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User Acceptance of Automated Vehicles in Public Transport

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the Netherlands

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User Acceptance of Automated Vehicles in Public Transport

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Summary

The acceptance of automated vehicles is a necessary condition for realizing the benefits of road vehicle automation. The objective of the thesis was to examine the acceptance of automated vehicles feeding public transport. The thesis investigated the factors contributing to user acceptance, as well as the interrelations of those factors. It was also investigated how acceptance differs across socio-demographic groups and countries. Online questionnaires, semi-structured interviews, a systematic literature review, and accompanied test rides were performed. Participants were asked to imagine the use of automated vehicles (Chapter 2) or physically experienced them in mixed traffic environments in Berlin (Germany) and Trikala (Greece) (Chapters 3–5, 7–8).

A large cross-national online questionnaire study in Chapter 2 found that respondents would enjoy a ride in an automated vehicle. The questionnaire items could be best explained through a general acceptance component, extracted using principal component analysis. The highest component loadings were found for items pertaining to the usefulness of automated vehicles. Correlations between the general acceptance score and socio-demographic variables were small. Furthermore, it was found that respondents from lower-income countries were more accepting of automated vehicles than respondents from higher-income countries.

Chapter 3 presents the results of a questionnaire study among individuals who physically experienced an automated vehicle. The results were in line with the online study of Chapter 2, in the sense that respondents were positive about the idea of using automated vehicles from the train station to their final destination. A principal component analysis reduced questionnaire data to the three components: (1) vehicle and service characteristics, (2) the effectiveness of the automated vehicle compared to existing transport, and (3) the intention to use automated vehicles in public transport. Again, correlations with individual characteristics (age and gender) were small. Participants were less positive about the effectiveness compared to existing transport and the speed of the automated vehicle.

Chapter 4 presents the results of an interview study among participants who experienced a ride in an automated vehicle. The interview data were classified into six categories: (1) expectations about the capabilities of the automated vehicle, (2) evaluation of the vehicle performance, (3) service quality, (4) risk and benefit perception, (5) travel purpose, and (6) trust. The interview quotes showed that participants were again positive about the idea of using automated shuttles as feeders to public transport systems. However, participants had idealized expectations about the technological capabilities of the automated shuttle; these expectations may have been shaped by the media.

Chapter 5 investigated the interrelations between the constructs of the Unified Theory of Acceptance and Use of Technology (UTAUT). Hedonic motivation (i.e., the degree to which using automated vehicles is perceived as enjoyable) was the strongest predictor of the intention to use automated vehicles, followed by performance expectancy, and social influence.

Chapter 6 presents MAVA, a multi-level model on automated vehicle acceptance. MAVA describes the process of automated vehicle acceptance by means of four stages: (1) the exposure to automated vehicles, (2) the formation of favourable or unfavourable attitudes towards automated vehicles, (3) deciding to adopt or reject automated vehicles, and (4) the implementation and use of automated vehicles. The factors of acceptance are organized at the micro-level (i.e., socio-demographics, travel behaviour, personality) and meso-level (i.e., domain-specific, symbolic-affective and moral-normative factors).

Chapter 7 examined the interrelations between the UTAUT and Diffusion of Innovation Technology (DIT) constructs compatibility, trialability, trust, and automated vehicle sharing. Compatibility (i.e., the extent to which automated vehicles are compatible with existing mobility needs and routines) was the strongest predictor of behavioural intention, followed by automated vehicle sharing. The effects of age and gender on the behavioural intention to use automated vehicles in public transport were not significant.

Chapter 8 describes a test ride with an automated vehicle accompanied by a ‘hidden’ safety steward. The respondents’ perceived safety was associated with the vehicle’s (low) speed, object and event identification, longitudinal and lateral control, pressing the emergency button inside the vehicle, general trust in technology, sharing the vehicle with fellow travellers, the operation of the vehicle in a controlled environment, and the behaviour of other road users outside the vehicle. Respondents expected to be cautious in crossing the road in front of an automated vehicle, due to a lack of trust in the behaviour of the automated vehicle and missing eye contact with the human driver.

This thesis concludes that respondents positively valued the idea of using automated vehicles in public transport. However, respondents had overly positive and idealized expectations of automated vehicles. Socio-demographic factors were weak predictors of automated vehicle acceptance. The most important predictors of automated vehicle acceptance are domain-specific factors, followed by symbolic-affective and moral-normative factors. The acceptance of automated vehicles follows a sequential decision-making process. The acceptance of automated vehicles does not only depend on passengers inside but also vulnerable road users outside automated vehicles. For future work, it is recommended to examine acceptance over time and use more objective data (e.g., data from vehicle usage) together with self-reports in functional automated public transport.

Samenvatting

De acceptatie van geautomatiseerde voertuigen is een noodzakelijke voorwaarde om de voordelen van automatisering van wegvoertuigen te realiseren. Het doel van het proefschrift was om de acceptatie te onderzoeken van geautomatiseerde voertuigen in last-mile openbaar vervoer. Het proefschrift onderzocht de factoren die bijdragen aan de acceptatie door gebruikers, evenals de onderlinge relaties tussen deze factoren. Er werd ook onderzocht hoe acceptatie verschilt tussen sociaal-demografische groepen en landen. Er werden online vragenlijsten, semi-gestructureerde interviews, een systematische literatuurstudie en begeleide testritten uitgevoerd. Deelnemers werd gevraagd zich het gebruik van geautomatiseerde voertuigen voor te stellen (hoofdstuk 2) en hebben deze fysiek ervaren in gemengde verkeersomgevingen in Berlijn (Duitsland) en Trikala (Griekenland) (hoofdstukken 3–5, 7–8).

Een grote cross-nationale online vragenlijststudie in hoofdstuk 2 wees uit dat respondenten graag een rit in een geautomatiseerd voertuig zouden maken. De vragenlijstitems konden het beste worden verklaard via een algemene acceptatiecomponent, geëxtraheerd met behulp van hoofdcomponentanalyse. De hoogste componentladingen werden gevonden voor items die betrekking hadden op het nut van geautomatiseerde voertuigen. De correlaties tussen de algemene acceptatiescore en sociaaldemografische variabelen waren klein. Verder bleek dat respondenten uit landen met een lager inkomen geautomatiseerde voertuigen meer accepteerden dan respondenten uit landen met een hoger inkomen.

Hoofdstuk 3 presenteert de resultaten van een vragenlijstonderzoek onder personen die fysiek een geautomatiseerd voertuig hebben ervaren. De resultaten kwamen overeen met de online studie van hoofdstuk 2, in die zin dat de respondenten positief waren over het idee om geautomatiseerde voertuigen van het treinstation naar hun eindbestemming te gebruiken. Een hoofdcomponentanalyse verminderde de vragenlijstgegevens tot de drie componenten: (1) voertuig- en servicekenmerken, (2) de effectiviteit van het geautomatiseerde voertuig in vergelijking met bestaand transport, en (3) de intentie om geautomatiseerde voertuigen in het openbaar vervoer te gebruiken. Ook hier waren de correlaties met individuele kenmerken (leeftijd en geslacht) klein. De deelnemers waren minder positief over de effectiviteit in vergelijking met bestaand transport en de snelheid van het geautomatiseerde voertuig.

Hoofdstuk 4 presenteert de resultaten van een interviewonderzoek onder deelnemers die een rit in een geautomatiseerd voertuig hebben meegemaakt. De interviewgegevens werden ingedeeld in zes categorieën: (1) verwachtingen over de mogelijkheden van het geautomatiseerde voertuig, (2) evaluatie van de voertuigprestaties, (3) servicekwaliteit, (4) risico- en batenperceptie, (5) reisdoel, en (6) vertrouwen. Uit de citaten van het interview bleek dat deelnemers opnieuw positief waren over het idee om geautomatiseerde shuttles te gebruiken als feeders voor openbaarvervoersystemen. De deelnemers hadden echter geïdealiseerde verwachtingen over de technologische mogelijkheden van de geautomatiseerde shuttle; deze verwachtingen zijn mogelijk door de media gevormd.

Hoofdstuk 5 onderzocht de onderlinge relaties tussen de constructen van de Unified Theory of Acceptance and Use of Technology (UTAUT). Hedonische motivatie (d.w.z. de mate waarin het gebruik van geautomatiseerde voertuigen als plezierig wordt ervaren) was de sterkste voorspeller van de intentie om geautomatiseerde voertuigen te gebruiken, gevolgd door de verwachte prestaties en sociale invloed.

Hoofdstuk 6 presenteert MAVA, een multi-level model van de acceptatie van geautomatiseerde voertuigen. MAVA beschrijft het proces van acceptatie door middel van vier fasen: (1) de

blootstelling aan geautomatiseerde voertuigen, (2) de vorming van een gunstige of ongunstige houding ten opzichte van geautomatiseerde voertuigen, (3) de beslissing om geautomatiseerde voertuigen te accepteren of te weigeren, en (4) implementatie en gebruik van geautomatiseerde voertuigen. De acceptatiefactoren zijn georganiseerd op microniveau (d.w.z. socio-demografie, reisgedrag, persoonlijkheid) en mesoniveau (d.w.z. domeinspecifieke, symbolisch-affectieve en moreel-normatieve factoren).

Hoofdstuk 7 onderzocht de onderlinge relaties tussen de UTAUT en Diffusion of Innovation Technology (DIT) constructen, compatibiliteit, testbaarheid, vertrouwen en het delen van geautomatiseerde voertuigen. Compatibiliteit (d.w.z. de mate waarin geautomatiseerde voertuigen compatibel zijn met bestaande mobiliteitsbehoeften en routines) was de sterkste voorspeller van gedragsintentie, gevolgd door het delen van geautomatiseerde voertuigen. De effecten van leeftijd en geslacht op de intentie om geautomatiseerde voertuigen in het openbaar vervoer te gebruiken, waren niet significant.

Hoofdstuk 8 beschrijft een testrit met een automatisch voertuig vergezeld van een ‘verborgen’ veiligheidssteward. De ervaren veiligheid van de respondenten werd geassocieerd met de (lage) snelheid van het voertuig, identificatie van objecten en gebeurtenissen, longitudinale en laterale beweging, het indrukken van de noodknop in het voertuig, algemeen vertrouwen in technologie, het voertuig delen met medereizigers, de bediening van het voertuig in een gecontroleerde omgeving en het gedrag van andere weggebruikers buiten het voertuig. Respondenten verwachten dat ze voorzichtig zullen zijn bij het oversteken van de weg voor een automatisch voertuig vanwege een gebrek aan vertrouwen in het gedrag van het geautomatiseerde voertuig en het ontbreken van oogcontact met de menselijke chauffeur.

Dit proefschrift concludeert dat respondenten het idee van het gebruik van geautomatiseerde voertuigen in het openbaar vervoer positief waardeerden. De respondenten hadden echter te positieve en geïdealiseerde verwachtingen van geautomatiseerde voertuigen. Socio-demografische factoren waren zwakke voorspellers van automatische voertuigacceptatie. De belangrijkste voorspellers van automatische voertuigacceptatie zijn domeinspecifieke factoren, gevolgd door symbolisch-affectieve en moreel-normatieve factoren. De acceptatie van geautomatiseerde voertuigen volgt een sequentieel besluitvormingsproces. De acceptatie van geautomatiseerde voertuigen is niet alleen afhankelijk van passagiers binnen, maar ook van kwetsbare weggebruikers buiten geautomatiseerde voertuigen. Voor toekomstige werkzaamheden wordt aanbevolen de acceptatie in de loop van de tijd te onderzoeken en objectievere gegevens (bijv. gegevens over voertuiggebruik) te gebruiken, samen met zelfrapportages in functioneel geautomatiseerd openbaar vervoer.

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Chapter 1: Introduction

Automated driving has received ample attention from researchers and practitioners in the past years. The evolutionary path to vehicle automation is embodied by private automated vehicles and rests on the notion of using the abilities of human drivers and automated vehicles in a symbiotic relationship. Human drivers transfer control to the automated vehicle in situations that can be safely handled by automation. Drivers resume manual control again upon request of the automated vehicle in situations that can be better handled by human drivers. The revolutionary path of vehicle automation departs from the challenges of the evolutionary vehicle automation path and assumes that the safe take-over of control from the automated vehicle by the human driver cannot be guaranteed, which is why standard human interfaces such as the steering wheel, gas, and brake pedals and thus the human driver in the loop have to be removed (Chan, 2017). SAE Level 4/5 Automated-Driving-System-Dedicated Vehicles such as automated vehicles that feed public transport on the first and last end of a public transport trip (SAE International, 2018) represent this development path (Fraedrich, Beiker, & Lenz, 2015).

The advent of public automated vehicles in public transport could instigate a paradigm shift towards more environmentally-friendly mobility by covering both the access and regress end of a public transport trip, thereby increasing the efficiency of public transport (Soteropoulos, Berger, & Ciari, 2019). With driverless operation, smaller vehicles become relatively economical, creating scope for flexible on-demand 24/7 operation. Studies have first focused on the technology and the automated vehicle itself and examined the impacts on transport, mobility, and society. Recently, the acceptance of automated vehicles by users has entered the scientific discourse. The acceptance of automated vehicles is a necessary condition to realise the benefits of road vehicle automation such as improvements in road safety, road capacity, reductions in travel time and greenhouse gas emissions. There is still a paucity of knowledge from real on-road studies examining the acceptance of automated vehicles in public transport systems. The present thesis obtained knowledge from potential users of automated vehicles who experienced automated vehicle prototypes before these have been commercialized. This knowledge can be fed into the design process of automated vehicles to closely align the design of automated vehicles to user needs and preferences. In this way, the fit between automated vehicles as end product and user needs and preferences and the likelihood of a large-scale acceptance and adoption of automated vehicles by end-users can be increased. If we do not obtain the knowledge on the factors impacting the acceptance of automated vehicles as early as possible before commercialization, we risk not to realize the aforementioned benefits of road vehicle automation and the potential to improve our current transport systems remains unleveraged.

1.1. Research gaps, objectives & research questions

The main research objective of the present PhD thesis therefore is:

To examine the acceptance of automated vehicles in public transport

The following research gaps were identified and research questions formulated to address the main research objective.

1.1.1. Lack of a conceptual model predicting automated vehicle acceptance

Automated vehicle acceptance is a complex and multifaceted phenomenon. The first research studies that entered the scientific debate examined general attitudes towards automated vehicles without systematically organizing opinions around factors. At that time, there was a limited understanding of the factors impacting the acceptance of automated vehicles in public transport and their relative importance. Identifying the factors that increase the chance that an individual will accept and use an automated vehicle is important to develop the right strategies to promote automated vehicle acceptance. It helps us to understand not only what and how people think about automated vehicles but also *why* they are more or less inclined to use these vehicles as part of public transport. No conceptual model existed when this PhD study was initiated that linked the acceptance factors with the acceptance construct itself nor investigated the interrelationships between the acceptance factors. Acheampong and Cugurullo (2019) have argued that automated vehicle acceptance is a complex and multifaceted research theme that can only be fully understood when an interdisciplinary perspective is adopted and the interrelationships between different acceptance factors considered. There was also little knowledge about how the factors are organized in a decision-making process leading to acceptance.

