention and community safety*, vol. 19, no. 3-4, pp. 163–167, 2017. [Online]. Available: <https://doi.org/10.1057/s41300-017-0024-5>
 - [164] P. D. Tremoulet, T. Seacrist, C. W. McIntosh, H. Loeb, A. DiPietro, and S. Tushak, "Transporting children in autonomous vehicles: An exploratory study," *Human Factors*, vol. 62, no. 2, pp. 278–287, 2020, pMID: 31268359. [Online]. Available: <https://doi.org/10.1177/0018720819853993>
 - [165] I. Kawgan-Kagan, "Early adopters of carsharing with and without bevs with respect to gender preferences," *European Transport Research Review*, vol. 7, no. 4, pp. 1–11, 2015. [Online]. Available: <https://doi.org/10.1007/s12544-015-0183-3>
 - [166] P. Delhomme and A. Gheorghiu, "Comparing french carpoolers and non-carpoolers: Which factors contribute the most to carpooling?" *Transportation Research Part D: Transport and Environment*, vol. 42, pp. 1–15, 2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1361920915001741>
 - [167] J. Schwieterman and C. S. Smith, "Sharing the ride: A paired-trip analysis of uberpool and chicago transit authority services in chicago, illinois," *Research in Transportation Economics*, vol. 71, pp. 9–16, 2018, journal of the Transportation Research Forum, Volume 57.

- [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0739885918302683>
- [168] C. Hohenberger, M. Spörrle, and I. M. Welp, “How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups,” *Transportation Research Part A: Policy and Practice*, vol. 94, pp. 374–385, 2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856415301464>
- [169] A. König, C. Wirth, and J. Grippenkov, “Generation Y’s Information Needs Concerning Sharing Rides in Autonomous Mobility on Demand Systems,” *Sustainability*, vol. 13, no. 14, 2021. [Online]. Available: <https://www.mdpi.com/2071-1050/13/14/8095>
- [170] H. Biermann, R. Philipsen, T. Brell, and M. Ziefle, “Shut Up and Drive? User Requirements for Communication Services in Autonomous Driving,” in *Proceedings of the 22nd International Conference on Human-Computer Interaction (HCII ’20)*. Springer International Publishing, 2020, pp. 3–14. [Online]. Available: http://dx.doi.org/10.1007/978-3-030-50523-3_{_}1
- [171] P. Jansen, M. Colley, and E. Rukzio, “A design space for human sensor and actuator focused in-vehicle interaction based on a systematic literature review,” *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 6, no. 2, jul 2022. [Online]. Available: <https://doi.org/10.1145/3534617>
- [172] T. Cresswell, “Towards a politics of mobility,” *Environment and Planning D: Society and Space*, vol. 28, no. 1, pp. 17–31, 2010. [Online]. Available: <https://doi.org/10.1068/d11407>
- [173] J. A. Rode, “A Theoretical Agenda for Feminist HCI,” *Interact. Comput.*, vol. 23, no. 5, pp. 393–400, sep 2011. [Online]. Available: <https://doi.org/10.1016/j.intcom.2011.04.005>
- [174] Autoevolution, “Remembering the 1955 Dodge La Femme, the first car designed exclusively for women,” <https://www.autoevolution.com/news/remembering-the-1955-dodge-la-femme-the-first-car-designed-exclusively-for-women-180922.html>, February 2022, last accessed April 2024.
- [175] B. Hunting, “How the 1955 Dodge La Femme missed the mark on designing cars for women,” <https://www.autoevolution.com/news/remembering-the-1955-dodge->

- la-femme-the-first-car-designed-exclusively-for-women-180922.html, February 2020, last accessed April 2024.
- [176] Pink Taxi, “Pink Taxi,” <https://pinktaxi.net/services>, last accessed April 2024.
- [177] A. Delatte, T. Baouni, R. Belwal, L. Daou, R. Imam, M. Zitoun, and A. Smadi, “Report user-oriented public transport. A research project of Mena Centre for Transport Excellence,” 04 2018. [Online]. Available: <https://doi.org/10.6092/1970-9870/5458>
- [178] A. Gluck, K. Boateng, E. W. Huff Jr., and J. Brinkley, “Putting older adults in the driver seat: Using user enactment to explore the design of a shared autonomous vehicle,” in *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 291–300. [Online]. Available: <https://doi.org/10.1145/3409120.3410645>
- [179] M. Sheller, “Sustainable mobility and mobility justice: Towards a twin transition,” *Mobilities: New perspectives on transport and society*, pp. 289–304, 2011.
- [180] R. Heimgärtner, “Denken und Handeln,” in *Interkulturelles User Interface Design: Von der Idee zum erfolgreichen Produkt*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2017, pp. 13–53.
- [181] F. Lachner, C. von Saucken, F. Mueller, and U. Lindemann, “Cross-cultural user experience design helping product designers to consider cultural differences,” in *Cross-Cultural Design Methods, Practice and Impact*, P. Rau, Ed. Cham: Springer International Publishing, 2015, pp. 58–70.
- [182] H. B. Santoso and M. Schrepp, “The impact of culture and product on the subjective importance of user experience aspects,” *Heliyon*, vol. 5, no. 9, p. e02434, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2405844019360943>
- [183] L. Salgado, R. Pereira, and I. Gasparini, “Cultural Issues in HCI: Challenges and Opportunities,” in *Human-Computer Interaction: Design and Evaluation*, M. Kurosu, Ed. Cham: Springer International Publishing, 2015, pp. 60–70.
- [184] H. Winschiers-Theophilus, “The art of cross-cultural design for usability,” in *Universal Access in Human-Computer Interaction. Addressing Diver-*

- sity, C. Stephanidis, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 665–671.
- [185] G. Hofstede, G. Hofstede, and M. Minkov, “Cultures and organizations: Software of the mind, third edition,” 2010. [Online]. Available: <https://books.google.de/books?id=o4OqTgV3V00C>
- [186] G. Hofstede and M. H. Bond, “Hofstede’s culture dimensions: An independent validation using Rokeach’s value survey,” *Journal of cross-cultural psychology*, vol. 15, no. 4, pp. 417–433, 1984.
- [187] G. Hofstede, *Culture’s consequences: comparing values, behaviors, institutions, and organizations across nations*, 2nd ed. Thousand Oaks, Calif: Sage Publications, 2001.
- [188] R. Heimgärtner, A. Holzinger, and R. Adams, “From cultural to individual adaptive end-user interfaces: Helping people with special needs,” 2008. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-540-70540-6_11
- [189] S.-Y. Chien, M. Lewis, S. Hergeth, Z. Semnani-Azad, and K. Sycara, “Cross-country validation of a cultural scale in measuring trust in automation,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 59, no. 1, pp. 686–690, 2015. [Online]. Available: <https://doi.org/10.1177/1541931215591149>
- [190] P. J. Sherman, R. L. Helmreich, and A. C. Merritt, “National culture and flight deck automation: Results of a multination survey,” *The International Journal of Aviation Psychology*, vol. 7, no. 4, pp. 311–329, 1997. [Online]. Available: https://doi.org/10.1207/s15327108ijap0704_4
- [191] D. Olaru, B. Smith, and J. H. Taplin, “Residential location and transit-oriented development in a new rail corridor,” *Transportation Research Part A: Policy and Practice*, vol. 45, no. 3, pp. 219–237, 2011. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856410001655>
- [192] M. Cerrutti and R. Bertoncello, “Urbanization and internal migration patterns in Latin America,” *Centro de Estudios de Población. Argentina*, vol. 1, p. 24, 2003. [Online]. Available: <http://www.rrojasdatabank.info/urban/1-Cerrutti.pdf>
- [193] UN-Habitat, *Enhancing urban safety and security: Global report on human settlements 2007*. Routledge, 2012.