The conceptual model that was developed in this thesis rests on the Unified Theory of Acceptance and Use of Technology (UTAUT) which is one of the most influential technology acceptance models and represents a synthesis of eight influential acceptance models (Venkatesh et al., 2003, 2012). It is also based on the Car Technology Acceptance Model (CTAM) by Osswald et al. (2013) to account for the relevance of safety-related aspects that were not part of the UTAUT model. The purpose of the resulting model is threefold: First, it serves as a qualitative synthesis of the acceptance research of automated vehicles by integrating acceptance factors and their relationships into one model. Second, it systematizes and organizes the acceptance process. Third, it can be used by researchers and practitioners to derive directions for future research and guide the development, design, implementation, and operation of automated vehicles in a way that is acceptable to its users.

1.1.2. Lack of qualitative in-depth knowledge about automated vehicle acceptance

The majority of research studies on automated vehicle acceptance are based on internet surveys and stated choice experiments and less on interviews and focus groups. Conducting qualitative research is pivotal due to respondents' lack of knowledge and actual experience with automated vehicles (Fraedrich & Lenz, 2014), and the imprecise and confusing handling with the terms used to define all types of automated driving systems and automation levels (Chan, 2017). Nees (2016) and Shladover (2016, 2017) have argued that the public discourse may have oversold automated driving, creating unrealistic expectations among the public as regards the technological capabilities of automated vehicles and their expected market release.

1.1.3. Lack of knowledge on automated vehicle acceptance across groups and countries

Furthermore, little is known about how the acceptance of automated vehicles in public transport differed across groups and countries. The study of how automated vehicle acceptance differs across groups of people within and between countries is important to cater for their different needs and preferences and incorporate these into the development, design, and implementation of automated vehicles.

The following research questions are addressed:

1. *What are the general attitudes towards automated vehicles in public transport?*
2. *What are the factors impacting the acceptance of automated vehicles in public transport, and what is their relative importance?*
3. *To what extent are the factors predicting automated vehicle acceptance interrelated?*
4. *What is the process leading to automated vehicle acceptance?*
5. *To what extent does automated vehicle acceptance differ across groups and countries?*

1.1.4. Lack of knowledge about safety perceptions, envisioned interactions and communication with automated vehicles

Automated vehicle acceptance does not only depend on the passengers inside the automated vehicle but also on external vulnerable road users such as pedestrians and cyclists and their safe and efficient interactions with automated vehicles. Little is known about the safety perceptions of passengers of automated vehicles, and their safety perceptions of pedestrians and cyclists as external road users interacting with automated vehicles. The interaction and communication between automated vehicles and cyclists and pedestrians are still poorly understood. Addressing this gap in research is crucial since safety is one of the basic human needs and key drivers of automated vehicle acceptance. Making sure that automated vehicles can safely interact with pedestrians and cyclists is pivotal since pedestrians and cyclists as vulnerable road users have been disproportionally involved in fatal accidents.

The corresponding research questions to address this gap in research therefore are:

6. *What are the safety perceptions of passengers of automated vehicles, and how do passengers view the safety of pedestrians and cyclists interacting with automated vehicles as external road users?*
7. *How do passengers of automated vehicles envision their interactions and communication with automated vehicles in a crossing situation as pedestrians and cyclists?*

1.2. Thesis outline

An overview of the studies in this thesis is given in Table 1.

While Chapter 2 examines opinions of naïve individuals who had no physical experience with an automated vehicle, Chapters 3–5 and Chapters 7–8 investigate opinions of individuals who physically experienced an automated vehicle. Chapter 2 presents the results of an international questionnaire survey among 10,000 respondents that were asked to imagine their acceptance and use of automated vehicles in public transport. Gathering data on opinions towards driverless vehicles in public transport from a large international naïve sample without physical experience with automated vehicles allowed the identification of individual and national predictors of automated vehicle acceptance. This first step was necessary to get a first overview of general opinions towards automated vehicles in public transport and establish the requirements of the public towards the development, design, and operation of these vehicles.

In addition, Chapter 3 investigates respondents’ ratings of the automated vehicle itself, its potential as feeder in public transport in urban and rural areas, as well as its advantages in comparison to respondents’ existing travel. In addition to examining the Unified Theory of

Acceptance and Use of Technology (UTAUT) constructs ‘performance expectancy’, ‘effort expectancy’, and ‘social influence’, which were partly addressed in Chapter 2, Chapter 3 investigated respondents’ safety perceptions, perceived enjoyment, desired level of control, and environmental attitudes. It also addressed the multi-dimensional nature of the acceptance construct itself by using several indicators to measure acceptance, including Van der Laan et al.’s (1997) acceptance scale, respondents’ intended frequency to use, willingness to pay, and behavioral intention to use automated vehicles in public transport. Chapter 3 also investigated how automated vehicle acceptance varied across age, gender, and employment. Chapter 5 investigated group-specific differences in automated vehicle acceptance, examining the role of an individual’s mobility behaviour (i.e., car and public transport use), technology savviness and experience with road vehicle automation (i.e., number of times of using and interacting with the automated vehicle) for automated vehicle acceptance that have been neglected in Chapters 2 and 3.

Chapter 4 summarizes the results of an interview study with 30 users of an automated vehicle on the EUREF campus in Berlin. Qualitative in-depth knowledge about why and under which conditions individuals are planning the use of automated vehicles in public transport is offered. This study allowed the identification of meaning that respondents attached to the factors of automated vehicle acceptance, which is less possible in standardized questionnaires where respondents are merely asked to give their opinion to a selected number of questionnaire items. The collection of qualitative, in-depth knowledge was necessary to gain a better understanding of the motives behind the responses to the quantitative questionnaire items presented to individuals in Chapters 2 and 3, and to reflect whether the factors predicting automated vehicle acceptance identified in Chapters 2–4 correspond indeed with the topics that are considered important by respondents.

Chapter 5 presents the results of a questionnaire study gathering data from individuals who physically experienced an automated vehicle in an open and mixed traffic environment on public roads in Trikala (Greece) as part of the CityMobil2 project. Chapters 2 and 3 employed exploratory analyses to detect patterns in the dataset and examine their correlations. Chapter 5 applied a confirmatory factor analysis to confirm the theoretical structure of the data. Structural equation modelling was applied to investigate the magnitude and direction of the effects of the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation on behavioral intentions to use automated vehicles. It also examined the interrelationships between the UTAUT constructs as this topic was neglected by Chapters 2–4.

Chapter 6 presents the multi-level model on automated vehicle acceptance, called MAVA, that originates from a systematic literature review of the literature on automated vehicle acceptance research, including the studies in Chapters 2–5. The model summarizes the factors predicting acceptance, and organizes these factors in terms of their relative importance, adherence to levels and processes.

Chapter 7 continues with the examination of the interrelationships between the acceptance constructs and integrated the UTAUT constructs performance and effort expectancy, social influence, and facilitating conditions, the Diffusion of Innovation Theory (DIT) constructs compatibility and trialability, as well as trust and automated vehicle sharing with fellow travelers into one structural model. Data was gathered from 340 individuals who physically experienced the automated vehicle ‘Emily’ from Easymile (i.e., 2nd vehicle generation of EZ10 that was experienced by respondents in Chapter 5) in a mixed traffic environment on the semi-public EUREF campus in Berlin.

Chapter 8 presents the results of a mixed method approach using semi-structured interviews and online questionnaires to investigate the safety perceptions of respondents who took a ride in an automated vehicle without obvious supervision onboard. Respondents were accompanied on their ride with the automated vehicle by a “hidden” steward and the first author of this study who interviewed respondents on the ride before respondents completed questionnaires after the ride. Chapter 8 further examines how individuals would interact and communicate with the automated vehicle as passengers and pedestrians and cyclists.

Table 1. Overview of research studies pursued in the present PhD thesis

Chapter number	Automated vehicle type	Data collection method	Sample size	Time of measurement & location	Automated vehicle experience	Data analysis method
Chapter 2	Imaginary, Easymile EZ10 	Online questionnaire	10.000	–	No	Descriptive statistics, principal component analysis
Chapter 3	‘Olli’, Local Motors 	Online questionnaire	384	Post-drive, Berlin, December 2016 – April 2017	Yes	Descriptive statistics, principal component analysis
Chapter 4	‘Olli’, Local Motors 	Semi-structured interviews	30	Post-drive, Berlin, March – July 2017	Yes	Principles of inductive category development
Chapter 5	Robosoft CityMobil2 shuttle 	Online questionnaire	315	Post-drive, Trikala, December 2015 – February 2016	Yes	Descriptive statistics, confirmatory factor analysis, structural equation modelling
Chapter 6	–	Literature review	–	–	–	–
Chapter 7	‘Emily’, Easymile EZ10 	Online questionnaire	340	Post-drive, Berlin, April 2018 – December 2018	Yes	Descriptive statistics, confirmatory factor analysis, structural equation modelling

Chapter 8	'Emily', Easymile EZ10 	Accompanied test ride study, online questionnaire	119	Intra-drive, post-drive, Berlin, March 2018 – December 2018	Yes	Descriptive statistics, principles of inductive and deductive category development

1.3. Contributions

The present thesis performed extensive on-road studies to enhance our theoretical and empirical knowledge on automated vehicle acceptance across groups and countries. The knowledge that is obtained in the thesis can be used by designers, operators, public transport companies and policy makers to inform the design, implementation, and operation of automated vehicles in public transport. The thesis makes the following *unique* scientific contributions:

1) *Development of a conceptual model* (i.e., MAVA) (Chapter 6) that enhances our knowledge on the factors impacting automated vehicle acceptance, and the interrelationships between these factors
2) Probing the *suitability of qualitative research methods* (i.e., semi-structured interviews) (Chapter 4) to examine automated vehicle acceptance
3) Probing the *suitability of mixed method approaches* (Chapter 8) to investigate safety perceptions, envisaged interactions and communication requirements of passengers of automated vehicles

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Chapter 2: Acceptance of driverless vehicles: Results from a large cross-national questionnaire study

2.1. ABSTRACT

Shuttles that operate without an onboard driver are currently being developed and tested in various projects worldwide. However, there is a paucity of knowledge on the determinants of acceptance of driverless shuttles in large cross-national samples. In the present study, we surveyed 10,000 respondents on the acceptance of driverless vehicles and socio-demographic characteristics, using a 94-item online questionnaire. After data filtering, data of 7,755 respondents from 116 countries were retained. Respondents reported that they would enjoy taking a ride in a driverless vehicle (mean = 4.90 on a scale from 1 = disagree strongly to 6 = agree strongly). We further found that the scores on the questionnaire items were most appropriately explained through a general acceptance component, which had loadings of about 0.7 for items pertaining to the usefulness of driverless vehicles, and loadings between 0.5 and 0.6 for items concerning the intention to use, ease of use, pleasure, and trust in driverless vehicles, as well as knowledge of mobility-related developments. Additional components were identified as (2) thrill-seeking, (3) wanting to be in control manually, (4) supporting a car-free environment, and (5) being comfortable with technology. Correlations between socio-demographic characteristics and general acceptance scores were small (< 0.20), yet interpretable (e.g., people who reported difficulty with finding a parking space were more accepting towards driverless vehicles). Finally, we found that the GDP per capita of the respondents' country was predictive of countries' mean general acceptance score (ρ = -0.48 across 43 countries with 25 or more respondents). In conclusion, self-reported acceptance of driverless vehicles is more strongly determined by domain-specific attitudes than by socio-demographic characteristics. We recommend further research, using objective measures, into the hypothesis that national characteristics are a predictor of the acceptance of driverless vehicles.

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2.2. Introduction

2.2.1. The rise of driverless vehicles

Driverless vehicles are currently being developed in a number of commercial and research projects worldwide (Eden et al., 2017; Shladover, 2016). Shuttles that function as shared transport systems are a promising business case (Attias, 2017). Such shuttles may contribute to environmentally friendly mobility and tackle the inefficiencies of today’s transport systems (Scheltes & Correira, 2017; Van Arem et al., 2015). However, driverless vehicles will only become a success if they are accepted by their users (Nordhoff et al., 2016). User acceptance of these vehicles needs to be studied at an early stage, preferably before the technology is publicly available.

2.2.2. Individual predictors of acceptance

Previous questionnaire studies on the acceptance of automated vehicles have identified several predictors of acceptance. It has been shown that men are more favorable towards automated vehicles than women. For example, it has been found that men were more likely to have a positive attitude towards automated vehicles (Hulse et al., 2018), were more willing to pay more and were less concerned about automated vehicles (Kyriakidis et al., 2015), were more comfortable to allow a fully-automated car to perform all functions (Regan et al., 2017), reported more pleasure and less anxiety with automated vehicles (Hohenberger et al., 2016), and were more likely to express a positive intention to use and own automated vehicles than women (Piao et al., 2016).

The effect of age on acceptance is mixed. Becker and Axhausen (2017) performed a review on questionnaire studies about automated vehicles and found that 6 out of 10 studies (i.e., Bansal et al., 2016; Missel, 2014; Seapine Software, 2014; J.D. Power, 2012; Schoettle & Sivak, 2014a, 2015) that examined age effects reported that younger people were more accepting of automated vehicles than older people. In contrast, one online survey study in their review (Rödel et al., 2014) found that people aged 36 to 65 had a more positive attitude and a stronger intention to use automated vehicles than people aged 18 to 35. In Nordhoff et al. (2017), older people were more likely to intend to use driverless vehicles and were more positive towards the vehicle characteristics, but gave lower ratings to the effectiveness of the vehicle compared to their existing travel mode.

It has also been found that people with a higher income are willing to pay more for vehicles equipped with automated driving features (Bansal et al., 2016; Kyriakidis et al., 2015). Furthermore, individuals with a higher driving mileage were more positive towards automated vehicles (Kyriakidis et al., 2015; Shabanpour et al., 2017) and had a higher willingness to pay for high automation levels (Bansal et al., 2016).

Several researchers (Madigan et al., 2016; Yap et al., 2015; Zmud & Sener, 2017) have studied the role of personality-related attitudes as predictors of acceptance. For example, Bansal et al. (2016) found that technology-savvy individuals were more positive towards automated vehicles, which is in agreement with Zmud and Sener (2017) who found that individuals with a higher intent to use automated vehicles were the ones using Smartphones, text-messaging, Facebook, and transportation apps, and with Lavieri et al. (2017) who found that tech-savvy individuals are likely to be early adopters of automated vehicles.