- [194] S. Pasternak and L. M. M. Bogus, “The city of extremes: Socio-spatial inequalities in São Paulo,” *Adequate & Affordable Housing for all. Research, policy, practice. Toronto, June*, pp. 24–27, 2004. [Online]. Available: https://www.academia.edu/65016429/The_city_of_extremes_socio_spatial_inequalities_in_S~A~T1\textsterlingo_Paulo
- [195] E. A. d. Vasconcellos, *Mobilidade cotidiana, segregação urbana e exclusão*. Instituto de Pesquisa Econômica Aplicada (Ipea), 2016.
- [196] C. Requena, “O paradigma da fluidez do automóvel: burocracias estatais e mobilidade em são paulo,” Ph.D. dissertation, Universidade de São Paulo, 2015.
- [197] R. Law, “Beyond ‘women and transport’: towards new geographies of gender and daily mobility,” *Progress in Human Geography*, vol. 23, no. 4, pp. 567–588, 1999. [Online]. Available: <https://doi.org/10.1191/030913299666161864>
- [198] J. Lee, J. Babcock, T. S. Pham, T. H. Bui, and M. Kang, “Smart city as a social transition towards inclusive development through technology: a tale of four smart cities,” *International Journal of Urban Sciences*, vol. 27, no. sup1, pp. 75–100, 2023. [Online]. Available: <https://doi.org/10.1080/12265934.2022.2074076>
- [199] T. Heo, K. Kim, H. Kim, C. Lee, J. H. Ryu, Y. T. Leem, J. A. Jun, C. Pyo, S.-M. Yoo, and J. Ko, “Escaping from ancient Rome! Applications and challenges for designing smart cities,” *Transactions on Emerging Telecommunications Technologies*, vol. 25, no. 1, pp. 109–119, 2014. [Online]. Available: <https://doi.org/10.1002/ett.2787>
- [200] The Seoul Times, “South Korea named one of the safest countries for solo female traveller,” <https://theseoultimes.com/ST/?url=/ST/db/read.php> April 2024.
- [201] K. Stojmenova Pečečnik, S. C. Lee, S. Hong, M. Schuß, H. Şahin undefinedppoliti, A. R. Patel, A. Löcken, D. Dey, A. Riener, A. G. Mirnig, and M. Jeon, “How to ensure diversity and inclusion at conferences? a workshop for general chairs, program committee members, reviewers and authors: A workshop for general chairs, program committee members, reviewers and authors,” in *Adjunct Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’23 Adjunct. New York, NY, USA: Association for Computing Machinery, 2023, pp. 241–244. [Online]. Available: <https://doi.org/10.1145/3581961.3609838>

- [202] B. Shneiderman and C. Plaisant, *Designing the user interface: strategies for effective human-computer interaction*. Pearson Education India, 2010.
- [203] W. E. Bijker, *The social construction of Bakelite: Toward a theory of invention*. MIT press Cambridge, MA, 1987.
- [204] R. Hofmann and D. Allhutter, “Situated (un-)learning in software design: A deconstructive approach,” *Poiesis and Praxis*, vol. 7, no. 1-2, pp. 87–98, 2010. [Online]. Available: <https://link.springer.com/article/10.1007/s10202-010-0075-5>
- [205] D. MacKenzie and J. Wajcman, *The social shaping of technology*. Open university press, 1999.
- [206] M. F. Fox, D. G. Johnson, and S. V. Rosser, *Women, gender, and technology*. University of Illinois Press, 2006.
- [207] S. Bødker, K. Grønbaek, and M. Kyng, “Cooperative Design: Techniques and experiences from the Scandinavian scene,” pp. 215–224, 1995. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/B978008051574850025X>
- [208] G. Bjerknes, P. Ehn, M. Kyng, and K. Nygaard, “Computers and Democracy: A Scandinavian Challenge,” 1987. [Online]. Available: <https://books.google.de/books?id=sjntAAAAMAAJ>
- [209] P. Ehn, B. Mölleryd, and D. Sjögren, “Playing in reality,” *Scandinavian Journal of Information Systems*, vol. 2, pp. 101–120, sep 1991. [Online]. Available: <https://link.springer.com/article/10.1057/ejis.1992.4>
- [210] J. Gregory, “Scandinavian approaches to participatory design,” *International Journal of Engineering Education*, vol. 19, no. 1, pp. 62–74, 2003. [Online]. Available: <https://www.ijee.ie/articles/Vol19-1/IJEE1353.pdf>
- [211] M. J. Muller, “Pictive—an exploration in participatory design,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI ’91. New York, NY, USA: Association for Computing Machinery, 1991, pp. 225–231. [Online]. Available: <https://doi.org/10.1145/108844.108896>
- [212] M. J. R. Perrier, T. Louw, R. C. Gonçalves, and O. Carsten, “Applying participatory design to symbols for SAE Level 2 automated driving systems,” in *Proceedings of the 11th International Conference*

- on *Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings*, ser. AutomotiveUI '19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 238–242. [Online]. Available: <https://doi.org/10.1145/3349263.3351512>
- [213] A. Z. Asha, F. Anzum, P. Finn, E. Sharlin, and M. Costa Sousa, “Designing external automotive displays: VR prototypes and analysis,” in *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 74–82. [Online]. Available: <https://doi.org/10.1145/3409120.3410658>
- [214] S. Tasoudis and A. Riener, “UX design for automated driving: Industry perspective.”
- [215] P. Wright and J. McCarthy, “Empathy and experience in HCI,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '08. New York, NY, USA: Association for Computing Machinery, 2008, pp. 637–646. [Online]. Available: <https://doi.org/10.1145/1357054.1357156>
- [216] S. Bardzell, “Feminisms through design: A practical guide to implement and extend feminism: Response,” *Interactions*, vol. 27, no. 6, pp. 40–41, nov 2020. [Online]. Available: <https://doi.org/10.1145/3428669>
- [217] C. Pigeon, A. Alauzet, and L. Paire-Ficout, “Factors of acceptability, acceptance and usage for non-rail autonomous public transport vehicles: A systematic literature review,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 81, pp. 251–270, 2021. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1369847821001480>
- [218] M. Goluža, *Planning Major Transport Infrastructure: Benefits and Limitations of the Participatory Decision-Making Processes*. Cham: Springer International Publishing, 2020, pp. 185–205. [Online]. Available: https://doi.org/10.1007/978-3-030-28014-7_12
- [219] R. Falanga, *Participatory Design: Participatory Urban Management*. Cham: Springer International Publishing, 2020, pp. 449–457. [Online]. Available: https://doi.org/10.1007/978-3-319-95717-3_7
- [220] E. Björgvinsson, P. Ehn, and P.-A. Hillgren, “Participatory design and “democratizing innovation”,” in *Proceedings of the 11th Biennial Participatory Design Conference*, ser. PDC '10. New York, NY, USA: Association for Computing Machinery, 2010, pp. 41–50. [Online]. Available: <https://doi.org/10.1145/1900441.1900448>

- [221] E. Churchill and M. Wiberg, “Feminist ecologies,” *Interactions*, vol. 30, no. 4, p. 5, jun 2023. [Online]. Available: <https://doi.org/10.1145/3604798>
- [222] C. Pakusch and P. Bossauer, “User acceptance of fully autonomous public transport.” in *ICE-B. 14th International Conference on e-Business*, 2017, pp. 52–60. [Online]. Available: <https://api.semanticscholar.org/CorpusID:28682392>
- [223] C. Lallemand, “Towards consolidated methods for the design and evaluation of user experience,” Ph.D. dissertation, University of Luxembourg, Luxembourg, 2015.
- [224] C. Rödel, S. Stadler, A. Meschtscherjakov, and M. Tscheligi, “Towards autonomous cars: The effect of autonomy levels on acceptance and user experience,” in *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’14. New York, NY, USA: Association for Computing Machinery, 2014, pp. 1–8. [Online]. Available: <https://doi.org/10.1145/2667317.2667330>
- [225] P. Dourish, *Where the action is: the foundations of embodied interaction*. Cambridge, MA: MIT press, 2004.
- [226] I. Pettersson and W. Ju, “Design techniques for exploring automotive interaction in the drive towards automation,” in *Proceedings of the 2017 Conference on Designing Interactive Systems*, ser. DIS ’17. New York, NY, USA: Association for Computing Machinery, 2017, pp. 147–160. [Online]. Available: <https://doi.org/10.1145/3064663.3064666>
- [227] R. Neuhaus, E. Lenz, S. S. Borojeni, and M. Hassenzahl, “Exploring the future experience of automated “valet parking” — a user enactment,” in *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 24–34. [Online]. Available: <https://doi.org/10.1145/3342197.3344518>
- [228] S. Davidoff, M. K. Lee, A. K. Dey, and J. Zimmerman, “Rapidly exploring application design through speed dating,” in *UbiComp 2007: Ubiquitous Computing*, J. Krumm, G. D. Abowd, A. Seneviratne, and T. Strang, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 429–446.
- [229] W. Odom, J. Zimmerman, S. Davidoff, J. Forlizzi, A. K. Dey, and M. K. Lee, “A fieldwork of the future with user enactments,” in *Proceedings of the Designing Interactive Systems Conference*, ser. DIS ’12. New York,