Some of the above-mentioned predictor variables are also used in technology acceptance models, which have been developed to explain and predict user behavior across a variety of domains. The Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) represents a synthesis of eight influential technology acceptance models, including the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), the Technology Acceptance Model (Davis, 1989; Davis et al., 1989) and the Theory of Planned Behavior (TPB) (Ajzen, 1985). Using the UTAUT model as baseline, a conceptual model of the acceptance of driverless vehicles by Nordhoff et al. (2016) postulates that acceptance is the result of the domain-specific attitudes performance expectancy and effort expectancy, as well as the symbolic-affective construct social influence and the pleasure-arousal-dominance framework (Mehrabian, 1996). The suitability of technology acceptance models to predict the acceptance of automated vehicles was shown by Madigan et al. (2016, 2017) and Zmud and Sener (2017).

2.2.3. National predictors of acceptance of driverless vehicles

In addition to individual differences in the acceptance of automated vehicles, national differences have been studied as well. Participants from higher income countries were found to be less comfortable with the transmission of their data (Kyriakidis et al., 2015) and less likely to express a positive comment about automated driving in an open-ended question (Bazilinskyy et al., 2015). Similarly, a cross-national survey by the World Economic Forum (WEF) and the Boston Consulting Group (BCG) (2015) showed that the question "How likely would you be to let your children ride alone in a fully self-driving car?" was answered more positively by respondents from lower-income countries. In the same vein, the willingness to share a self-driving taxi was higher in low-income than in high-income countries (WEF & BCG, 2015), and respondents from China and India were more positive about automated vehicles than Japan, the US, UK, and Australia. However, both low- and high-income countries were equally concerned about safety issues related to fully automated cars (Schoettle and Sivak, 2014b).

2.2.4. Objectives of this research

Although a large number of survey studies on automated driving exist (see Becker & Axhausen, 2017, for a review), most of these studies have used relatively small and specific populations from Western countries (e.g., France, Switzerland, Germany, US, UK, Australia). These studies examined the influence of respondents' demographics (e.g., age, gender) or attitudes (e.g., technology acceptance) on the acceptance of automated vehicles.

Based on findings from previous research (e.g., Kyriakidis et al., 2015; Stern, 2000), it may be expected that correlations between socio-demographics and technology acceptance will be small at best (i.e., around $r = 0.10$). For example, a review of thirty years of acceptance research on wind energy suggests that demographic variables only explain a small amount of variance in attitudes towards wind energy (Rand & Hoen, 2017). Large sample sizes are thus needed to be able to detect significant correlations. For example, for a sample size of 400, the 99% confidence interval of a correlation of 0 is -0.13 to 0.13. Substantially larger sample sizes are needed to achieve statistical power for differentiating whether one correlation is stronger than another.

In summary, the above studies have contributed to knowledge of the acceptance of automated vehicles, but there is a paucity of knowledge regarding their acceptance in large cross-national samples. As the mobility sector faces a shift from motorized to sustainable and collaborative forms of mobility (Barr & Shaw, 2016), this paper examines the role of individuals' wish for a car-free future, their knowledge of mobility-related developments, and their attitudes towards driverless vehicles (e.g., transport-related, symbolic-affective, usefulness, ease of use) among 7,755 respondents from 116 countries. To examine cross-national effects, correlations between countries' GDP per capita and respondents' mean ratings were examined. The present study did not test hypotheses but used an exploratory analysis to detect patterns in a large-sample dataset. More specifically, respondents completed a large number of diverse items, and we subjected the items to descriptive analyses to examine for which items the respondents showed low or high agreement. We subsequently performed a data reduction (principal component analysis) to examine the sources of variation in the data.

2.3. Methods

2.3.1. Instrument & procedure

A 94-question survey was created on CrowdFlower (http://www.crowdflower.com). The survey instructions informed the respondents that their answer would be anonymous and that the completion of the survey would take around 20 minutes.

The instructions informed the respondents about a typical usage scenario with driverless vehicles as follows:

Automated vehicles are now being extensively tested on public roads by auto builders, suppliers and software companies. These vehicles still have steering wheel and pedals, and require a qualified driver to monitor the automation and to take back control when needed. This questionnaire is about the next level of automation being driverless vehicles. Driverless vehicles operate without a driver and do not have a steering wheel, gas or brake pedals. In the beginning, they will not operate on all roads and not in all traffic situations. With this survey, I would like to find out what do you think about these driverless vehicles and whether you would be ready and willing to accept and use them.

Imagine that a driverless vehicle is waiting for you outside the train station or some other public transport stop (e.g. bus, tram, metro) to drive you to your final destination, providing last-mile transport. It can also drive you back to your original destination. The driverless vehicle is 100% electric. You may also book it on-demand via your smartphone-app. When you enter the vehicle, you may need to give in your destination via an interface – for example a keyboard – so that the vehicle knows where you would like to go. As the vehicle can accommodate 6-8 passengers, it may be the case that you share the vehicle with a few unknown travelers having the same destination like you. The pictures below show the interior and exterior of such a driverless vehicle.

Next, two pictures of a driverless vehicle were shown from the French company Easymile (Easymile, 2015; Schuhmacher, 2015) (Fig. 1) to ensure that respondents had an idea of the type of vehicle being the topic of our research.

Figure 1. Photos included at the top of the questionnaire (Easymile, 2015; Schuhmacher, 2015).

No requirements regarding respondents' country were set. Each respondent was paid €0.20 for the participation in the survey.

2.3.2. Questionnaire content

2.3.2.1. Survey instructions, socio-demographic characteristics

The first two questions asked respondents whether they had read and understood the questionnaire instructions (Q1) and whether the instructions were clear (Q2). Questions Q3–Q27 and Q71 asked respondents about their socio-demographic characteristics and their travel behavior, including questions such as gender (Q3), year of birth (Q4), type of residential situation (Q7), and monthly net household income (Q12).

2.3.2.2. Domain-specific attitudes: Usefulness and ease of use

Questions Q49 and Q53 asked respondents to provide their agreement with whether they would use a driverless vehicle for their daily travel because it would be better and more convenient, or more useful than their existing form of travel, respectively. Respondents were also asked to rate their agreement with whether using a driverless vehicle would be easier than existing travel (Q50) and whether learning to operate a driverless vehicle would be easy for them (Q52).

2.3.2.3. Transport-related attitudes: Satisfaction with daily travel and enjoyment of manual driving

Respondents were asked whether they were satisfied with their daily travel in terms of the ability to organize their day flexibly with public transport (Q28), and whether they are satisfied with the possibilities available to cover their daily travel needs (Q31). In questions Q29, Q30, Q66, and Q69, respondents were asked whether they need a vehicle to be flexible (Q29), whether they consider driving especially fun (Q30), whether they often feel like a racing driver when driving manually (Q66), and whether they would like to learn to drive vehicles exceeding a speed of 300 km/h (Q69).

2.3.2.4. Symbolic-affective attitudes: Pleasure and social influence

Respondents were asked whether they would enjoy taking a ride in a driverless vehicle (Q37) and whether they would find it important that driverless vehicles are aesthetic in terms of styling and design (Q39). They were further asked questions relating to whether they would like to have their friends or family or other important people to them adopt the driverless vehicle before they do (Q60) and whether people who are important to them would like it when they would use a driverless vehicle (Q63).

2.3.2.5. Personality-related attitudes: Trust, liking of being in control, enjoyment of technology, knowledge of mobility, future orientation, wish for car-free future, skepticism

Further questions concerned the trust in driverless vehicles (Q44, Q56, Q58, Q64) and the preferred level of control and supervision in driverless vehicles (Q36, Q46, Q48, Q68, Q70). Respondents were also asked questions regarding their enjoyment of technology in general (Q72–Q74) and their knowledge of mobility-related developments (Q75–Q78, Q87). In Q83–Q86 and Q88–Q94, respondents were asked to indicate their level of agreement with items pertaining to their future orientation and their wish for a car-free future in cities. Questions Q42, Q57, Q59, and Q65 asked respondents to rate their level of skepticism with driverless vehicles Specifically, respondents indicated whether they agreed with the statement that driverless vehicles would take away the driving pleasure or enjoyment (Q42), whether they would feel uncomfortable entrusting the safety of a family member to a driverless vehicle (Q57), whether they would refrain from using driverless vehicles because technology can sometimes fail (Q59), and whether they think that there will always be accidents, even with driverless vehicles on the road (Q65).

2.3.2.6. Intention to use driverless vehicles

Respondents were presented with questions that addressed whether they would use a driverless vehicle that is 100% electric (Q38), whether they would share a driverless vehicle with around 6–8 fellow travelers having the same route as them (Q40), how often they intend to use a driverless vehicle when it is available on the market (Q41), and whether they would use a 100% electric driverless vehicle from the train station or some other public transport stop to their final destination or vice versa (Q43). Q54 asked respondents at which usage rate they would use a driverless vehicle. Respondents were further asked to indicate whether they would buy a driverless vehicle (Q80), use it with other passengers as part of public transport (Q81), or in a carsharing scheme (Q82).

2.3.2.7. Miscellaneous questions

As automated shuttles can accommodate 8 to 10 passengers in a small space at the same time, respondents were asked to indicate whether they prefer to keep a physical distance between themselves and strangers (Q61). They were also asked whether environmental protection is crucial for their choice of transportation in Q62. Q67 asked respondents to rate their agreement with whether driving without accidents is mainly a matter of luck.

2.3.2.8. Questions not included in the analysis

Respondents were asked why they would use a driverless vehicle (e.g., to pick up kids from school or bring them to soccer practice) (Q32), which activities they would perform in a driverless vehicle (e.g., reading a book) (Q33), for which travel purposes they would use driverless vehicles (e.g., commuting to work) (Q34), which features they find attractive in driverless vehicles (e.g., button to stop the vehicle) (Q35), and how driverless vehicles should be operated (e.g., on a fixed schedule) (Q45). Q47 asked respondents about their preferred level of human supervision (e.g., remote supervision from external control room). In Q55, respondents were asked to indicate under which financial condition they would use a driverless vehicle. In Q79, respondents were asked to indicate the potential factors or concerns that would discourage them from using a driverless vehicle (e.g., loss of driving enjoyment). These questions were not included in the analysis because they had multiple options in a checkbox format and were not measured on an ordinal scale.

2.3.2.9. Measurement of questionnaire items

The above survey questions were based on literature about automated vehicles and technology acceptance (Krueger et al., 2016; Kyriakidis et al., 2015; Madigan et al., 2016; Parasuraman, 2000; Schoettle & Sivak, 2014a; Venkatesh et al., 2003; Vlassenroot et al., 2011; Yagil, 2001; Yap et al., 2015). More specifically, the relevance of each response category was demonstrated by prior work on technology acceptance models, most notably the UTAUT model (Section 1.3). The role of transport-related attitudes (Section 2.2.3) was considered pivotal, as the success of driverless vehicles hinges on individuals' willingness to change their travel mode. Personality-related attitudes (Section 2.2.5) have been investigated before (e.g., Kyriakidis et al., 2015), but may need further investigation as their potential relevance for predicting preferences to use automated vehicles has been indicated before (e.g., Yap et al., 2015; Zmud & Sener, 2017). With developments such as the electrification of transport, the redesign of cities to promote sustainable modes of transport, and the restriction of private car use, people's attitudes towards a car-free future (Section 2.2.5) are important to be able to implement the necessary changes.

Questions Q28–Q31, Q36–Q40, Q42–Q44, Q48–Q53, Q56–Q70, Q72–Q78, and Q80–Q83, Q87, Q92, and Q93 were measured on a six-point scale from 1 (*Disagree strongly*) to 6 (*Agree strongly*). Questions Q84–Q86 were measured on a four-point scale from 1 (*Unlikely*) to 4 (*Probable*). Questions Q88–Q91 were measured on a four-point scale from 1 (*I would not* *appreciate this development at all*) to 4 (*I would really appreciate this development*). Q41 was on a scale from 1 (*Never or almost never*) to 5 (*Daily or almost daily).* Q54 was on a scale from 1 (*Never*) to 6 (*When it is used by 95% to 100% of the people*). Finally, Q94 was on a scale from 1 (*All parts of the city must be accessible by car. Therefore, more car parking space should be provided*), 2 (*The number of parking spaces should stay as it is*), to 3 (*The number of parking spaces should be reduced to make more space available for other uses (e.g., pedestrians, bike parking, playgrounds or parks*). All items had a response option 'I prefer not to respond'. The survey was administered in English.

2.3.3. Analyses of responses

Descriptive statistics (i.e., means, standard deviations, distribution of responses) were calculated per questionnaire item, and the mean ratings of items that were measured on a scale from *Disagree strongly* to *Agree strongly* were compared. Next, a principal component analysis (PCA) was conducted on all questions that were measured on an ordinal scale (except for the questions on the instructions Q1–Q2 and the socio-demographic questions Q3–Q27, Q71) to investigate the major sources of variation in the items. For the PCA, missing data due to respondents selecting 'I prefer not to respond' were replaced with the value from the single 'nearest neighbor' variable (1NN), using Euclidean distance. According to Beretta and Santaniello (2016), 1NN imputation preserves the original variability of the data, which is why we selected this method instead of a multiple neighbors approach (kNN).

Spearman correlation coefficients were calculated between respondents' socio-demographics (Q3–Q27, Q71) and the PCA scores. These correlations were assessed in three ways: (1) across the whole sample of respondents, (2) across the respondents within each respondent's country, and then sample-size weighting the correlations across the countries, and (3) across the whole sample while partialling out (i.e., controlling for) the time to complete the survey and whether participants found the instructions clear (Q2). Note that the second (i.e., 'within-country') correlation coefficient is similar to the estimated fixed-effect coefficient when fitting a mixed-effects model to the data, with the respondents' country as grouping variable. The correlations between socio-demographics and PCA scores were deemed robust only if all three correlations were similar (i.e., all three correlations being 0.05 or higher, or -0.05 or lower). This three-fold approach to assessing correlations with socio-demographics was intended to protect against the ecological fallacy (i.e., national differences may contribute to first correlation, but not to the second) and response style (i.e., the third correlation statistically controls for how quickly people answer the survey and whether they found the instructions clear).

Finally, it was investigated whether the acceptance of driverless vehicles is associated with the countries' developmental status. Spearman rank-order correlation coefficients (ρ) were calculated between countries' GDP per capita and the countries' mean PCA scores. Only countries with at least 25 respondents were selected for this cross-national analysis (Kyriakidis et al., 2015). All analyses were conducted in MATLAB 2016a.

2.4. Results

2.4.1. Number of respondents and respondents' satisfaction

In total, 10,000 questionnaires were completed. Responses were gathered between April 13 and April 19, 2015. CrowdFlower enables participants to rate their satisfaction with the questionnaire. Respondents were overall satisfied with the survey, with a score of 4.0 on a scale from 1 (*very dissatisfied*) to 5 (*very satisfied*).

2.4.2. Data filtering

We applied strict data screening to enhance data quality. Participants were excluded if they indicated that they had not read the instructions (*n* = 107), if they reported a birth year yielding an age younger than 18 (*n* = 70) or older than 110 (*n* = 111) or if they did not indicate their age or gender (*n* = 156). This upper limit of age was selected as a reasonable maximum human lifespan (Dong et al., 2016). Only strings that contained a four-digit birth year were retained for calculating the participants' age.

Respondents were also excluded if their country of origin was not identified by CrowdFlower (*n* = 1), if they were affiliated with the same IP address (*n* = 172; the first response was kept, but subsequent items from the same IP address were removed), were faster than the fastest 5% (*n* = 497; see De Winter & Hancock, 2015 for rationale), had missing data due to database/recording errors (*n* = 24), or responded 'I prefer not to respond' or 'I don't know' to 9 or more questions (i.e., 10% of the questions) (*n* = 731). Furthermore, we excluded respondents (*n* = 848) who selected the same answer (*Disagree strongly, Disagree moderately, Agree moderately, or Agree strongly*) to the questions "I would feel comfortable in a vehicle without a steering wheel, gas or brake pedals" (Q44) and "I would not use a driverless vehicle because technology can sometimes fail" (Q59) as these questions have opposite meaning. This exclusion was performed to filter out respondents with an acquiescent response style. In total, 2,245 respondents were excluded, leaving 7,755 respondents from 116 countries in the analysis.

2.4.3. Descriptive statistics of the questionnaire items

The mean age of respondents was 32.49 years (*SD* = 10.53, Q4). 31.20% of the respondents were female, and 68.80% were male (Q3). 7,032 of 7,755 respondents answered the question about their net household income. Of those 7,032 respondents, 35% had a net monthly household income below $ 1,000, 23% between $ 1,000 and $ 1,599, 20% between $ 1,600 and $ 2,899, 11% between $ 2,900 and 3,999, 6% between $ 4,000 and $ 5,000, and 5% more than $ 5,000 (Q12).

Respondents lived on average 9.43 miles away from their workplace, training post, or school (*SD* = 15.56, median = 5, Q9), and on average had 1.34 vehicles in their household (*SD* = 0.86, Q15). Their most frequent mode of transport was "walking more than 500 meters per trip" (*M* = 3.96, Q22), the "conventional vehicle, as a driver or passenger" (*M* = 3.90, Q25), followed by "public transport for distances below and over 100 km per one way" (*M* = 2.91, 2.15; Q26–Q27), "cycling" (*M* = 2.14, Q23), and a "moped or motorcycle as a driver" (*M* = 1.76, Q24).

2.4.4. Domain-specific attitudes: Usefulness and ease of use

For usefulness (Q49, Q53), the higher rating was obtained for using a driverless vehicle for daily travel because it would be better and more convenient than existing travel (*M* = 4.48, Q49), and the lower for thinking that driverless vehicles would be more useful than existing travel (*M* = 4.35, Q53). For ease of use (Q50, Q52), the higher rating was obtained for thinking that learning to operate a driverless vehicle would be easy (*M* = 4.76, Q52), while the lower rating was obtained for thinking that driverless vehicles would be easier to use than existing travel (*M* = 4.46, Q50).

2.4.5. Transport-related attitudes: Satisfaction with daily travel and enjoyment of manual driving

For satisfaction with daily travel (Q28, Q31), the higher rating was obtained for being satisfied with the possibilities available to cover daily travel needs (*M* = 4.36, Q31), and the lower for being able to organize the day flexibly with public transport (*M* = 3.73, Q28). For enjoyment of manual driving (Q29, Q30, Q66, Q69), the highest rating was obtained for needing a vehicle to be flexible (*M* = 4.77, Q29), the lowest for liking to learn to drive vehicles that can exceed the speed of 300 km/h (*M* = 3.27, Q69).

2.4.6. Symbolic-affective attitudes: Pleasure and social influence

For pleasure (Q37, Q39), respondents gave the higher rating for thinking that they would enjoy taking a ride in a driverless vehicle (*M* = 4.90, Q37), and the lower for finding it important that driverless vehicles are aesthethic in terms of styling and design (*M* = 4.62, Q39). For social influence (Q60, Q63), respondents gave the higher rating for believing that people important to them would like it when they use driverless vehicles (*M* = 4.33, Q63), and the lower for liking to have their friends or family or other important people to them adopting the driverless vehicle before they do (*M* = 3.77, Q60).

2.4.7. Personality-related attitudes: Trust, liking of being in control, enjoyment of technology, knowledge of mobility, future orientation, wish for car-free future, skepticism

Similar mean ratings were also obtained for trusting driverless vehicles (3.80–4.36; Q44, Q56, Q58, Q64), liking of being in control (3.92–5.18; Q36, Q48, Q68, Q70), enjoyment of technology (4.00–4.99; Q73–Q75), knowledge of mobility (4.00–4.63; Q76–Q78, Q87), future orientation (3.22–4.14; Q83–Q86), wish for car-free future (1.83–4.22; Q88–Q94), and skepticism (3.48–4.38; Q42, Q57, Q59, Q65).

For trusting driverless vehicles, respondents gave the highest rating for trusting that a driverless vehicle can drive without their assistance (*M* = 4.36, Q56), whereas the lowest rating was obtained for trusting the driving skills of a driverless vehicle more than one’s own driving skills (*M* = 3.80, Q64).

The highest rating for liking of being in control and the highest overall mean rating was obtained for liking to have a stop button inside the driverless vehicle (*M* = 5.18, Q36), and the lowest rating for believing that when a driver is involved in an accident, (s)he did not drive properly (*M* = 3.92, Q68).

For skepticism, the highest rating was obtained for believing that there will always be accidents, even with driverless vehicles on the road (*M* = 4.38, Q65), and the lowest for not using a driverless vehicle because technology can sometimes fail (*M* = 3.48, Q59).

2.4.8. Intention to use driverless vehicles

For intention to use (Q38, Q40, Q43, Q51, Q80–Q82), the highest rating was obtained for using a driverless vehicle that is 100% electric (*M* = 5.09, Q38), and the lowest for preferring driverless vehicles even if they are more expensive than existing travel (*M* = 3.72, Q51).

2.4.9. Miscellaneous questions

For the miscellaneous items (Q62, Q67), the higher mean rating was obtained for environmental protection being crucial in the choice of transportation (*M* = 4.64, Q62), and the lower for believing that driving without accidents is mainly a matter of luck (*M* = 3.16, Q67).
In summary, the results indicate that driverless vehicles are regarded as fun, useful, and easy to use. Lower mean ratings, yet on the ‘agree’ end of the scale (i.e., > 3.5), were obtained for items relating to trusting those vehicles more than one’s own driving skills.

Table 1
*Means (M), standard deviations (SD), and distribution of questionnaire items on a scale from 1 (disagree strongly) to 6 (agree strongly), unless indicated otherwise**

Semantic content	**Item**	***M***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**
Liking of being in control	Q36. Would like to have button inside DV.	5.18	1.15	146	144	297	1299	1532	4296
Intention to use	Q38. Would use 100% electric DV.	5.09	1.20	200	168	301	1316	1804	3924
Enjoyment of technology	Q74. Fun to use electronic device.	4.99	1.10	79	179	402	1656	2143	3261
Pleasure	Q37. Think I would enjoy taking a ride in DV.	4.90	1.22	226	213	350	1610	2213	3114
Enjoy manual	Q29. Need vehicle to be flexible.	4.77	1.38	294	355	601	1539	1700	3230
Ease of use	Q52. Learning to operate DV would be easy for me.	4.76	1.18	162	218	536	2015	2228	2535
Intention to use	Q43. Would use 100% electric DV from train station to final destination.	4.72	1.25	256	227	506	1965	2217	2546
Enjoyment of technology	Q73. Rapidly and intuitively learn to handle unfamiliar electronic devices.	4.67	1.17	136	255	605	2201	2304	2210
Miscellaneous	Q62. Environmental protection crucial for transportation.	4.64	1.21	143	291	697	2267	1999	2312
Knowledge of mobility	Q75. Often think about how mobility in city could be improved.	4.63	1.22	163	320	681	2179	2110	2268
Pleasure	Q39. Would find it important that DVs are aesthetic in terms of styling and design.	4.62	1.21	201	263	601	2252	2286	2101
Intention to use	Q40. Would share DV with 6-8 fellow travelers.	4.48	1.29	296	343	752	2235	2192	1905
Usefulness	Q49. Would use DV for daily travel because would be better and more convenient.	4.48	1.28	289	329	754	2293	2168	1894
Ease of use	Q50. Think DV would be easier to use than existing travel.	4.46	1.28	273	328	849	2280	2118	1879
Enjoy manual	Q30. Driving is especially fun for me.	4.44	1.45	458	445	741	1899	1812	2263
Skeptical	Q65. There will always be accidents, even with DVs on the road.	4.38	1.27	227	434	908	2463	1976	1698
Trust	Q56. Trust that DV can drive without assistance from me.	4.36	1.25	280	370	872	2456	2280	1479
Satisfaction daily travel	Q31. Satisfied with possibilities available to cover daily travel needs.	4.36	1.28	272	442	886	2348	2189	1582
Usefulness	Q53. Think that DV would be more useful than existing travel.	4.35	1.30	308	391	948	2376	2033	1663

Liking of being in control	Q48. Would like to take over control from DV.	4.34	1.40	438	425	832	2314	1755	1940
Liking of being in control	Q70. Careful driver can prevent any accident on road.	4.33	1.40	322	600	1059	1865	1996	1886
Knowledge of mobility	Q87. Would like to use mobility flat-rate for mobility services in city.	4.33	1.12	191	296	731	3194	2036	1173
Social influence	Q63. People who are important to me would like it when I use DV.	4.33	1.18	221	328	896	2725	2193	1253
Intention to use	Q81. Would use SDVs together with passengers in public transport.	4.32	1.29	366	384	793	2505	2214	1453
Intention to use	Q80. Would like to buy SDV.	4.22	1.37	446	504	900	2452	1914	1504
Wish for car-free future	Q93. Roads be redesigned with bicycle lane that replaces car lane.	4.20	1.35	407	461	1077	2491	1741	1501
Trust	Q58. Trust DV to be safe and reliable in severe weather conditions.	4.15	1.34	384	532	1212	2346	1891	1354
Future orientation	Q83. SDVs will be legally accepted as independent drivers.	4.14	1.24	345	414	1122	2816	1935	1045
Intention to use	Q82. Would like to use SDVs in carsharing scheme.	4.09	1.27	402	492	1013	2807	1950	975
Miscellaneous	Q61. Prefer to keep physical distance between myself and strangers.	4.09	1.32	369	601	1193	2538	1797	1201
Trust	Q44. Would feel comfortable in vehicle without steering wheel, gas or brake pedals.	4.01	1.43	563	587	1388	2232	1581	1368
Knowledge of mobility	Q76. Friends and acquaintances often consult me on mobility options.	4.00	1.30	401	656	1208	2633	1883	929
Enjoyment of technology	Q72. Friends and acquaintances often ask for advice, when they have technical problem.	4.00	1.31	450	655	1066	2719	1886	921
Knowledge of mobility	Q78. Often provide others with information regarding mobility options.	4.00	1.30	396	662	1207	2670	1868	916
Knowledge of mobility	Q77. Often first to make people aware of new mobility.	4.00	1.33	428	656	1267	2542	1798	1014
Liking of being in control	Q68. When driver is involved in accident, (s)he did not drive properly.	3.92	1.41	471	877	1415	2100	1748	1099
Wish for car-free future	Q92. Would like to live in car-free neighbourhood.	3.88	1.48	703	730	1330	2236	1471	1238
Trust	Q64. Would trust driving skills of DV more than own driving skills	3.80	1.47	732	803	1446	2060	1637	1019
Skeptical	Q42. DVs would take away the pleasure or enjoyment.	3.78	1.42	693	780	1340	2497	1477	920
Skeptical	Q57. Would feel uncomfortable entrusting safety of family to DV.	3.78	1.33	492	830	1621	2503	1461	806

Social influence	Q60. Would like to have friends or family adopt DV before I do.	3.77	1.30	520	740	1592	2676	1450	692
Intention to use	Q54. Indicate when you would use DV. Only most relevant option.*	3.74	1.15	221	768	2228	2555	1408	507
Satisfaction daily travel	Q28. Can organize my day flexibly with public transport.	3.73	1.49	884	821	1149	2308	1638	883
Intention to use	Q51. Even if more expensive than existing travel, would prefer DVs.	3.72	1.45	756	850	1537	2170	1504	904
Intention to use	Q41. Indicate when you would use DV. Only most relevant option.*	3.67	1.27	633	894	1399	2163	2573	
Skeptical	Q59. Would not use DV because technology can fail.	3.48	1.32	636	1128	1995	2429	946	594
Future orientation	Q86. SDVs will be normal part of everyday mobility.*	3.43	0.79	231	665	2102	4242		
Enjoy manual	Q66. Often feel like racing driver when driving manually.	3.40	1.55	1314	932	1388	2036	1250	687
Wish for car-free future	Q91. In cities, EVs will completely replace combustion engines within next 20-30 years.*	3.37	0.82	307	598	2284	3845		
Future orientation	Q84. SDVs will mostly be shared vehicles.*	3.36	0.85	338	671	2050	3796		
Enjoy manual	Q69. Like to learn to drive vehicles that exceed speed of 300 km/h.	3.27	1.72	1836	1011	1164	1604	1077	1014
Future orientation	Q85. SDVs will mostly be privately owned.*	3.22	0.93	426	1133	1870	3516		
Wish for car-free future	Q90. Roads in cities will be redesigned to privilege non-motorized travel.*	3.21	0.88	411	913	2590	3253		
Miscellaneous	Q67. Driving without accidents is mainly matter of luck.	3.16	1.53	1439	1445	1417	1849	989	575
Wish for car-free future	Q88. Many car-free neighborhoods with exceptional car use and no parking space. *	2.94	0.96	672	1258	2563	2226		
Wish for car-free future	Q89. City centers closed to car-traffic.*	2.89	0.99	789	1399	2439	2242		
Wish for car-free future	Q94. Think of your own neighbourhood. Which of following statements do you agree to most? Select only one option.*	1.83	0.82	3375	2302	2078			
Liking of being in control	Q46. Mind being transported by DV supervised by ECR?*	1.58	0.49	3136	4390				

Note. (E)DV = (electric) driverless vehicle, SDV = self-driving vehicle, ECR = external control room

2.4.10. Principal component analysis of the questionnaire items: General acceptance component

A PCA was performed of the responses on the 58 items that were measured on an ordinal scale (i.e., Q28–Q31, Q36–Q44, Q46, Q48–Q54, Q56–Q70, Q72–Q78, Q80–Q94). The Kaiser-Meyer-Olkin (KMO) index of sampling adequacy was 0.941, indicating that the data are suitable for factor-analytic purposes (Kaiser, 1970).