- NY, USA: Association for Computing Machinery, 2012, pp. 338–347. [Online]. Available: <https://doi.org/10.1145/2317956.2318008>
- [230] K. M. Sheldon, A. J. Elliot, Y. Kim, and T. Kasser, “What is satisfying about satisfying events? testing 10 candidate psychological needs.” *Journal of personality and social psychology*, vol. 80, no. 2, p. 325, 2001. [Online]. Available: <https://www.apa.org/pubs/journals/releases/psp802325.pdf>
- [231] T. Litman, “Autonomous vehicle implementation predictions: Implications for transport planning,” 2015.
- [232] P. Mayring, “Qualitative Inhaltsanalyse,” in *Handbuch qualitative Forschung in der Psychologie*. Weinheim: Springer, 2010, pp. 601–613.
- [233] U. Kuckartz, “Qualitative Inhaltsanalyse,” 2012.
- [234] MAXQDA, “Maxqda: Qualitative data analysis software,” 2020. [Online]. Available: <https://www.maxqda.com/>
- [235] A. Brown, J. Gonder, and B. Repac, *An Analysis of Possible Energy Impacts of Automated Vehicles*. Cham: Springer International Publishing, 2014, pp. 137–153. [Online]. Available: https://doi.org/10.1007/978-3-319-05990-7_13
- [236] N. Hitti, “Layer’s joyn platform is a ride-sharing concept that “alleviates eco-guilt”,” <https://www.dezeen.com/2020/01/27/layer-joyn-driverless-ride-sharing/>, 2020, last accessed April 2024.
- [237] N. Gardner, J. Cui, and E. Coiacetto, “Harassment on public transport and its impacts on women’s travel behaviour,” *Australian Planner*, vol. 54, no. 1, pp. 8–15, 2017. [Online]. Available: <https://doi.org/10.1080/07293682.2017.1299189>
- [238] A. G. Mirnig, V. Wallner, M. Gärtner, A. Meschtscherjakov, and M. Tscheligi, “Capacity management in an automated shuttle bus: Findings from a lab study,” in *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI ’20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 270–279. [Online]. Available: <https://doi.org/10.1145/3409120.3410665>
- [239] A. Jones and C. Brooker, “Black Mirror Episode: Nosedive,” 2016, directed by J. Wright.

- [240] —, “Black Mirror Series,” 2011.
- [241] R. Fernandez Abenoza, J. Romero-Torres, O. Cats, and Y. Susilo, “User experiences and perceptions of women-only transport services in Mexico,” *Gendering Smart Mobilities*, vol. 12, pp. 188–209, 2019.
- [242] G. L. Kelling, J. Q. Wilson *et al.*, “Broken windows,” *Atlantic monthly*, vol. 249, no. 3, pp. 29–38, 1982.
- [243] D. T. O’Brien, C. Farrell, and B. C. Welsh, “Looking through broken windows: The impact of neighborhood disorder on aggression and fear of crime is an artifact of research design,” *Annual Review of Criminology*, vol. 2, no. 1, pp. 53–71, 2019. [Online]. Available: <https://doi.org/10.1146/annurev-criminol-011518-024638>
- [244] M. B. Miles and A. M. Huberman, *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage, 1994.
- [245] P. S. Lavieri and C. R. Bhat, “Modeling individuals’ willingness to share trips with strangers in an autonomous vehicle future,” *Transportation Research Part A: Policy and Practice*, vol. 124, pp. 242–261, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856418309819>
- [246] T. Almeida, M. Balaam, and R. Comber, “Woman-centered design through humanity, activism, and inclusion,” *ACM Trans. Comput.-Hum. Interact.*, vol. 27, no. 4, sep 2020. [Online]. Available: <https://doi.org/10.1145/3397176>
- [247] A. Köhler, F. Prinz, L. Wang, J. Becker, G. Voß, S. Ladwig, L. Eckstein, T. Schulte, and N. Depner, “How will we travel autonomously? User needs for interior concepts and requirements towards occupant safety,” 2019. [Online]. Available: https://www.unicaragil.de/images/downloads/Publication_2019-10-08_Koehler_et_al._2019_UNICAR_OSCCAR_AC_Colloquium.pdf
- [248] A. Riener, D. Schlackl, J. Malsam, J. Huber, B. Homm, M. Kaczmar, I. Kleitsch, A. Megos, E. Park, G. Sanverdi, S. Schmidt, D. Bracaci, and E. Anees, “Improving the UX for Users of Automated Shuttle Buses in Public Transport: Investigating Aspects of Exterior Communication and Interior Design,” 2021. [Online]. Available: <https://www.mdpi.com/2414-4088/5/10/61>
- [249] N. Tsai, J. S. Eccles, and S. M. Jaeggi, “Stress and executive control: Mechanisms, moderators, and malleability,” *Brain and Cognition*,

- vol. 133, pp. 54–59, 2019, acute Stress, Memory and the Brain. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0278262618301702>
- [250] A. Sanguinetti, B. Ferguson, J. Oka, E. Alston-Stepnitz, and K. Kurani, “Designing robo-taxis to promote ride-pooling,” Springer, pp. 10–16, 2020. [Online]. Available: <https://escholarship.org/uc/item/65s3m92w>
- [251] D. Dmitrenko, E. Maggioni, G. Brianza, B. E. Holthausen, B. N. Walker, and M. Obrist, *CARoma Therapy: Pleasant Scents Promote Safer Driving, Better Mood, and Improved Well-Being in Angry Drivers*. New York, NY, USA: Association for Computing Machinery, 2020, pp. 1–13. [Online]. Available: <https://doi.org/10.1145/3313831.3376176>
- [252] United Nations Development Programme, “Human development reports,” <http://hdr.undp.org/en>, 2018, last accessed April 2024.
- [253] E. Fraedrich, R. Cyganski, I. Wolf, and B. Lenz, “User perspectives on autonomous driving: A use-case-driven study in Germany,” 2016. [Online]. Available: <https://www.geographie.hu-berlin.de/de/institut/publikationsreihen/arbeitsberichte/arbeitsberichte>
- [254] A. Polydoropoulou, I. Tsouros, N. Thomopoulos, C. Pronello, A. Elvarsson, H. Sigþórsson, N. Dadashzadeh, K. Stojmenova, J. Sodnik, S. Neophytou, D. Esztergár-Kiss, J. Hamadneh, G. Parkhurst, S. Etzioni, Y. Shifan, and F. Di Ciommo, “Who is willing to share their av? insights about gender differences among seven countries,” *Sustainability*, vol. 13, no. 9, 2021. [Online]. Available: <https://www.mdpi.com/2071-1050/13/9/4769>
- [255] G. Currie, A. Delbosc, and S. Mahmoud, “Factors influencing young peoples’ perceptions of personal safety on public transport,” *Journal of Public Transportation*, vol. 16, no. 1, pp. 1–19, 2013. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1077291X22012358>
- [256] L. A. Flohr, D. Janetzko, D. P. Wallach, S. C. Scholz, and A. Krüger, “Context-Based Interface Prototyping and Evaluation for (Shared) Autonomous Vehicles Using a Lightweight Immersive Video-Based Simulator,” in *Proceedings of the 2020 Designing Interactive Systems Conference (DIS ’20)*. Association for Computing Machinery, 2020, pp. 1379–1390.
- [257] C. Kray, P. Olivier, A. W. Guo, P. Singh, H. N. Ha, and P. Blythe, “Taming context: A key challenge in evaluating the usability of ubiquitous systems,” in *Ubiquitous Systems Evaluation 2007 (USE ’07) - Workshop at Ubicomp 2007*, 2007.