Based on the scree plot (Fig. 1), and based on the interpretability of the loadings, we decided to retain one general component. This component was interpreted as 'general acceptance'. The Cronbach alpha for the 58 variables was 0.899, and 0.928 if selecting only the 32 from 58 variables that loaded higher than 0.4, a common cut-off value (Peterson, 2000). The participants' scores on the component were standardized, so that the mean was equal to zero and the standard deviation was equal to 1 (min = -4.71, max = 2.36, N = 7,755).

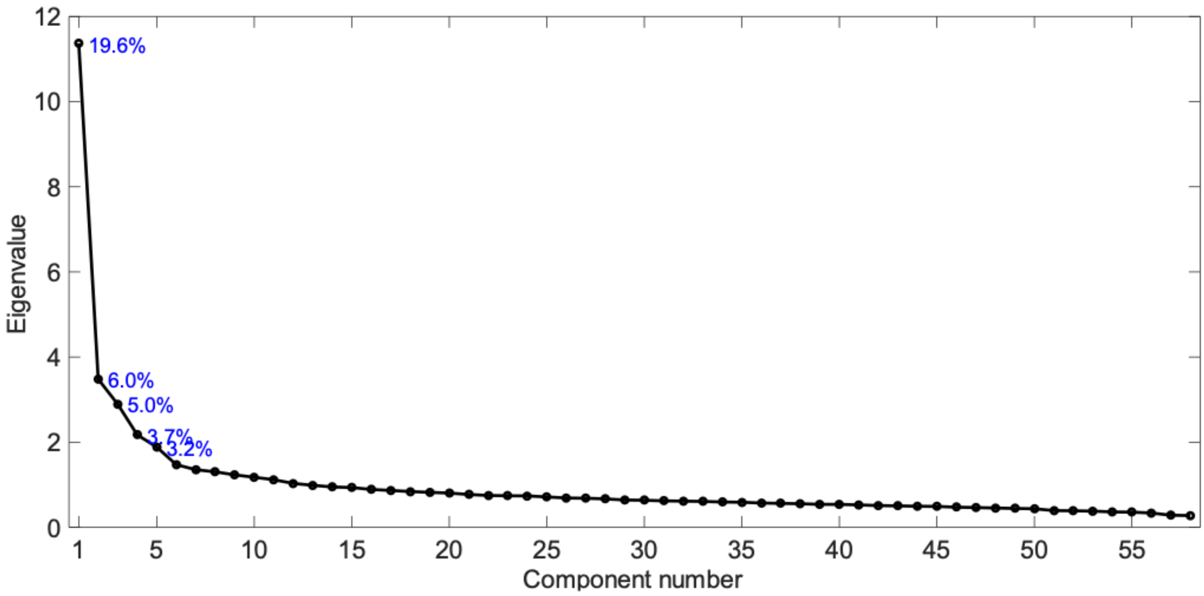

Figure 2. Eigenvalues of the correlation matrix sorted in descending order ('scree plot'). Also shown are the percentages of variance explained (being proportional to the eigenvalue) for the first five components. It can be seen that one dominant component emerged, explaining 19.6% of the variance.

Table 2 provides an overview of the 58 items and their corresponding loadings on the general acceptance component. Loadings are referred to as negative if smaller than 0, small if between 0 and 0.40, medium if between 0.40 and 0.60, and high if larger than 0.60.

- Negative and small mean loadings were obtained for skepticism towards driverless vehicles (-0.35 to -0.08; Q42, Q57, Q59, Q65; mean loading = -0.16)
- Small mean loadings were obtained for items capturing the satisfaction with daily travel (0.11–0.22; Q28, Q31; mean loading = 0.16), enjoyment of manual driving (0.16–0.19; Q29–Q30, Q66, Q69; mean loading = 0.17) and the liking of being in control (0.08–0.31; Q36, Q46, Q48, Q68, Q70; mean loading = 0.20).
- Small to medium mean loadings were obtained for the wish for a car-free future (0.14–0.47; Q88–Q94; mean loading = 0.37), future orientation (0.24–0.56; Q83–Q86; mean loading = 0.39) and enjoyment of technology (0.33–0.46; Q72–Q74; mean loading = 0.39). Medium mean loadings were obtained for items measuring social influence (0.29–0.66; Q60, Q63; mean loading = 0.47), intention to use (0.11–0.65; Q38, Q40–Q41, Q43, Q51,Q54, Q80-Q81; mean loading = 0.52), knowledge of mobility-related developments

(0.49–0.58; Q75–78, Q87; mean loading = 0.53), pleasure of driverless vehicles (0.46–0.67; Q39, Q37; mean loading = 0.57), trust in driverless vehicles (0.49–0.65; Q44, Q56, Q58, Q64; mean loading = 0.57), and ease of use of driverless vehicles compared to respondents' existing form of travel (0.49–0.71; Q50, Q52; mean loading = 0.60).

- High mean loadings were obtained for items pertaining to the perceived usefulness of driverless vehicles (0.72–0.73; Q49, Q53; mean loading = 0.73).

We have also done a supplementary analysis in which we retained five components instead of one component, because the scree plot suggests that, although a single dominant component exists, a five-component solution may also be appropriate. After oblique rotation of the loadings (Promax, with kappa = 4), the five components were interpreted as: 1) General acceptance (PCA-1), 2) Thrill seeking (PCA-2), 3) Wanting to be in control manually (PCA-3), 4) Supporting a car-free environment (PCA-4), and 5) Being comfortable with technology (PCA-5). The loadings of the five-component solution are shown in Table 2. The Cronbach's alpha for these five components (after selecting the items that loaded higher than 0.4) were 0.916, 0.587, 0.580, 0.763, and 0.800, indicating that the first component is most consistent.

Table 2

Principal component loadings on the general acceptance component (GAC)

Semantic content	**Item**	**GAC**		**PCA-1**	**PCA-2**	**PCA-3**	**PCA-4**	**PCA-5**
Usefulness	Q49. Would use DV for daily travel because would be better and more convenient.	**0.73**		**0.80**	0.08	0.03	-0.03	-0.05
Usefulness	Q53. Think that DV would be more useful than existing travel.	**0.72**		**0.75**	0.15	-0.03	-0.01	-0.01
Ease of use	Q50. Think DV would be easier to use than existing travel.	**0.71**		**0.77**	0.14	-0.01	-0.02	-0.04
Ease of use	Q52. Think that learning to operate DV would be easy for me.	**0.49**		**0.43**	-0.12	0.30	-0.08	0.11
Pleasure	Q37. Think I would enjoy taking a ride in DV.	**0.67**		**0.79**	-0.11	0.18	-0.06	-0.11
Pleasure	Q39. Would find it important that DVs are aesthetic.	**0.46**		**0.43**	0.12	0.36	-0.05	-0.03
Social influence	Q63. People who are important to me would like it when I use DV.	**0.66**		**0.57**	0.20	0.02	0.03	0.09
Social influence	Q60. Would like to have friends or family adopt DV before I do.	0.29		0.28	**0.49**	0.21	-0.02	-0.13
Trust	Q56. Trust that DV can drive without assistance from me.	**0.65**		**0.75**	-0.03	-0.03	-0.07	-0.02
Trust	Q58. Trust DV to be safe and reliable in severe weather conditions.	**0.58**		**0.64**	0.18	-0.11	-0.07	0.02
Trust	Q44. Would feel comfortable in vehicle without steering wheel, gas or brake pedals.	**0.56**		**0.65**	0.10	-0.18	-0.02	-0.03
Trust	Q64. Would trust driving skills of DV more than own driving skills.	**0.49**		**0.52**	0.34	-0.22	0.08	-0.08
Intention to use	Q80. Would like to buy SDV.	**0.65**		**0.62**	0.10	-0.03	-0.02	0.09
Intention to use	Q38. Would use 100% electric DV.	**0.61**		**0.69**	-0.19	0.30	0.01	-0.15
Intention to use	Q43. Would use 100% EDV from train station to final destination.	**0.59**		**0.67**	-0.16	0.20	-0.02	-0.10
Intention to use	Q81. Would use SDVs together with passengers in public transport.	**0.59**		**0.53**	0.05	-0.06	0.07	0.06
Intention to use	Q82. Would like to use SDVs in carsharing scheme.	**0.57**		**0.47**	0.18	-0.08	0.06	0.13

Intention to use	Q51. Even if more expensive than existing travel, would prefer DVs.	**0.55**		**0.51**	**0.42**	-0.12	-0.03	0.08
Intention to use	Q41. Indicate when you would use DV. Only most relevant option.	**0.53**		**0.60**	-0.17	-0.09	-0.04	0.04
Intention to use	Q40. Would share DV with 6-8 fellow travelers with same route like.	**0.52**		**0.51**	0.00	0.11	0.03	-0.03
Intention to use	Q54. Indicate when you would use DV. Only most relevant option.	0.11		0.17	0.26	0.14	0.00	-0.20
Knowledge of mobility	Q87. Would like to use mobility flat-rate for mobility services in city.	**0.58**		0.38	-0.05	0.12	0.17	0.13
Knowledge of mobility	Q75. Often think about how mobility in city could be improved.	0.56		0.19	-0.07	0.12	0.13	**0.42**
Knowledge of mobility	Q78. Often provide others with information regarding mobility options.	**0.52**		-0.02	0.27	-0.10	0.03	**0.78**
Knowledge of mobility	Q77. Often first to make people aware of new mobility options.	**0.51**		-0.05	0.28	-0.12	0.02	**0.80**
Knowledge of mobility	Q76. Friends and acquaintances often consult me on mobility options.	**0.49**		-0.06	0.26	-0.08	0.02	**0.78**
Future orientation	Q83. SDVs will be legally accepted as independent drivers.	**0.56**		**0.52**	0.14	-0.10	0.03	0.08
Future orientation	Q86. SDVs will be normal part of everyday mobility.	**0.45**		0.31	0.04	0.02	0.23	0.00
Future orientation	Q84. SDVs will mostly be shared vehicles.	0.31		0.16	0.04	0.10	0.23	-0.03
Future orientation	Q85. SDVs will mostly be privately owned.	0.24		0.12	0.27	0.08	0.12	-0.02
Wish for car-free future	Q93. Roads be redesigned with bicycle lane that replaces car lane.	**0.47**		0.05	-0.01	0.04	**0.58**	0.08
Wish for car-free future	Q91. In cities, EVs will completely replace combustion engines within next 20-30 years.	0.43		0.08	-0.19	0.04	**0.60**	-0.02
Wish for car-free future	Q90. Roads and streets in cities will be redesigned to privilege non-motorized travel.	0.41		-0.06	-0.07	-0.04	**0.76**	0.01
Wish for car-free future	Q92. Would like to live in car-free neighbourhood.	**0.41**		0.01	-0.04	-0.04	**0.67**	0.00
Wish for car-free future	Q88. Many car-free neighborhoods with exceptional car use and no parking space.	0.39		-0.07	0.10	-0.10	**0.72**	0.04
Wish for car-free future	Q89. City centers closed to car-traffic.	0.32		-0.15	0.02	-0.10	**0.78**	-0.01
Wish for car-free future	Q94. Think of your own neighbourhood. Which of following statements do you agree to most? Select only one option.	0.14		-0.08	-0.27	-0.13	**0.46**	0.00
Enjoyment of technology	Q74. Fun to use electronic device.	**0.46**		0.19	-0.34	0.31	0.00	0.37
Enjoyment of technology	Q73. Rapidly and intuitively learn to handle unfamiliar electronic devices.	0.39		0.04	-0.27	0.22	-0.02	**0.53**
Enjoyment of technology	Q72. Friends and acquaintances often ask for advice, when they have technical problem.	0.33		-0.12	0.00	0.03	-0.03	**0.69**
Liking of being in control	Q70. Careful driver can prevent any accident on road.	0.31		0.08	0.19	0.20	0.09	0.15

Liking of being in control	Q36. Would like to have button inside DV.	0.27		0.28	-0.26	**0.58**	-0.01	-0.16
Liking of being in control	Q68. When driver is involved in accident, (s)he did not drive properly.	0.22		0.01	0.32	0.09	0.10	0.12
Liking of being in control	Q46. Mind being transported by DV supervised by ECR?	0.12		0.01	0.20	-0.04	0.06	0.08
Liking of being in control	Q48. Would like to take over control from DV when want this.	0.08		-0.02	0.17	**0.53**	-0.06	-0.03
Enjoy manual	Q30. Driving is especially fun for me.	0.19		0.01	0.19	**0.48**	-0.16	0.19
Enjoy manual	Q66. Often feel like racing driver when driving manually.	0.18		-0.05	**0.60**	0.10	-0.07	0.24
Enjoy manual	Q29. Need vehicle to be flexible.	0.17		0.19	-0.01	**0.43**	-0.22	0.04
Enjoy manual	Q69. Like to learn to drive vehicles that exceed speed of 300 km/h.	0.16		-0.05	**0.45**	0.05	-0.13	0.32
Satisfaction daily travel	Q28. Can organize my day flexibly with public transport.	0.22		0.12	0.11	0.10	0.22	-0.11
Satisfaction daily travel	Q31. Satisfied with possibilities available to cover daily travel.	0.11		0.05	0.13	**0.47**	0.01	-0.13
Skeptical	Q42. DVs would take away the pleasure or enjoyment.	-0.08		-0.26	0.30	**0.42**	-0.03	0.06
Skeptical	Q65. There will always be accidents, even with DVs on the road.	-0.09		-0.17	-0.10	**0.41**	0.07	-0.10
Skeptical	Q57. Would feel uncomfortable entrusting safety of family to DV.	-0.13		-0.34	0.29	0.39	0.10	-0.01
Skeptical	Q59. Would not use DV because technology can fail.	-0.35		**-0.58**	0.30	0.34	0.13	-0.02
Miscellaneous	Q61. Prefer to keep physical distance between myself and strangers.	-0.03		-0.09	0.19	0.37	0.05	-0.15
Miscellaneous	Q62. Environmental protection crucial for transportation.	**0.50**		0.26	0.06	0.18	0.21	0.10
Miscellaneous	Q67. Driving without accidents is mainly matter of luck.	0.05		-0.03	**0.54**	0.00	0.00	0.00

Note. DV = driverless vehicle, SDV = self-driving vehicle. The general acceptance component is the first principal component. PCA-1, PCA-2, PCA-3, PCA-4, and PCA-5 are the first five principal components, after Promax rotation. Component loadings of magnitude > 0.40 are listed in boldface.

2.4.11. Correlations between socio-demographic characteristics and the general acceptance score

Table 3 shows the correlations between socio-demographic characteristics and the general acceptance score. It can be seen that the survey time and whether the respondents found the survey instructions clear (Q2) correlated relatively strongly with the general acceptance score (ρ = 0.20 and 0.22, respectively). Hence, these two variables were partialled out. These partial correlations were similar to the zero-order correlations (Table 3).