- [258] L. A. Flohr, S. Kalinke, A. Krüger, and D. P. Wallach, “Chat or Tap ? — Comparing Chatbots with “Classic” Graphical User Interfaces for Mobile Interaction with Autonomous Mobility-on-Demand Systems,” in *Proceedings of the 2021 International Conference on Mobile Human-Computer Interaction (MobileHCI '21)*. Association for Computing Machinery, 2021, pp. 1–20.
- [259] L. A. Flohr and D. P. Wallach, “The value of context-based interface prototyping for the autonomous vehicle domain: A method overview,” *Multimodal Technologies and Interaction*, vol. 7, pp. 1–17, 2023. [Online]. Available: <https://doi.org/10.3390/mti7010004>
- [260] S. Krome, W. Goddard, S. Greuter, S. P. Walz, and A. Gerlicher, “A context-based design process for future use cases of autonomous driving: prototyping autogym,” in *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '15. New York, NY, USA: Association for Computing Machinery, 2015, pp. 265–272. [Online]. Available: <https://doi.org/10.1145/2799250.2799257>
- [261] M. A. Gerber, R. Schroeter, and J. Vehns, “A video-based automated driving simulator for automotive ui prototyping, ux and behaviour research,” in *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 14–23. [Online]. Available: <https://doi.org/10.1145/3342197.3344533>
- [262] German Research Center for Artificial Intelligence (DFKI), “OpenDS: Open Source Driving Simulation,” <https://opens.dfki.de/>, 2019, last accessed April 2024.
- [263] H. Detjen, B. Pfleging, and S. Schneegass, “A wizard of oz field study to understand non-driving-related activities, trust, and acceptance of automated vehicles,” in *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '20. New York, NY, USA: Association for Computing Machinery, 2020, pp. 19–29. [Online]. Available: <https://doi.org/10.1145/3409120.3410662>
- [264] S. Kim, J. J. E. Chang, H. H. Park, S. U. Song, C. B. Cha, J. W. Kim, and N. Kang, “Autonomous Taxi Service Design and User Experience,” *International Journal of Human-Computer Interaction*, vol. 36, no. 5, pp. 429–448, 2020. [Online]. Available: <https://doi.org/10.1080/10447318.2019.1653556>

- [265] S. Baltodano, S. Sibi, N. Martelaro, N. Gowda, and W. Ju, “The RRADS platform: a real road autonomous driving simulator,” in *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. AutomotiveUI '15. New York, NY, USA: Association for Computing Machinery, 2015, pp. 281–288. [Online]. Available: <https://doi.org/10.1145/2799250.2799288>
- [266] R. Madigan, T. Louw, M. Dziennus, T. Graindorge, E. Ortega, M. Graindorge, and N. Merat, “Acceptance of Automated Road Transport Systems (ARTS): An Adaptation of the UTAUT Model,” *Transportation Research Procedia*, vol. 14, pp. 2217–2226, 2016, transport Research Arena TRA2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352146516302435>
- [267] S. Nordhoff, J. de Winter, R. Madigan, N. Merat, B. van Arem, and R. Happee, “User acceptance of automated shuttles in Berlin-Schöneberg: A questionnaire study,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 58, pp. 843–854, 2018. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1369847817305478>
- [268] World Medical Association, “Declaration of Helsinki. Ethical principles for medical research involving human subjects,” *Jahrbuch Für Wissenschaft und Ethik*, vol. 14, no. 1, pp. 233–238, 2009.
- [269] Generated Photos, “AI Generated Faces,” <https://generated.photos/faces>, last accessed April 2024.
- [270] C. D. Spielberger, “State-trait anxiety inventory for adults,” 1983.
- [271] B. Rammstedt, C. Kemper, M. C. Klein, C. Beierlein, and A. Kovaleva, “Eine kurze Skala zur Messung der fünf Dimensionen der Persönlichkeit: big-five-inventory-10 (BFI-10),” *Methoden, Daten, Analysen (mda)*, vol. 7, no. 2, pp. 233–249, 2013.
- [272] J. W. Creswell, *A Concise Introduction to Mixed Methods Research*. Thousand Oaks, California, USA.: Sage Publications.
- [273] B. Rammstedt and O. P. John, “Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German,” *Journal of Research in Personality*, vol. 41, no. 1, pp. 203–212, 2007. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0092656606000195>
- [274] O. P. John, E. M. Donahue, and R. L. Kentle, “Big five inventory,” *Journal of Personality and Social Psychology*, 1991.

- [275] M. D. Yap, G. Correia, and B. van Arem, "Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips," *Transportation Research Part A: Policy and Practice*, vol. 94, pp. 1–16, 2016. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0965856416307765>
- [276] C. J. Haboucha, R. Ishaq, and Y. Shiftan, "User preferences regarding autonomous vehicles," *Transportation Research Part C: Emerging Technologies*, vol. 78, pp. 37–49, 2017. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0968090X17300177>
- [277] J. Zmud, I. N. Sener, J. Wagner *et al.*, "Consumer acceptance and travel behavior: impacts of automated vehicles," Texas A&M Transportation Institute, Tech. Rep., 2016. [Online]. Available: <https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-15-49-F.pdf>
- [278] K. S. Kurani *et al.*, "User perceptions of safety and security: A framework for a transition to electric-shared-automated vehicles," 2019. [Online]. Available: <https://doi.org/10.7922/G2891438>
- [279] J. A. Russell, A. Weiss, and G. A. Mendelsohn, "Affect grid: a single-item scale of pleasure and arousal." *Journal of personality and social psychology*, vol. 57, no. 3, p. 493, 1989. [Online]. Available: <https://doi.org/10.1037/0022-3514.57.3.493>
- [280] A. Toet, D. Kaneko, S. Ushiyama, S. Hoving, I. de Kruijf, A.-M. Brouwer, V. Kallen, and J. B. F. van Erp, "Emojigrid: A 2d pictorial scale for the assessment of food elicited emotions," *Frontiers in Psychology*, vol. 9, p. 2396, 2018. [Online]. Available: <https://www.frontiersin.org/article/10.3389/fpsyg.2018.02396>
- [281] M. Jeon, "Chapter 1 - emotions and affect in human factors and human-computer interaction: Taxonomy, theories, approaches, and methods," in *Emotions and Affect in Human Factors and Human-Computer Interaction*, M. Jeon, Ed. San Diego: Academic Press, 2017, pp. 3–26. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/B978012801851400001X>
- [282] M. Schrepp, A. Hinderks, and J. Thomaschewski, "Design and Evaluation of a Short Version of the User Experience Questionnaire (UEQ-S)," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 6, p. 103, 2017. [Online]. Available: <https://www.ijimai.org/journal/bibcite/reference/2634>
- [283] M. Schrepp and J. Thomaschewski, "Design and validation of a framework

- for the creation of user experience questionnaires,” *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 5, no. 7, p. 88, 2019.
- [284] B. Laugwitz, T. Held, and M. Schrepp, “Construction and evaluation of a user experience questionnaire,” in *Proceedings of the 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society (USAB'08)*, vol. 5298, 2008, pp. 63–76. [Online]. Available: http://dx.doi.org/10.1007/978-3-540-89350-9{ }_6
- [285] M. Schrepp, “User Experience Questionnaire Handbook,” pp. 1–12, 2018.
- [286] M. Körber, “Theoretical considerations and development of a questionnaire to measure trust in automation,” in *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018): Volume VI: Transport Ergonomics and Human Factors (TEHF), Aerospace Human Factors and Ergonomics*, 1st ed., 2019, pp. 13–30. [Online]. Available: http://link.springer.com/10.1007/978-3-319-96074-6_2
- [287] C. F. Chen, “Factors affecting the decision to use autonomous shuttle services: Evidence from a scooter-dominant urban context,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 67, pp. 195–204, 2019. [Online]. Available: <https://doi.org/10.1016/j.trf.2019.10.016>
- [288] M. J. Dekker, “Riding a self-driving bus to work: Investigating how travellers perceive ADS-DVs on the last mile,” <http://resolver.tudelft.nl/uuid:c9773355-d4a3-4063-9799-11343c625c01>, 2017.
- [289] M. A. Ribeiro, D. Gursoy, and O. H. Chi, “Customer acceptance of autonomous vehicles in travel and tourism,” *Journal of Travel Research*, p. 0047287521993578, 2021. [Online]. Available: <https://doi.org/10.1177/00472875219935>
- [290] T. Schubert, F. Friedmann, and H. Regenbrecht, “The Experience of Presence: Factor Analytic Insights,” *Presence*, vol. 10, no. 3, pp. 266–281, 2001.
- [291] JASP Team, “JASP,” <https://jasp-stats.org/>, 2022, last accessed April 2024.
- [292] The jamovi Project, “jamovi (Version 2.2.5).” <https://www.jamovi.org>, 2022, last accessed April 2024.