Furthermore, it can be seen that whole-sample and within-country correlations were similar, but not for all items. For example, across the whole sample a near-zero correlation was found between respondents' income (Q12) and general acceptance (ρ = -0.01), while within countries this correlation was slightly positive (ρ = 0.06). Here, it is possible that the large national differences in income masked the positive correlation between income and general acceptance within nations.

Overall, the correlations between socio-demographic characteristics and general acceptance component scores were small (< 0.20). The strongest correlation with the general acceptance score was found with the difficulty of finding a parking place (ρ = 0.17, Q16) and the frequency of use of public transport (< 100 km) (ρ = 0.14, Q26). Having a monthly pass or annual travel card for public transport (ρ = 0.11, Q19), living in a city environment (ρ = 0.12, Q7), frequency of walking more than 500 m per trip (ρ = 0.08, Q22), frequency of cycling (ρ = 0.06, Q23), and distance of living from workplace, training post, or school (ρ = 0.07, Q9) also correlated with general acceptance. No robust correlations (i.e., stronger than 0.05 for all three correlation types) were found between age (Q4) and gender (Q3), and the general acceptance score. Males had a higher general acceptance score than females across the whole sample, but this effect was not statistically significant within countries.

Table 3

Means (M) and Spearman rank-order correlations (ρ) between socio-demographic characteristics and the general acceptance score (GAC) for the whole sample, for respondents within countries, and (3) for the whole sample after partialling out the time to complete the survey and whether respondents found instructions clear (N = 7,755).

Item	***M***	***ρ* with GAC** (whole sample)	***ρ* with GAC** (within country)	***ρ* with GAC** (survey time & instruct-tions clear partialled out)
Survey time ranking 0–1	0.54	0.20	0.14	—
Survey start time	—	0.05	0.02	0.05
Survey end time	—	0.05	0.02	0.05
Q2. The definitions given in the instructions are clear to me.	5.36	0.22	0.26	—
Q3. What is your gender? 1 (female), 2 (male)	1.69	0.07	0.01	0.09
Q4. Year of birth (converted to age) (open question)	32.49	0.02	0.08	-0.02
Q7. Which of the following possibilities describe your current residential situation the most? 1 (Outside city in house in countryside) to 4 (In apartment in immediate city centre)	2.95	0.12	0.08	0.10
Q8. Number of people in household between 14 and 17 years (open question)	0.27	0.05	0.03	0.06
Q8. Number of people in household between 6 and 13 years (open question)	0.36	0.04	0.02	0.04
Q8. Number of people in household younger than 6 years (open question)	0.35	0.04	0.02	0.04
Q8. Number of people older than 18 years old (open question)	2.67	0.09	0.01	0.08
Q9. Distance between home and workplace, training post or school (in miles) (open question)	9.43	0.07	0.06	0.08
Q12. Net monthly household income 1 (< $ 1,000) to 6 (> $ 5,000)	2.45	-0.01	0.06	-0.01
Q13. Having valid driver license 1 (No), 2 (Yes)	1.80	0.03	0.05	0.02
Q15. Number of vehicles in household 1 (0), 2 (1), 3 (2), 4 (3), 5 (> 3)	1.34	0.00	0.01	-0.01
Q16. Difficulty of finding parking space 1 (Not at all difficult) to 4 (Very difficult)	2.52	0.17	0.12	0.16

Q17. Annual driving mileage as driver or passenger (in miles) (open question)	8,190	-0.00	0.07	-0.04
Q18. Involvement in accidents in last three years 1 (0), 2 (1), 3 (2), 4 (3), 5 (4), 6 (5), 7 (> 5)	0.43	0.02	-0.01	0.04
Q19. Having monthly pass or annual travel card for public transport 1 (No), 2 (Yes)	1.34	0.11	0.07	0.13
Q20. Distance between home and nearest public transport stop (in min.) 1 (< 5 min.), 2 (5–10 min.), 3 (10–20 min.), 4 (20–30 min.), 5 (> 30 min.)	1.93	0.03	0.01	0.05
Q21. Number of carsharing memberships 1 (0), 2 (1), 3 (2), 4 (> 2)	0.22	0.03	0.01	0.08
Q22. Frequency of walking more than 500 meters per trip 1 (Never or almost never) to 5 (Daily or almost daily)	3.96	0.08	0.08	0.07
Q23. Frequency of cycling 1 (Never or almost never) to 5 (Daily or almost daily)	2.14	0.06	0.06	0.09
Q24. Frequency of using moped or motorcycle as driver 1 (Never or almost never) to 5 (Daily or almost daily)	1.76	0.08	0.01	0.11
Q25. Frequency of using conventional vehicle as driver or passenger 1 (Never or almost never) to 5 (Daily or almost daily)	3.90	0.08	0.07	0.05
Q26. Frequency of using light transit (< 100 km per one way) 1 (Never or almost never) to 5 (Daily or almost daily)	2.91	0.14	0.09	0.15
Q27. Frequency of using public transport (> 100 km per one way) 1 (Never or almost never) to 5 (Daily or almost daily)	2.15	0.10	0.03	0.14
Q71. Severity of motion sickness 1 (I do not experience motion sickness), 2 (Moderate), 3 (Severe)	1.70	-0.09	-0.08	-0.05

Note. For a sample size of 7,755, correlations of 0.03 and higher, or -0.03 and lower are statistically significantly different from zero, $p < 0.01$.

2.4.12. National differences in the general acceptance score

This section presents results from 7,188 respondents from 43 countries with 25 or more respondents. The three countries with the highest GDP per capita were the USA ($ 52,980), Canada ($ 52,305), and the Netherlands ($ 50,793), whereas the three countries with the lowest GDP per capita were India ($ 1,455), Pakistan ($ 1,282), and Bangladesh ($ 954).

We found that the developmental status of the respondents' country (GDP per capita) was predictive of the countries mean general acceptance score (ρ = -0.48, n = 43; Fig 2). For example, respondents from higher-income countries gave more negative ratings to intention to use (e.g., Q51 'Even if it were more expensive than my existing form of travel, I would prefer driverless vehicles to my existing form of travel', ρ = -0.64), the perceived effectiveness (e.g., Q50, 'I think driverless vehicles would be easier to use than my existing form of travel', ρ = -0.57), and pleasure of driverless vehicles (e.g., Q39, 'I would find it important that driverless vehicles are aesthetic in terms of styling and design', ρ = -0.57).
As a validity check of the self-reports, we observed that the mean self-reported income (Q12) correlated strongly with GDP per capita (ρ = 0.71, n = 43), whereas the median self-reported annual mileage (Q17) correlated strongly with GDP per capita on a national level (ρ = 0.71, n = 43; Fig 3).

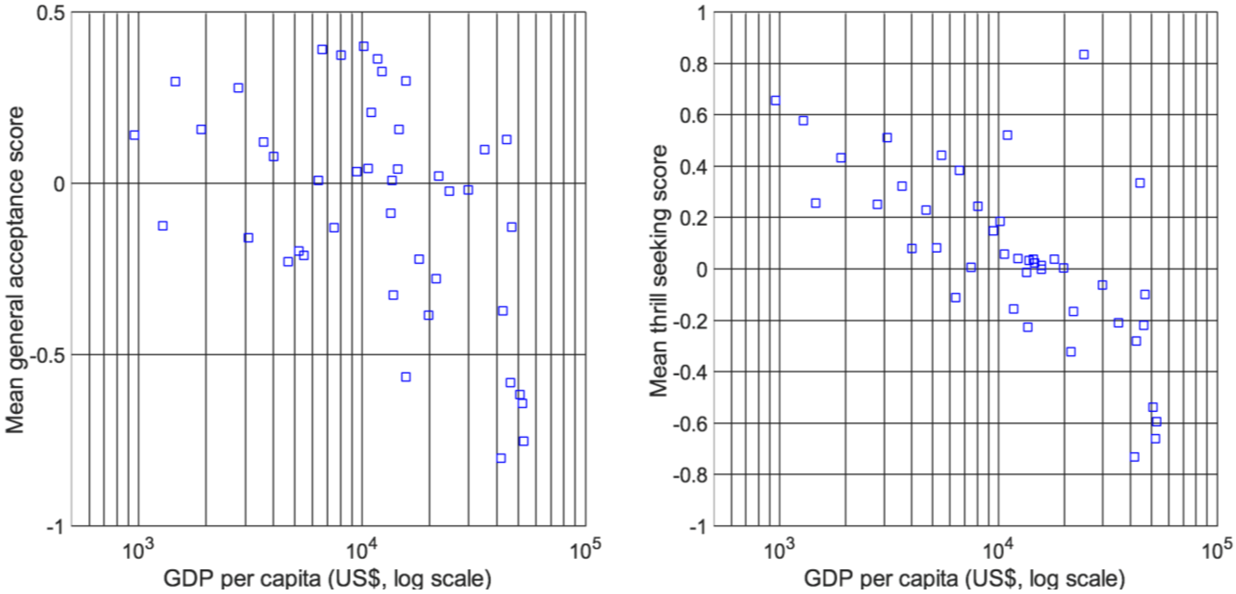

Figure 3. Correlation between countries' gross domestic product (GDP) per capita and participants' mean general acceptance score (left) and participants' mean thrill seeking score (right). Each marker represents a country with 25 or more respondents (*n* = 43).

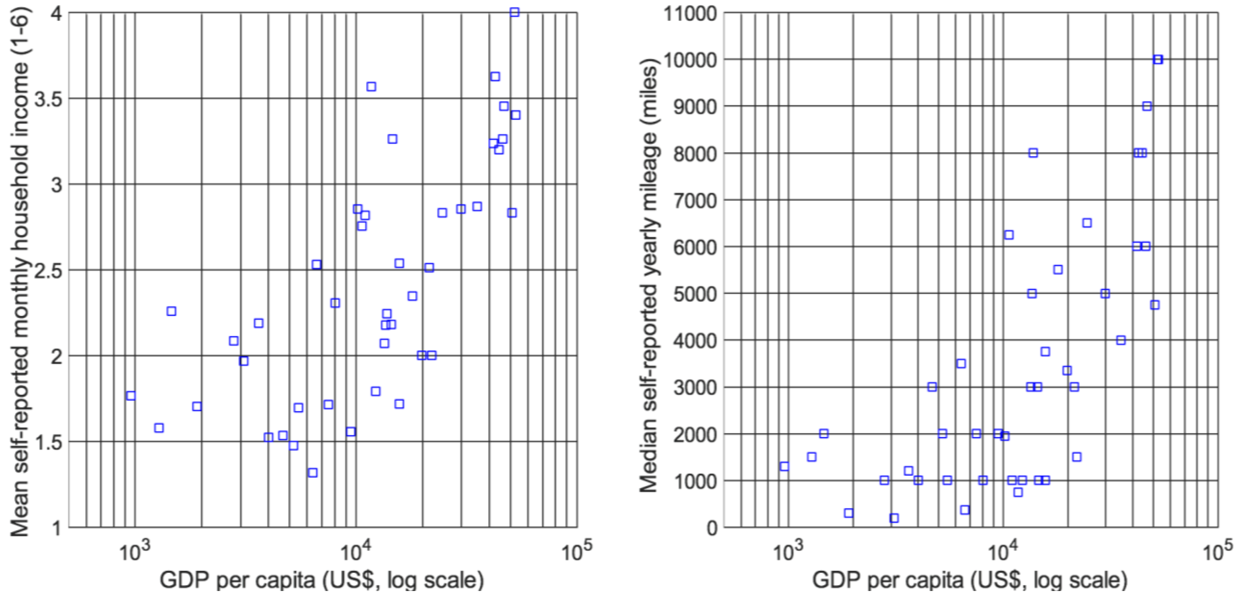

Figure 4. Correlation between countries' gross domestic product (GDP) per capita and participants' mean self-reported net household income (left) and participants' median self-reported yearly mileage (right). Each marker represents a country with 25 or more respondents (*n* = 43).

Table 4 shows cross-national correlations for a number of additional variables (selected from De Winter & Dodou, 2016). It can be seen that the general acceptance score not only correlates substantially with GDP per capita but also with other developmental indexes, including national performance in educational tests (Rindermann, 2007; ρ = -0.60), average life expectancy in 2013 (World Bank, 2015; ρ = -0.43), motor vehicle density (World Bank, 2015; ρ = -0.59), median age in 2014 (Central Intelligence Agency, 2015; ρ = -0.52), and road traffic death rate per 100,000 population (World Health Organization, 2015; ρ = 0.56). The second component (i.e., thrill seeking) correlates negatively (ρ = -0.72; see Fig. 2, right) with GDP per capita, meaning that people in lower income countries are more thrill-seeking. Also, respondents in higher-income countries reported to be less supportive of a car-free environment (ρ = -0.44) and to be less comfortable with technology (ρ = -0.44).

Table 4
Spearman correlation matrix at the national level (n = 43)

	1	2	3	4	5	6	7	8	9	10	11
1. General acceptance score											
2. PCA-1 score (General acceptance)	0.98										
3. PCA-2 score (Thrill seeking)	0.50	0.41									
4. PCA-3 score (Wanting to be in control manually)	0.04	0.05	-0.32								
5. PCA-4 score (Supporting a car-free environment)	0.82	0.78	0.38	0.10							
6. PCA-5 score (Being comfortable with technology)	0.92	0.88	0.55	-0.04	0.72						
7. Road traffic death rate per 100,000 population	0.56	0.52	0.67	-0.22	0.26	0.58					
8. Gross domestic product (GDP) per capita	-0.48	-0.42	-0.72	0.21	-0.44	-0.44	-0.58				
9. National performance in educational tests	-0.60	-0.56	-0.78	0.35	-0.39	-0.67	-0.71	0.66			
10. Average life expectancy	-0.43	-0.37	-0.70	0.16	-0.25	-0.45	-0.67	0.82	0.67		
11. Motor vehicle density	-0.59	-0.53	-0.86	0.27	-0.45	-0.60	-0.71	0.88	0.81	0.81	
12. Median age	-0.52	-0.45	-0.79	0.11	-0.25	-0.55	-0.73	0.60	0.73	0.66	0.80

Note. The general acceptance score is the first principal component score. PCA-1, PCA-2, PCA-3, PCA-4, and PCA-5 are the scores for the first five principal components, after Promax rotation.

2.5. Discussion

2.5.1. Main results at the individual level

A variety of studies have previously examined the acceptance of automated vehicles. However, there is limited knowledge on the acceptance of automated vehicles without steering wheel, and brake and gas pedals across countries. The present study surveyed 7,755 respondents from 116 countries on their acceptance of driverless vehicles, attitudes towards technology, knowledge of mobility-related developments, and socio-demographic characteristics, using a 94-item online questionnaire.