- [293] P. D. Allison, “Missing Data,” in *SAGE Handbook of Quantitative Methods in Psychology*, R. E. Millsap and A. Maydeu-Olivares, Eds. Thousand Oaks, CA: Sage Publications Inc., 2009, pp. 72–89.
- [294] M. J. Blanca, R. Alarcón, J. Arnau, R. Bono, and R. Bendayan, “Non-normal data: Is ANOVA still a valid option?” *Psicothema*, vol. 29, no. 4, pp. 552–557, 2017. [Online]. Available: <https://www.psicothema.com/pdf/4434.pdf>
- [295] G. Norman, “Likert scales, levels of measurement and the “laws” of statistics,” *Advances in Health Sciences Education*, vol. 15, no. 5, pp. 625–632, 2010. [Online]. Available: <https://pubmed.ncbi.nlm.nih.gov/20146096/>
- [296] G. M. Sullivan and A. R. Artino, “Analyzing and Interpreting Data From Likert-Type Scales,” *Journal of Graduate Medical Education*, vol. 5, no. 4, pp. 541–542, 2013. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3886444/>
- [297] J. Cohen, “A Power Primer,” *Psychological Bulletin*, vol. 112, no. 1, pp. 155–159, 1992. [Online]. Available: <https://doi.org/10.1037/0033-2909.112.1.155>
- [298] M. Schrepp, A. Hinderks, and J. Thomaschewski, “Construction of a Benchmark for the User Experience Questionnaire (UEQ),” *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 4, p. 40, 2017. [Online]. Available: <https://www.ijimai.org/journal/bibcite/reference/2634>
- [299] J. Blom, D. Viswanathan, M. Spasojevic, J. Go, K. Acharya, and R. Ahonius, *Fear and the City: Role of Mobile Services in Harnessing Safety and Security in Urban Use Contexts*. New York, NY, USA: Association for Computing Machinery, 2010, pp. 1841–1850. [Online]. Available: <https://doi.org/10.1145/1753326.1753602>
- [300] T. Ahmed, A. Kapadia, V. Potluri, and M. Swaminathan, “Up to a Limit? Privacy Concerns of Bystanders and Their Willingness to Share Additional Information with Visually Impaired Users of Assistive Technologies,” *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 2, no. 3, sep 2018. [Online]. Available: <https://doi.org/10.1145/3264899>
- [301] Z. Fang, B. Fu, Z. Qin, F. Zhang, and D. Zhang, “PrivateBus: Privacy Identification and Protection in Large-Scale Bus WiFi Systems,” *Proc.*

- ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 4, no. 1, mar 2020. [Online]. Available: <https://doi.org/10.1145/3380990>
- [302] K. Matsumura and D. S. Kirk, “On active passengering: Supporting in-car experiences,” *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 1, no. 4, jan 2018. [Online]. Available: <https://doi.org/10.1145/3161176>
- [303] R. Philipsen, T. Brell, and M. Ziefle, “Carriage without a Driver—User Requirements for Intelligent Autonomous Mobility Services,” in *Proceedings of the International Conference on Human Factors in Transportation (AHFE ’18)*, vol. 786. Springer International Publishing, 2019, pp. 339–350. [Online]. Available: <http://link.springer.com/10.1007/978-3-319-93885-1>
- [304] M. Thomas and D. Tiku, “Reinventing carsharing as a modern and profitable service,” in *The Intelligent Transportation Society of America, Annual Meeting White Paper*. [Online]. Available: https://ridecell.com/wp-content/uploads/White-Paper-Presentation_Rein-venting-Carsharing-As-A-Modern-And-Profitable-Service.pdf
- [305] D. Sperling, *Three revolutions: Steering automated, shared, and electric vehicles to a better future*. Washington: Island Press, 2018.
- [306] T. D. Chen, “Management of a Shared, Autonomous, Electric Vehicle Fleet: Vehicle Choice, Charging Infrastructure & Pricing Strategies,” Ph.D. dissertation, 2015.
- [307] C. Cavoli, B. Phillips, T. Cohen, and P. Jones, “Social and behavioural questions associated with Automated Vehicles. A Literature Review,” *UCL Transport Institute*, <https://assets.publishing.service.gov.uk/media/5a7f934940f0b62305b87f9f/social-and-behavioural-questions-associated-with-automated-vehicles-literature-review.pdf>, 2017, last accessed April 2024.
- [308] D. Milakis and B. van Wee, “Chapter 4 - implications of vehicle automation for accessibility and social inclusion of people on low income, people with physical and sensory disabilities, and older people,” in *Demand for Emerging Transportation Systems*, C. Antoniou, D. Efthymiou, and E. Chaniotakis, Eds. Elsevier, 2020, pp. 61–73. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/B9780128150184000048>
- [309] R. N. Brewer, A. M. Austin, and N. B. Ellison, “Stories from the front seat: Supporting accessible transportation in the sharing economy,”

- Proc. ACM Hum.-Comput. Interact.*, vol. 3, no. CSCW, nov 2019. [Online]. Available: <https://doi.org/10.1145/3359197>
- [310] J. Festerling and I. Siraj, “Anthropomorphizing technology: A conceptual review of anthropomorphism research and how it relates to children’s engagements with digital voice assistants,” *Integrative Psychological and Behavioral Science*, pp. 1–30, 2021. [Online]. Available: <https://doi.org/10.1007/s12124-021-09668-y>
- [311] E. Bouquet, V. Mäkelä, and A. Schmidt, “Exploring the design of companions in video games,” in *Academic Mindtrek 2021*, ser. Mindtrek 2021. New York, NY, USA: Association for Computing Machinery, 2021, pp. 145–153. [Online]. Available: <https://doi.org/10.1145/3464327.3464371>
- [312] BGBl, “Artikel 1 - Gesetz zur Änderung des Straßenverkehrsgesetzes und des Pflichtversicherungsgesetzes - Gesetz zum autonomen Fahren.” <https://www.buzer.de/gesetz/14868/a276043.htm>, July 2021, last accessed April 2024.
- [313] D. Dey, A. Habibovic, A. Löcken, P. Wintersberger, B. Pfleging, A. Riener, M. Martens, and J. Terken, “Taming the eHMI jungle: A classification taxonomy to guide, compare, and assess the design principles of automated vehicles’ external human-machine interfaces,” *Transportation Research Interdisciplinary Perspectives*, vol. 7, p. 100174, 2020. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2590198220300853>
- [314] Deutscher Bundestag, “§ 49a StVZO Lichttechnische Einrichtungen, allgemeine Grundsätze: StVZO,” <https://www.buzer.de/gesetz/14868/a276043.htm>, April 2012, last accessed April 2024.
- [315] N. Epley, A. Waytz, and J. T. Cacioppo, “On seeing human: A three-factor theory of anthropomorphism.” *Psychological Review*, vol. 114, no. 4, pp. 864–886, 2007. [Online]. Available: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-295X.114.4.864>
- [316] A. Pradhan, L. Findlater, and A. Lazar, ““Phantom Friend” or “Just a Box with Information”: Personification and Ontological Categorization of Smart Speaker-based Voice Assistants by Older Adults,” *Proceedings of the ACM on Human-Computer Interaction*, vol. 3, no. CSCW, pp. 1–21, Nov. 2019. [Online]. Available: <https://dl.acm.org/doi/10.1145/3359316>
- [317] I. Lopatovska and H. Williams, “Personification of the Amazon Alexa:

- BFF or a Mindless Companion,” in *Proceedings of the 2018 Conference on Human Information Interaction & Retrieval - CHIIR '18*. New Brunswick, NJ, USA: ACM Press, 2018, pp. 265–268. [Online]. Available: <http://dl.acm.org/citation.cfm?doid=3176349.3176868>
- [318] M. L. Walters, D. S. Syrdal, K. Dautenhahn, R. te Boekhorst, and K. L. Koay, “Avoiding the uncanny valley: robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion,” *Autonomous Robots*, vol. 24, no. 2, pp. 159–178, 2008. [Online]. Available: <http://link.springer.com/10.1007/s10514-007-9058-3>
- [319] M. Mori, K. F. MacDorman, and N. Kageki, “The Uncanny Valley [From the Field],” *IEEE Robotics & Automation Magazine*, vol. 19, no. 2, pp. 98–100, 2012. [Online]. Available: <https://ieeexplore.ieee.org/document/6213238>
- [320] C. Bartneck, T. Kanda, H. Ishiguro, and N. Hagita, “My robotic Doppelgänger - a critical look at the Uncanny Valley,” in *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication*, 2009, pp. 269–276. [Online]. Available: <https://ieeexplore.ieee.org/document/5326351>
- [321] K. Dautenhahn, S. Woods, C. Kaouri, M. Walters, Kheng Lee Koay, and I. Werry, “What is a robot companion — friend, assistant or butler?” in *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*. Edmonton, Alta., Canada: IEEE, 2005, pp. 1192–1197. [Online]. Available: <http://ieeexplore.ieee.org/document/1545189/>
- [322] F. Eyssel, D. Kuchenbrandt, S. Bobinger, L. de Ruiter, and F. Hegel, “‘If you sound like me, you must be more human’: on the interplay of robot and user features on human-robot acceptance and anthropomorphism,” in *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction - HRI '12*. Boston, Massachusetts, USA: ACM Press, 2012, p. 125. [Online]. Available: <http://dl.acm.org/citation.cfm?doid=2157689.2157717>
- [323] V. Kameswaran, L. Cameron, and T. R. Dillahun, “Support for social and cultural capital development in real-time ridesharing services,” in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ser. CHI '18. New York, NY, USA: Association for Computing Machinery, 2018, pp. 1–12. [Online]. Available: <https://doi.org/10.1145/3173574.3173916>
- [324] P. Wintersberger, A. Riener, and A.-K. Frison, “Automated Driving System, Male, or Female Driver: Who’d You Prefer? Comparative

- Analysis of Passengers' Mental Conditions, Emotional States & Qualitative Feedback," in *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, ser. Automotive'UI 16. New York, NY, USA: Association for Computing Machinery, 2016, pp. 51–58. [Online]. Available: <https://doi.org/10.1145/3003715.3005410>
- [325] A. Waytz, J. Heafner, and N. Epley, "The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle," *Journal of Experimental Social Psychology*, vol. 52, pp. 113–117, 2014. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0022103114000067>
- [326] M. Burmester, K. Zeiner, K. Schippert, and A. Platz, "Creating positive experiences with digital companions," in *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, ser. CHI EA '19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 1–6. [Online]. Available: <https://doi.org/10.1145/3290607.3312821>
- [327] J. Niess, S. Diefenbach, and A. Platz, "Moving beyond assistance: psychological qualities of digital companions," in *Proceedings of the 10th Nordic Conference on Human-Computer Interaction*. Oslo Norway: ACM, Sep. 2018, pp. 916–921. [Online]. Available: <https://dl.acm.org/doi/10.1145/3240167.3240240>
- [328] W. Johal, C. Adam, H. Fiorino, S. Pesty, C. Jost, and D. Duhaut, "Acceptability of a companion robot for children in daily life situations," in *2014 5th IEEE Conference on Cognitive Infocommunications (CogInfoCom)*. Vietri sul Mare, Italy: IEEE, Nov. 2014, pp. 31–36. [Online]. Available: <http://ieeexplore.ieee.org/document/7020474/>
- [329] A. Millonig and P. Fröhlich, "Where Autonomous Buses Might and Might Not Bridge the Gaps in the 4 A's of Public Transport Passenger Needs: A Review," pp. 291–297, 2018. [Online]. Available: <https://doi.org/10.1145/3239060.3239079>
- [330] P. Kong, P. Y. Lim, H. Cornet, and F. Frenkler, "User Emotion and Perception of Virtual and Robot Companion Concepts for Shared Autonomous Mobility in Singapore," *International Journal of Affective Engineering*, vol. 20, pp. 285–295, 2021. [Online]. Available: <https://doi.org/10.5057/ijae.IJAE-D-20-00038>
- [331] D. Bissell, "Passenger mobilities: Affective atmospheres and the sociality of public transport," *Environment and Planning D: Society*

- and Space*, vol. 28, pp. 270–289, 2010. [Online]. Available: <https://doi.org/10.1068/d3>
- [332] A. Ghandeharioun, D. McDuff, M. Czerwinski, and K. Rowan, “EMMA: An Emotion-Aware Wellbeing Chatbot,” Jul. 2019, arXiv:1812.11423 [cs]. [Online]. Available: <http://arxiv.org/abs/1812.11423>
- [333] A. Purington, J. G. Taft, S. Sannon, N. N. Bazarova, and S. H. Taylor, ““Alexa is my new BFF”: Social Roles, User Satisfaction, and Personification of the Amazon Echo,” in *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. Denver Colorado USA: ACM, May 2017, pp. 2853–2859. [Online]. Available: <https://dl.acm.org/doi/10.1145/3027063.3053246>
- [334] L. Sproull, M. Subramani, S. Kiesler, J. Walker, and K. Waters, “When the Interface Is a Face,” *Human-Computer Interaction*, vol. 11, no. 2, pp. 97–124, Jun. 1996. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1207/s15327051hci1102_1
- [335] R. Pak, A. C. McLaughlin, and B. Bass, “A multi-level analysis of the effects of age and gender stereotypes on trust in anthropomorphic technology by younger and older adults,” *Ergonomics*, vol. 57, no. 9, pp. 1277–1289, 2014. [Online]. Available: <https://doi.org/10.1080/00140139.2014.928750>
- [336] F. Nori, A. A. Lipi, and Y. Nakano, “Cultural difference in nonverbal behaviors in negotiation conversations: Towards a model for culture-adapted conversational agents,” in *Universal Access in Human-Computer Interaction. Design for All and eInclusion*, C. Stephanidis, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 410–419. [Online]. Available: https://doi.org/10.1007/978-3-642-21672-5_45
- [337] C. Zhai and S. Wibowo, “A systematic review on cross-culture, humor and empathy dimensions in conversational chatbots: the case of second language acquisition,” *Heliyon*, vol. 8, no. 12, p. e12056, 2022. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2405844022033448>
- [338] H.-H. Huang, K. Tarasenko, T. Nishida, A. Cerekovic, V. Levacic, G. Zoric, I. S. Pandzic, and Y. Nakano, “An agent based multicultural tour guide system with nonverbal user interface,” *Journal on Multimodal User Interfaces*, vol. 1, no. 1, pp. 41–48, 2007. [Online]. Available: <https://doi.org/10.1007/BF02884431>
- [339] Y. Kim and H. Yoo, “Cross-cultural comparison of preferences for the

- external appearance of artificial intelligence agents,” *Social Behavior and Personality: an international journal*, vol. 49, no. 11, pp. 1–23, 2021. [Online]. Available: <https://doi.org/10.2224/sbp.10824>
- [340] I. Lopatovska, D. Brown, and E. Korshakova, “Contextual perceptions of feminine-, masculine-and gender-ambiguous-sounding conversational agents,” in *International Conference on Information*. Springer, 2022, pp. 459–480. [Online]. Available: https://doi.org/10.1007/978-3-030-96957-8_38
- [341] M. Cuciniello, T. Amorese, C. Greco, G. Raimo, G. Cordasco, M. S. Kornes, A. Torp Johansen, K. B. Gjellesvik, A. Fernandez, D. Kyslitska, E. González-Fraile, B. Fernández-Ruanova, J. Tenorio-Laranga, M. I. Torres, and A. Esposito, “A cross-cultural survey to identify seniors’ preferences towards the empathic virtual coach,” in *2022 IEEE Intl Conf on Dependable, Autonomic and Secure Computing, Intl Conf on Pervasive Intelligence and Computing, Intl Conf on Cloud and Big Data Computing, Intl Conf on Cyber Science and Technology Congress (DASC/PiCom/CBDCoM/CyberSciTech)*, 2022, pp. 1–6. [Online]. Available: <https://ieeexplore.ieee.org/document/9927961>
- [342] B. Chaudhry, A.-U.-H. Yasar, S. El-Amine, and E. Shakshuki, “Passenger safety in ride-sharing services,” *Procedia Computer Science*, vol. 130, pp. 1044–1050, 2018, the 9th International Conference on Ambient Systems, Networks and Technologies (ANT 2018). [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1877050918305088>
- [343] Chalik and Chalik, “Study: Top Fears of Rideshare Passengers in the U.S.,” <https://www.chaliklaw.com/blog/top-rideshare-fears/>, June 2018, last accessed April 2024.
- [344] J.-J. Lee and K.-P. Lee, “Cultural differences and design methods for user experience research: Dutch and Korean participants compared,” in *Proceedings of the 2007 conference on Designing pleasurable products and interfaces - DPPI '07*. Helsinki, Finland: ACM Press, 2007, p. 21. [Online]. Available: <http://portal.acm.org/citation.cfm?doid=1314161.1314164>
- [345] —, “Facilitating dynamics of focus group interviews in east asia: Evidence and tools by cross-cultural study,” *International Journal of Design*, vol. 3, pp. 17–28, 04 2009. [Online]. Available: <http://www.ijdesign.org/index.php/IJDesign/article/view/351>
- [346] S. C. Lee, H. Sanghavi, S. Ko, and M. Jeon, “Autonomous driving with an agent: speech style and embodiment,” in *Proceedings of*

- the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings*. Utrecht Netherlands: ACM, Sep. 2019, pp. 209–214. [Online]. Available: <https://dl.acm.org/doi/10.1145/3349263.3351515>
- [347] J. Niess and P. W. Woźniak, “Embracing companion technologies,” in *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*, ser. NordiCHI '20. New York, NY, USA: Association for Computing Machinery, 2020. [Online]. Available: <https://doi.org/10.1145/3419249.3420134>
- [348] A. Goudey and G. Bonnin, “Must smart objects look human? study of the impact of anthropomorphism on the acceptance of companion robots,” *Recherche et Applications en Marketing (English Edition)*, vol. 31, no. 2, pp. 2–20, 2016. [Online]. Available: <https://doi.org/10.1177/2051570716643961>
- [349] H. R. Lee and S. Sabanović, “Culturally variable preferences for robot design and use in South Korea, Turkey, and the United States,” in *Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction*. Bielefeld Germany: ACM, Mar. 2014, pp. 17–24. [Online]. Available: <https://dl.acm.org/doi/10.1145/2559636.2559676>
- [350] H. Jones, “Intersectional design cards: Exploring intersecting social and environmental factors across four levels of design,” *Journal of Writing in Creative Practice*, vol. 15, no. 1, pp. 7–20, 2022. [Online]. Available: <https://www.sup.org/books/title/?id=35687>
- [351] Wolf3D, “Metaverse full-body online 3d avatar creator | ready player me,” <https://readyplayer.me/de>, last accessed April 2024.
- [352] Animaze, “Animaze by Facerig | Custom Avatars | Create Your own Avatar,” <https://www.animaze.us/>, last accessed April 2024.
- [353] SuperSeancurtis, “Drunk people on buses,” <https://www.youtube.com/watch?v=-9kyzV97Gsw>, May 2012, last accessed April 2024.
- [354] A. C. M. Fioravanti-Bastos, E. Cheniaux, and J. Landeira-Fernandez, “Development and validation of a short-form version of the Brazilian state-trait anxiety inventory,” *Psicologia: Reflexão e Crítica*, vol. 24, no. 3, pp. 485–494, 2011. [Online]. Available: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-79722011000300009&lng=en&nrm=iso&tlng=en

- [355] V. Graff, L. Cai, I. Badiola, and N. M. Elkassabany, “Music versus midazolam during preoperative nerve block placements: a prospective randomized controlled study,” *Regional Anesthesia & Pain Medicine*, vol. 44, no. 8, pp. 796–799, Aug. 2019. [Online]. Available: <http://rapm.bmj.com/lookup/doi/10.1136/rapm-2018-100251>
- [356] L. Laux, *Das State-Trait-Angstinventar (STAI): theoretische Grundlagen und Handanweisung*. Beltz, 1981.
- [357] T. M. Marteau and H. Bekker, “The development of a six-item short-form of the state scale of the Spiegelberger State-Trait Anxiety Inventory STAI,” *British Journal of Clinical Psychology*, vol. 31, no. 3, pp. 301–306, Sep. 1992. [Online]. Available: <https://onlinelibrary.wiley.com/doi/10.1111/j.2044-8260.1992.tb00997.x>
- [358] UEQ Team, “User Experience Questionnaire (UEQ),” <https://www.ueq-online.org/>, last accessed April 2024.
- [359] G. M. Bashir and H. U. Khan, “Factors affecting learning capacity of information technology concepts in a classroom environment of adult learner,” in *2016 15th International Conference on Information Technology Based Higher Education and Training (ITHET)*. Istanbul, Turkey: IEEE, Sep. 2016, pp. 1–6. [Online]. Available: <http://ieeexplore.ieee.org/document/7760729/>
- [360] H. Tennent, S. Shen, and M. Jung, “Micbot: A peripheral robotic object to shape conversational dynamics and team performance,” in *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 2019, pp. 133–142. [Online]. Available: <https://ieeexplore.ieee.org/document/8673013>
- [361] R. Hortensius, F. Hekele, and E. S. Cross, “The perception of emotion in artificial agents,” *IEEE Transactions on Cognitive and Developmental Systems*, vol. 10, pp. 852–864, 12 2018. [Online]. Available: <https://ieeexplore.ieee.org/document/8341761>
- [362] Eyekon, “Fahrplan und Ticket-App mit Chat-Interface | eyekon digital craft,” <https://www.eyekon.ch/projekte/bls-chat-app>, last accessed April 2024.
- [363] Deutsche Bahn, <https://www.eyekon.ch/projekte/bls-chat-app>, last accessed April 2024.
- [364] D. Zumstein and S. Hundertmark, *Communicating and Transacting with Chatbots: Insights from Public Transport*, 2017.

- [Online]. Available: <https://www.iadisportal.org/digital-library/communicating-and-transacting-with-chatbots-insights-from-public-transport>
- [365] P. A. M. Ruijten, *Responses to Human-like Artificial Agents*, 2015.
- [366] E. Bouquet, V. Mäkelä, and A. Schmidt, “Exploring the design of companions in video games,” *ACM International Conference Proceeding Series*, pp. 145–153, 6 2021. [Online]. Available: <https://doi.org/10.1145/3464327.3464371>
- [367] K. Emmerich, P. Ring, and M. Masuch, “I’m glad you are on my side: How to design compelling game companions,” *CHI PLAY 2018 - Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, pp. 153–162, 10 2018. [Online]. Available: <https://dl-acm-org.thi.idm.oclc.org/doi/10.1145/3242671.3242709>
- [368] D. Pinchbeck, “An analysis of persistent non-player characters in the first-person gaming genre 1998-2007: a case for the fusion of mechanics and diegetics,” *Eludamos: Journal for Computer Game Culture*, vol. 3, pp. 261–279, 10 2009. [Online]. Available: <https://eludamos.org/index.php/eludamos/article/view/vol3no2-9/5907><https://eludamos.org/index.php/eludamos/article/view/vol3no2-9>
- [369] H. Warpefelt and H. Verhagen, “A model of non-player character believability,” *Journal of Gaming and Virtual Worlds*, vol. 9, pp. 39–53, 3 2017. [Online]. Available: https://www.researchgate.net/publication/318590210_A_model_of_non-player_character_believability
- [370] M. L. J. Søndergaard and L. K. Hansen, “Intimate futures: Staying with the trouble of digital personal assistants through design fiction,” in *Proceedings of the 2018 Designing Interactive Systems Conference*, ser. DIS ’18. New York, NY, USA: Association for Computing Machinery, 2018, pp. 869–880. [Online]. Available: <https://doi.org/10.1145/3196709.3196766>
- [371] J. Feine, U. Gnewuch, S. Morana, and A. Maedche, “A taxonomy of social cues for conversational agents,” *International Journal of Human-Computer Studies*, vol. 132, pp. 138–161, 2019. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1071581918305238>
- [372] N. N. Loideain and R. Adams, “From alexa to siri and the gdpr: The gendering of virtual personal assistants and the role of data protection impact assessments,” *Computer Law and Security Review*, vol. 36, p. 105366, 2020. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0267364919303772>