We found that respondents considered driverless vehicles easy to use and convenient (Q49, Q50, Q52). Furthermore, respondents could imagine using 100% electric driverless vehicles in connection to public transport (Q43). The perceived enjoyment of taking a ride in driverless vehicles was also rated positively by respondents (M = 4.90/6, Q37). This corresponds with Nordhoff et al. (2017), who found that respondents strongly agreed with the statement that the driverless vehicle was fun and enjoyable after having taken a ride in the vehicle (M = 5.40/6). Our respondents gave the highest rating (M = 5.18/6, Q36) to being able to take over control from a driverless vehicle by a button inside the vehicle to stop it, which indicates that participants want to be able to retain some degree of control over the driverless vehicle. This finding is in line with Schoettle and Sivak (2015) who found that 96.2% of respondents preferred the availability of vehicle controls.

By means of a PCA, we reduced the scores on all questionnaire items into one general component of acceptance. A general acceptance component for driverless vehicles is a novel idea, which could move research on the acceptance of driverless vehicles in a new direction. The decision to retain one component may come at a price of oversimplification. However, we argue that the general acceptance component is a parsimonious reflection of the diverse items that concern acceptance of driverless vehicles. Also, the single component is in accordance with the percentage of variance explained by the components (scree plot), and was clearly interpretable. The notion of a single factor or component has also been proposed in various psychological domains with the general intelligence factor and the general personality factor being notable examples (Jensen, 1998; Musek, 2007). Future studies should explore the hierarchical structure of the acceptance component. Thus, while we argue that a single acceptance component exists at the top of the hierarchy, the existence of lower-level constructs is also likely. While the current general acceptance component is mainly an assembly of attitudinal constructs (e.g., knowledge of mobility, wish for car-free future) and behavioral beliefs (e.g., pleasure, social influence), the role of further entities such as values or norms (e.g., economic or pro-environmental attitudes; Steg & Vlek, 2009) could be investigated.

High mean loadings (> 0.60) on the general acceptance component were obtained for perceived usefulness. This aligns with the UTAUT model (Venkatesh et al., 2003), which found that usefulness ('performance expectancy') is a main determinant of the acceptance of driverless vehicles. Medium mean loadings (~0.5) occurred for social influence, trust, and intention to use. These findings support the role of social influence, intention to use (Madigan et al., 2016) and trust (Choi & Ji, 2015) as determinants of the acceptance of driverless vehicles.

The correlations between socio-demographic characteristics and general acceptance scores were small (< 0.20), which is in agreement with studies examining the influence of socio-demographics on pro-environmental behaviour (Stern, 2000) or with acceptance research on wind energy (Rand & Hoen, 2017). However, the small correlations were interpretable: The strongest correlation was found for the difficulty of finding a parking place, which is consistent with the literature on acceptance of transport-related measures (e.g., Steg & Vlek, 1997; Rienstra et al., 1999). The difficulty of finding a parking place may be indicative of the severity of transport-related problems and could therefore be a factor that influences people's willingness to accept driverless vehicles as a solution to this problem. The present study further found that living in the city and frequency of public transport use were positively correlated with the general acceptance score. These positive correlations may be explained because the driverless shuttle as depicted in the survey (Fig. 1) is a form of public transport, and some people are more accustomed to using public transport and sharing space with strangers than others. In summary, our findings indicate that socio-demographic characteristics are less influential than domain-specific attitudes (e.g., performance expectancy) in predicting self-reported acceptance of driverless vehicles.

2.5.2. Main results at the national level

The countries' mean general acceptance score was negatively correlated with national GDP per capita and other developmental indexes (e.g., average life expectancy, motor vehicle density). In an additional analysis, we retained five instead of one component (Table 2), and we observed substantial negative correlations between countries' GDP per capita and the mean thrill-seeking score, and between GDP per capita and the mean score for supporting a car-free environment (Table 4). These national differences may reflect national differences in thrill-seeking personality, or effects of differences in road infrastructure (see also De Winter & Dodou, 2016). For example, low-income countries suffer more from transport-related problems (Forjuoh, 2003; World Health Organization, 2015), which may make technological solutions and a car-free infrastructure in cities appealing for people living in these countries. It is recommended for future research to examine the mechanisms that explain the national differences in the acceptance of driverless vehicles. The relationships between the general acceptance component, and the four additional components, as well as with other variables identified in this study could be more closely examined in confirmatory studies using multiple well-defined scales (e.g., sensation seeking scale by Zuckerman et al., 1978, in addition to our thrill-related items) and multivariate analyses (e.g., structural equation modeling).

Our study revealed differences between within-country and across-countries correlations. For example, the correlation between gender and the general acceptance scores was stronger for males across countries than within countries. This can be explained by a confounding effect, in the sense that the lower-income countries contained a relatively high proportion of males (ρ = -0.49, n = 43, Q2, see supplementary material), and respondents in lower-income countries were more accepting of driverless cars. We recommend that future research makes a distinction between within-country and between-country effects.

2.5.3. Study limitations

Although it is important to study the acceptance before the technology is commercially available, the respondents did not physically get to see driverless vehicles, which may bias results. For example, it is possible that the respondents had overly positive attitudes that may have been nurtured by the portrayal of automated vehicles in the media.

Second, the survey instructions did not include a reference to the capabilities of the driverless vehicle, nor its speed. Current prototypes of driverless vehicles drive at a speed of 8 to 20 km/h (Nordhoff et al., 2017). It can be assumed that these speeds are too slow for integrating these vehicles into traffic without jeopardizing traffic flow efficiency or the acceptance by potential users.

Third, the crowdsourcing participants are not necessarily representative of the general population as they younger and more highly educated compared to the general population (De Winter et al., 2015). Future research should more closely examine the effects in representative cross-national populations, using gender and age-stratified samples.

Fourth, the survey was conducted in April 2015, meaning that the possibility exists that our data are not representative of today's public opinion, for example due to changes in media coverage about automated vehicles. Abraham et al. (2018) found that respondents were less comfortable with self-driving vehicles than a sample from one year ago. On the other hand, self-driving vehicles have not been commercialized yet, but are only used as part of various experiments and demonstration projects worldwide. Therefore, there has been little opportunity for respondents to actually experience self-driving vehicles and to adjust their opinion accordingly.

Finally, the use of self-reported measures in technology acceptance studies has been criticized, as the data that are collected are not independent of the method that is used to collect the data (Straub & Burton-Jones, 2007). Our study indeed found evidence for common method effects, as the general acceptance score correlated relatively strongly with the time to complete the survey and with whether participants found the survey instructions clear (ρ ~ 0.20 at the individual level, n = 7,755). At the national level (n = 43), it is possible that the negative correlation between the countries' mean general acceptance scores and GDP per capita (ρ = -0.48) reflects a common method bias due to social desirability or response style. For example, it is possible that respondents in higher-income countries gave lower acceptance ratings because of their better command of the English language. Better English language skills may be a reason why respondents in higher-income countries took less time to complete the survey (ρ = -0.65) and found the instructions clearer (ρ = 0.43, Q2), see supplementary material. Indeed, it cannot be ruled out that language barriers jeopardized the validity of our results, in the sense that it is possible that respondents in non-English speaking countries had difficulty with understanding the meaning of certain questions, and the notion of driverless shuttles. Then again, we did find strong correlations between GDP per capita and mean self-reported income (Q12) and median mileage (Q17) (ρ = 0.71 and 0.71, respectively), suggesting that self-reports are largely valid. Furthermore, GDP per capita correlated *positively* with some items (e.g., ρ = 0.39 for 'Q36. I would like to have a button inside the driverless vehicle which I can press to stop it'), but *negatively* with others (e.g., ρ = -0.64 for 'Q51. Even if it were more expensive than my existing form of travel, I would prefer driverless vehicles to my existing form of travel'), which suggests that respondents in different countries meaningfully responded to item content, and showed no strong acquiescence bias by 'agreeing' with all survey items. More fundamentally, our research points to interesting issues when it comes to measuring 'acceptance', as acceptance is inherently a subjective construct that is substantively related to bias and preconceptions. Similar discussions have been held regarding the interpretation of the general factor of personality (GFP). Musek (2017, p. 120) pointed out that "considering the fact that some variance of the social desirability itself represents a substantive trait, the obvious conclusion is that GFP can only partly be explained by social desirability as a mere response style." Future research should use self-reports together with objective usage data of driverless vehicles.

2.5.4. Conclusions

In conclusion, our survey showed that respondents believe that driverless shuttles are easy to use and convenient. Our study also revealed cross-national differences and found that lower-income countries were more accepting of driverless vehicles than higher-income countries. Finally, we extracted a general acceptance component, which is an innovative measure that comprises pivotal items concerning the acceptance, and hence future success, of driverless vehicles.

2.6. Supplementary material (sorted by name)

- cronbach.m: MATLAB script for computation of Cronbach alpha
- Editor Preview of Task – Tasks by CrowdFlower.pdf: Online questionnaire
- f891680-5.xls: Raw questionnaire data
- Figure_eigenvalues.fig: Eigenvalues
- Figure_GDPcapita_vs_general_acceptance.fig: Correlation between GDP per capita and general acceptance score
- Figure_GDPcapita_vs_income.fig: Correlation between GDP per capita and income
- Figure_GDPcapita_vs_mileage.fig: Correlation between GDP per capita and driving mileage
- Life expectancy.xlsx: National level data_life expectancy
- Median_age.xlsx: National level data_Median age
- nanzscore.m: MATLAB script for computation of standardized z-scorespcaj.m: MATLAB script for PCA analysis
- Results_overview19.xlsx: Overview of questionnaire results
- Rindermann_2007_data.xlsx: National level data_Performance in educational test Ten_thousand_read_and_proccess19.m: MATLAB script for data filtering, coding and analysis
- Veh_density.xlsx: National level data_Vehicle density
- WHO_data_2015_all_countries.xlsx: Country level data
- X2.xls

To access the supplementary material, please follow this link: https://www.dropbox.com/sh/gsn3kbo1brs7bql/AAC9W2TwwTwhAdfAA7eXZ2-fa?dl=0

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Chapter 3: User acceptance of automated shuttles in Berlin-Schöneberg: A questionnaire study

3.1. ABSTRACT

Automated shuttles are now in a prototyping phase in several research projects. However, there is still a paucity of knowledge on the acceptance of these shuttles. This paper presents the results of a questionnaire study among individuals (n = 384) who physically experienced an automated shuttle on an office campus in Berlin-Schöneberg. The findings indicate that the respondents were positive towards automated shuttles and could envision their use as feeders to public transport systems, in both urban and rural areas. The respondents were less satisfied with the effectiveness of the shuttle compared to their existing form of travel, the speed of the shuttle, and the space for luggage. A principal component analysis resulted in the retention of three components: 1) intention to use, 2) shuttle and service characteristics, and 3) shuttle effectiveness compared to existing transport. Older respondents expressed a higher intention to use, but found the shuttle less effective than their existing travel. We argue that automated shuttles are a valued concept, but speed and efficiency have to improve, in order for automated shuttles to become viable on a wide scale. Future research should use more objective measures and establish long-term effects in larger, more representative samples.

Nordhoff, S., De Winter, J., Madigan, R., Merat, N., Van Arem, B., & Happee, R. (2018). User acceptance of automated shuttles in Berlin-Schöneberg: A questionnaire study. *Transportation Research Part F: Traffic Psychology and Behavior, 58,* 843–854.

3.2. Introduction

3.2.1. Automated shuttles

Since the DARPA Challenges in 2004–2007 and the initiation of Google's self-driving car project in 2009, automated driving has seen a marked upsurge (Shladover, 2017). Current developments in the field of automated driving can be assigned to an evolutionary, revolutionary, or transformatory path of vehicle automation (Fraedrich et al., 2015). The evolutionary path is pursued by various automotive manufacturers, combining driver assistance systems such as adaptive cruise control, automated emergency braking, and automated lane keeping. The revolutionary path to vehicle automation, which is pursued by several ICT companies, targets the deployment of fully automated vehicles, enabling hands-free and eyes-off-the-road driving under every possible driving and traffic situation. The transformatory path includes automated shuttles that deliver on-demand transport and may serve as (last mile) feeders to public transport systems (Fraedrich et al., 2015).

Automated trams and metros that operate without a driver already exist in various cities worldwide (e.g., Fraszczyk & Mulley, 2017). The difference between existing automated public transport and automated shuttle projects is that the latter aim for operation in a mixed traffic environment without relying on specialized infrastructure. Shuttles that drive automatically in restricted conditions, on specified routes, may be released within three years (Shladover, 2017). Full 'revolutionary' automation, on the other hand, will probably not be commercialized anytime soon (Kyriakidis et al., 2019; Shladover, 2016), and SAE Level 2–4 'evolutionary' automation may need to overcome human factors challenges associated with transitions between manual and automated control in order to be safe and accepted (Kyriakidis et al., 2019).

Automated shuttles are now in a prototyping phase in various projects around the world (e.g., STIMULATE, 2018; Drive Sweden, 2018). Current shuttles run on specified routes at limited speeds, typically provide space for about 8 to 10 passengers, and require some level of supervision by a steward onboard the vehicle or by an external control room. The CityMobil1 (2006–2011) and CityMobil2 (2012–2016) projects implemented automated shuttles in urban environments in several European cities with the aim to identify and remove barriers to deployment. More recent projects include WePods in the Netherlands (Liang et al., 2016; Van der Wiel, 2017) and Smartshuttle in Switzerland (Eden et al., 2017). The EUREF demonstrator project in Berlin-Schöneberg, which is the topic of the present study, involves an automated shuttle 'Olli' developed by Local Motors, driving on the EUREF office campus in Berlin-Schöneberg.

3.2.2. Previous studies on the acceptance of automated shuttles

The vision of a multimodal mobility system with automated shuttles as feeders to public transport can only become a reality if the shuttles are accepted by their target users. A large number of survey studies exist in which people were asked to imagine and give their opinion on various types of automated driving concepts (e.g., Bansal et al., 2016; Bazilinskyy et al., 2015; European Commission, 2015, 2017; Hohenberger et al., 2016; Schoettle & Sivak, 2016). However, as summarized below, only a few studies have asked respondents to reflect on automated shuttles after having physically experienced a ride in the shuttle.

An evaluation of user acceptance across six demonstrations (Trondheim, Vantaa, La Rochelle, Daventry, Orta San Guilio, Castellon) of the CityMobil1 project showed that the most highly rated indicator was 'ease of use' with an average of 3.7 on a scale from 1 (completely dissatisfied) to 5 (completely satisfied), followed by usefulness (3.5), reliability, integration with other systems, perception of safety, perceived level of privacy, and perceived cleanliness (3.4), and comfort (3.3) (Gorris et al., 2011).

The results of interviews with over 1,500 users of automated shuttles of the CityMobil2 project showed general user acceptance regarding the performance of the shuttles, with high ratings on comfort and safety. Users were willing to pay for ticket fares, but the price should be comparable to conventional transport (e.g., bus) (Alessandrini, 2016).