- [373] J. Dong, E. Lawson, J. Olsen, and M. Jeon, “Female voice agents in fully autonomous vehicles are not only more likeable and comfortable, but also more competent,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 64, pp. 1033–1037, 12 2020. [Online]. Available: https://www.researchgate.net/publication/349282095_Female_Voice_Agents_in_Fully_Autonomous_Vehicles_Are_Not_Only_More_Likeable_and_Comfortable_But_Also_More_Competent
- [374] F. He and C. M. Burns, “A battle of voices: A study of the relationship between driving experience, driving style, and in-vehicle voice assistant character.” *ACM*, 9 2022, pp. 236–242. [Online]. Available: <https://dl.acm.org/doi/10.1145/3543174.3546845>
- [375] M. Scanlon, T. Swanson, P. Darvasi, and J. Jenson, “The first door: gender, authority and choice in The Stanley Parable,” in *Proceedings of the 12th International Conference on the Foundations of Digital Games*, ser. FDG ’17. New York, NY, USA: Association for Computing Machinery, 2017. [Online]. Available: <https://doi.org/10.1145/3102071.3106349>
- [376] C. Fiesler, S. Morrison, and A. S. Bruckman, “An Archive of Their Own: A Case Study of Feminist HCI and Values in Design,” in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ser. CHI ’16. New York, NY, USA: Association for Computing Machinery, 2016, pp. 2574–2585. [Online]. Available: <https://doi.org/10.1145/2858036.2858409>
- [377] R. Conli, “Baymax,” 2014, directed by Don Hall and Chris Williams.
- [378] S. L. Jon Davison, “Robocop,” 1987, directed by Paul Verhoeven.
- [379] P. Dickinson, A. Jones, W. Christian, A. Westerside, F. Mulloy, K. Gerling, K. Hicks, L. Wilson, and A. Parke, “Experiencing simulated confrontations in virtual reality,” *Conference on Human Factors in Computing Systems - Proceedings*, 5 2021. [Online]. Available: <https://doi.org/10.1145/3411764.3445401>
- [380] A. Riegler, A. Riener, and C. Holzmann, “Virtual reality driving simulator for user studies on automated driving,” in *Adjunct proceedings, 11th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications*, C. P. Janssen, S. F. Donker, L. L. Chuang, and W. Ju, Eds. New York, New York: The Association for Computing Machinery, 2019, pp. 502–507.

- [381] Mixamo, “Animate 3D characters for games, film, and more,” <https://www.mixamo.com/>, last accessed April 2024.
- [382] M. Slater, C. Gonzalez-Liencre, P. Haggard, C. Vinkers, R. Gregory-Clarke, S. Jelley, Z. Watson, G. Breen, R. Schwarz, W. Steptoe, D. Szostak, S. Halan, D. Fox, and J. Silver, “The ethics of realism in virtual and augmented reality,” *Frontiers in Virtual Reality*, vol. 1, 3 2020. [Online]. Available: <https://www.frontiersin.org/articles/10.3389/frvir.2020.00001/full>
- [383] C. Jicol, J. Feltham, J. Yoon, M. J. Proulx, E. O’Neill, and C. Lutteroth, “Designing and assessing a virtual reality simulation to build resilience to street harassment,” *Conference on Human Factors in Computing Systems - Proceedings*, 4 2022. [Online]. Available: <https://doi.org/10.1145/3491102.3502129>
- [384] R. Sommer, “Personal space. the behavioral basis of design.” 1969.
- [385] J. C. Zoellick, A. Kuhlmei, L. Schenk, D. Schindel, and S. Blüher, “Assessing acceptance of electric automated vehicles after exposure in a realistic traffic environment,” *PloS one*, vol. 14, no. 5, p. e0215969, 2019. [Online]. Available: <https://doi.org/10.1371/journal.pone.0215969>
- [386] I. Thielmann and B. E. Hilbig, “Trust: An integrative review from a person-situation perspective,” *Review of General Psychology*, vol. 19, no. 3, pp. 249–277, 2015. [Online]. Available: <https://doi.org/10.1037/gpr0000046>
- [387] R. Munoz-Raskin, “Walking accessibility to bus rapid transit: Does it affect property values? the case of bogotá, colombia,” *Transport Policy*, vol. 17, no. 2, pp. 72–84, 2010. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0967070X09001334>
- [388] C. J. Mercado Velandia, “Viabilidad técnica y financiera de la utilización del bicitaxi como medio de transporte público en el marco del sistema integrado de transporte público en bogotá dc,” 2012. [Online]. Available: <https://repositorio.unal.edu.co/handle/unal/12182>
- [389] H. Allen, G. Cárdenas, L. P. Pereyra, and L. Sagaris, “Ella se mueve segura. A study on women’s personal safety in public transport in three Latin American cities,” 2019. [Online]. Available: <https://womenmobilize.org/pubs/ella-se-mueve-segura-a-study-on-womens-personal-safety-in-public-transport-in-three-latin>
- [390] F. R. Morgado, J. F. Meireles, C. M. Neves, A. C. Amaral,

- and M. E. Ferreira, “Scale development: Ten main limitations and recommendations to improve future research practices. psychology: Research and review, 30 (1), 1-20,” 2018. [Online]. Available: <https://doi.org/10.1186/s41155-016-0057-1>
- [391] G. O. Boateng, T. B. Neilands, E. A. Frongillo, H. R. Melgar-Quinonez, and S. L. Young, “Best practices for developing and validating scales for health, social, and behavioral research: a primer,” *Frontiers in Public Health*, vol. 6, p. 149, 2018. [Online]. Available: <https://doi.org/10.3389/fpubh.2018.00149>
- [392] D. B. McCoach, R. K. Gable, and J. P. Madura, *Evidence Based on the Internal Structure of the Instrument: Factor Analysis*. New York, NY: Springer New York, 2013, pp. 109–161. [Online]. Available: https://doi.org/10.1007/978-1-4614-7135-6_4
- [393] R, “R: A Language and Environment for Statistical Computing,” Vienna, Austria, <https://www.R-project.org/>, 2021, last accessed April 2024.
- [394] A. Field, J. Miles, and Z. Field, *Discovering statistics using R*. Sage publications, 2012.
- [395] P. Kline, *Handbook of psychological testing*. London: Routledge, 2013.
- [396] R. Cattell, *The scientific use of factor analysis in behavioral and life sciences*. Springer Science & Business Media, 2012.
- [397] J. C. Nunnally, “An overview of psychological measurement,” *Clinical diagnosis of mental disorders: A handbook*, pp. 97–146, 1978. [Online]. Available: https://link.springer.com/chapter/10.1007/978-1-4684-2490-4_4
- [398] L. J. Cronbach and P. E. Meehl, “Construct validity in psychological tests.” *Psychological bulletin*, vol. 52, no. 4, p. 281, 1955. [Online]. Available: <https://doi.org/10.1037/h0040957>
- [399] G. A. Churchill Jr, “A paradigm for developing better measures of marketing constructs,” *Journal of marketing research*, vol. 16, no. 1, pp. 64–73, 1979. [Online]. Available: <https://doi.org/10.1177/002224377901600110>
- [400] L. A. Clark and D. Watson, “Constructing validity: Basic issues in objective scale development.” 2016. [Online]. Available: <https://psycnet.apa.org/buy/1996-93318-001>

-
- [401] J. P. Stevens, *Applied multivariate statistics for the social sciences*. Hillsdale, NS; Erlbaum, 2002.
- [402] W. Revelle and M. W. Revelle, “Package ‘psych’,” *The comprehensive R archive network*, vol. 337, p. 338, 2015. [Online]. Available: <https://cran.r-project.org/web/packages/psych/index.html>
- [403] M. W. Browne, “Alternative ways of assessing model fit,” *Testing structural equation models*, pp. 136–162, 1993. [Online]. Available: <https://doi.org/10.1177/0049124192021002005>
- [404] L. Hu and P. M. Bentler, “Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives,” *Structural equation modeling: a multidisciplinary journal*, vol. 6, no. 1, pp. 1–55, 1999. [Online]. Available: <https://doi.org/10.1080/10705519909540118>
- [405] S. Breslin and B. Wadhwa, “Exploring Nuanced Gender Perspectives within the HCI Community,” in *Proceedings of the India HCI 2014 Conference on Human Computer Interaction*, ser. IndiaHCI ’14. New York, NY, USA: Association for Computing Machinery, 2014, pp. 45–54. [Online]. Available: <https://doi.org/10.1145/2676702.2676709>
- [406] D. Haraway, “A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century,” in *Simians, Cyborgs and Women: The Reinvention of Nature*. Routledge, 1991, p. 180.