Another CityMobil2 questionnaire study examined user acceptance with 349 respondents who had used an automated shuttle along a popular tourist route in La Rochelle (France), and as a link between a metro station and key working sites/campuses in the district in Lausanne, Switzerland (Madigan et al., 2016). The means for the key constructs 'performance expectancy', 'effort expectancy', and 'behavioral intention' were 3.08, 3.89, and 3.59 from 1 (strongly disagree) to 5 (strongly agree). A consecutive study surveyed 315 passengers who experienced a CityMobil2 automated shuttle on a dedicated lane in the center of Trikala (Greece) and found that the means for 'performance expectancy', 'effort expectancy', and 'behavioral intention' were 3.62, 3.92, and 3.74. Thus, people found automated shuttles useful, easy to use, and expressed an intention to use them again in the future (Madigan et al., 2017).

Portouli et al. (2017) asked 200 respondents about their satisfaction with automated shuttles that run in Trikala as part of the CityMobil2 project. Their results showed that passengers rated the usefulness and comfort as 1.29 and 0.95 respectively, on a scale from -2 (very poor) to 2 (very good). Ratings of the service quality in terms of waiting time and on-board time (0.59) and the integration with other modes (0.57) were considerably lower. 182 people (91%) responded that permanent operation of the shuttle in the city would be useful; only 18 respondents (9%) responded that this would not be useful.

Finally, results from interviews with local residents of Sion (Switzerland) who experienced an automated shuttle as part of the SmartShuttle project in Sion's Old Town district of the city, also showed that opinions towards the shuttle were positive overall. However, many participants felt that the shuttle slows down other traffic because of its low maximum speed of 20 km/h (Eden et al., 2017).

3.2.3. Objectives of the present study

The surveys reviewed above indicate that substantial progress has been made in the understanding of attitudes of users towards automated shuttles. However, whether participants are positive about the shuttle as a replacement of their current transport is a question that has received relatively little attention so far. The aim of the present study was to investigate how users rate the shuttle itself, its potential as a feeder to transport systems in urban and rural areas, and its advantages in comparison to respondents' existing form of travel.

We have included items from the Unified Theory of Acceptance and Use of Technology (UTAUT) constructs 'performance expectancy', 'effort expectancy', and 'social influence', which have been found to be predictive of the intention to use technologies across a variety of domains (Venkatesh et al., 2003). Additionally, we investigated respondents' perceptions with regard to perceived safety, perceived enjoyment, desired level of control, and environmental attitudes, because these variables have been identified as potentially critical determinants of the acceptance of automated vehicles in previous studies (e.g., Gorris et al., 2011, Moták et al., 2017; Nordhoff et al., 2018). Finally, the present 68-item survey study includes information on respondents' ratings of the acceptance of automated shuttles, using Van der Laan et al.'s (1997) acceptance scale, in addition to other indicators of acceptance, including respondents' intended frequency to use, willingness to pay, and behavioral intention to use shuttles as feeders in public transport.

A principal component analysis (PCA) was conducted on respondents' ratings to investigate the major sources of variation in the attitudes towards automated shuttles. To date, there has been little exploration of how the attitudes of various demographic groups towards automated shuttles might differ. Therefore, the component scores were correlated with personal characteristics (e.g., age, gender, employment on the EUREF campus) in order to assess individual differences.

It can be assumed that the acceptance ratings as measured in the current study are generalizable to other types of automated shuttles, because current shuttle prototypes worldwide have similar forms and sizes and are deployed in similar settings (e.g., university and office campuses, near public transport). This similarity renders the knowledge obtained in this study relevant beyond the trial in Berlin-Schöneberg.

3.3. Methods

3.3.1. Shuttle and route

During the period of the survey from December 2016 to April 2017, the automated shuttle drove on a 700 m route on the EUREF office campus in Berlin-Schöneberg. This route took on average 8 to 12 minutes per trip at an average speed of 8 km/h, and a maximum campus speed of 10 km/h. The shuttle operated on the basis of 3 fixed stops along the route from 09:00 to 17:00 to provide a transport option for the EUREF campus employees. The stopping and continuing to drive at the stops was done manually by the steward. The shuttle was also used by national and international guests, as well as interested persons who visited the EUREF campus to experience a ride in the shuttle. At the end of the shuttle ride, the steward handed out tablet computers with a questionnaire to passengers (see Figure 1, left, for an image of the shuttle).

The shuttle was fully electric, had a driving range of 80 km at a speed of 8 km/h. It was charged at night and during the lunch break (45 minutes) of the stewards to integrate the charging process into the daily operations. The shuttle operated on 'virtual tracks' using Lidar (Light Detection and Ranging), radar, and geopositioning technology for localization, mapping, and navigation.

As the shuttle was still in a prototype phase, a steward was on-board to supervise its operations and to intervene when requested by the system (see Figure 1, right). For example, given that the shuttle only had obstacle detection sensors in the front, obstacles that were on the path of the shuttle (e.g., parked cars) had to be passed manually by the steward using a joystick. As shown by Figure 2, the shuttle shared the road with pedestrians and cyclists, and occasional cars and trucks. It stopped for road users (e.g., pedestrians, cyclists) that crossed its trajectory within a distance of about 4 meters. Campus visitors were informed via a sign at the campus entrance of the shuttle operation and that the shuttle has right of way and should not be overtaken. The sign also stated that road users should maintain a distance of 10 meters from the shuttle.

Figure 1. Left: Automated shuttle Olli by Local Motors at the EUREF campus, Right: Inside view, with passenger and steward

Figure 2. Left: Part of the route. Right: View on shared space on the EUREF campus and entrance to the campus

3.3.2. Respondent recruitment and procedure

To bring the research to the attention of potential shuttle users, social media accounts (e.g., Twitter, Facebook) of the Innovation Centre for Mobility and Societal Change (InnoZ) were used in addition to publishing the project on the InnoZ website. An invitation for a test ride and participation in an online study was also sent to the Geography department of the Humboldt University in Berlin. The invitation to participate in our questionnaire study was also offered to delegations or other groups who performed around 20% of all test rides.

A maximum of 12 passengers was accepted (8 seated and 4 standing), with an average occupancy rate of around 3. The stewards explained the shuttle's functionality before the ride, by showing users the technology behind Olli, including the location of the sensors, the Lidar system, and the position of the touchpad that is used by the stewards to intervene. The shuttle's functionality was also explained during the ride inside the shuttle while making sure that passengers could also experience the ride. The respondents were told that the shuttle was a prototype and in a continuous state of development.

Furthermore, the respondents were informed that the use of the shuttle on a semi-public domain, such as the EUREF campus, was a first step in the deployment of automated shuttles as feeders to public transport systems on public roads. Taking a ride in the shuttle was free of charge, and no financial compensation was offered for the participation in the test ride and the questionnaire study.

3.3.3. Questionnaire content

3.3.3.1. Demographics and Shuttle and Service Characteristics

The questionnaire asked for personal details, namely whether the respondents completed the questionnaire for the first time (Q1), gender (Q2), age (Q3), whether they worked on the EUREF campus (Q4), in which field they worked (Q5), which transport mode they used on the EUREF campus (Q6; multiple responses possible), whether they have used the shuttle before (Q7), and if so, how many times (Q8).

The next section asked the respondents to rate the service, including the attractiveness of the shuttle service (Q9), its reliability (Q10), and its usability/comfort for the daily commute (Q11).

Next, questions were presented about the shuttle itself, including the attractiveness of the automated shuttle (Q12), the size of the shuttle (Q13), the perceived quality of the exterior of the shuttle (Q14), the design of the exterior of the shuttle (Q15), the speed (Q16), the comfort of entry and exit (Q17), the spaciousness of the shuttle (Q18), the number of seats (Q19), the seating comfort (if having taken a seat) (Q20), the number of standing positions (Q21), the handholds in the bus (Q22), the space for luggage (Q23), the brightness (Q24), the quality of the shuttle interior (Q25), the design of the interior of the shuttle (Q26), the atmosphere (Q27), and the safety (Q28).

3.3.3.2. Attitudinal questions

Next, eleven questions (Q29, Q34, Q36–Q42, Q44, Q45) were presented to assess respondents' level of agreement with items pertaining to the perceived enjoyment of taking a ride in the shuttle, perceived usefulness (performance expectancy), as well as the ease of use (effort expectancy) of the automated shuttle.

In particular, the respondents were asked how they liked the trip with the automated shuttle (Q29), whether taking a ride in the shuttle was fun and enjoyable (Q34), and whether the respondents found the trip in the shuttle boring (Q37).

The respondents were asked whether the driverless shuttle is useful (Q36), whether they would use an automated shuttle for their day-to-day commuting as it is better and more convenient than their existing form of travel (Q38), whether they think that the automated shuttle will become an important part of the existing public transport system (Q39), whether using the automated shuttle is similar to using existing public transport systems (e.g., busses, trains, and trams) (Q41), and whether the automated shuttle is more efficient/faster than their existing form of travel (Q44).

The respondents were also asked whether using the automated shuttle is easier for them than using their existing form of travel (Q40), whether the automated shuttle is easy to understand how to use (Q42), and whether it would not take long to learn how to use an automated shuttle (Q45).

Thirteen questions (Q43, Q46, Q53–Q62, Q67) were presented about the respondents' perceived level of safety and desired level of control in an automated shuttle, their environmental attitudes, as well as their reliance on the opinion of others (social influence).

The respondents were asked whether they like it that the driverless shuttle drives at a low speed (Q43), whether they felt safe in the automated shuttle throughout the whole trip (Q46), whether they felt comfortable in a vehicle without steering wheel, gas or brake pedal (Q56), whether people who are important to them would like it if the respondent used an automated shuttle (Q57), whether they would prefer the automated shuttle to drive without a steward onboard (Q58), whether they would like to manually steer the automated shuttle when they want to (Q59), whether they would like to have a button inside the automated shuttle which they can press to stop it (Q60), whether they would like to have their friends or family or other important people to them adopt the automated shuttle before they themselves do (Q61), and whether the automated shuttle is safe and reliable under severe weather conditions, such as snow, heavy rain, or fog (Q62). Question Q67 asked respondents to provide their level of agreement with "Driverless vehicles can operate without human supervision. Would you still prefer having some level of supervision?", on a scale ranging from no human supervision, remote supervision from a control room, to supervision by a steward onboard.

Specifically, the respondents were asked about their agreement with the statement that the protection of the environment is crucial for the choice of the automated shuttle (Q53), whether they like it to use a 100% electric automated shuttle from the train station to their final destination (Q54), and whether they would like to choose the automated shuttle as a more ecological form of travel even if it were more expensive (Q55).

3.3.3.3. Indicators of acceptance

Fifteen questions (Q30–Q33, Q35, Q47–Q52, Q63–Q66) asked the respondents to indicate their level of acceptance of automated shuttles. The respondents were asked how they liked the idea of using automated shuttles for public transport (Q30), and whether they would use automated shuttles as mobility offer in the city (Q31) and in rural areas (Q32). Question Q33 asked the respondents to what extent the service of automated shuttles fits existing railway facilities. The respondents were further asked whether they would be willing to share the shuttle with other travelers having the same destination (Q35), whether they dislike it that they might have to share the automated shuttle with unknown passengers (Q47), whether they would use an electric automated shuttle from the train station or some other public transport stop to their final destination or vice versa (Q48), whether they would use the automated shuttle with another 6 to 8 passengers having the same destination as themselves (Q49), whether they plan to use automated shuttles when they are available on the market (Q50), and whether they intend to use an automated shuttle for their daily trips (Q51), or to replace their current form of transport with an automated shuttle (Q52). The respondents were asked whether they would use an automated shuttle as mobility offer in rural areas (Q63) or in urban areas (Q64), and how often they intend to use automated shuttles on their daily trips (Q65). Question Q66 asked the respondents to rate the usefulness of and satisfaction with the automated shuttle, using Van der Laan's usefulness and satisfaction scale (Van der Laan et al., 1997). With the final question Q68, the respondents were asked how much they would be willing to pay for a 10-minute use of an automated shuttle.

The respondents indicated their level of agreement for Q9 to Q28 on a scale from 1 (very good) to 6 (very bad), while questions Q34 to Q64 were measured on a six-point Likert scale from strongly disagree to strongly agree. Responses to the response option 'I don't know' in Q34 to Q64 were excluded from the analysis. Responses were gathered between December 01, 2016 and April 2017. The questionnaire was offered in German and English, depending on the preference of the respondent.

3.3.4. Analysis of responses

Responses were included only if the survey was completed for the first time (Q1). Descriptive statistics (means, 95% confidence intervals) were calculated per questionnaire item. A principal component analysis (PCA) was conducted on all questions (except for the demographic questions Q1–Q8) to investigate the major sources of variation in the attitudes towards automated shuttles. Correlations were computed between the PCA scores and personal characteristics (i.e., age, gender, employment on the EUREF campus). The number of components to be retained was decided based on the percentage variance explained (scree plot) as well as the interpretability of the components. The loadings were rotated using the Promax rotation procedure with a power of 4 (Hendrickson & White, 1964). For the PCA, the respondents who had 20% or more missing items (e.g., due to not completing the questionnaire or because the questionnaire was extended later, by adding Q34 to Q68) were excluded from the analysis. Missing data were imputed using the 'nearest neighbor' participant on that item (Euclidean distance). Pearson product-moment correlations between respondents' personal details measured by Q2-Q8 and the PCA scores were calculated. All analyses were conducted in MATLAB 2016a.

3.4. Results

3.4.1. Respondents

From the around 1,600 passengers that were transported from December 2016 to April 2017, 384 participated in our questionnaire study (mean age = 35.5, *SD* = 14.4; 227 were male, 135 were female, and 22 did not specify their gender). 274 respondents were included in the PCA (mean age = 34.9, *SD* = 14.2; 169 were male, 102 were female, and 3 did not specify their gender). Regarding their common mode of transport on the EUREF campus (Q6), 3 reported using an electric scooter, 9 an electric vehicle, 45 a bike, 16 a conventional vehicle with a combustion engine, 202 walked, 23 used another type of transport, and no one used a truck. 211 respondents indicated to not work at the EUREF campus, 59 did work at the EUREF campus, and 4 did not specify whether they worked at the campus.

3.4.2. Ratings of shuttle and service characteristics

As shown in Figure 3, the respondents indicated that they liked the trip in the shuttle (Q29), with a mean (*M*) of 5.17 on the scale from 1 (strongly disagree) to 6 (strongly agree). They found the service of the shuttle (Q9) and the shuttle itself (Q12) attractive. The shuttle was also regarded as bright (Q24), spacious (Q13, Q18, Q19), and comfortable in terms of seating (Q20). The respondents also liked the atmosphere (Q27), especially the quality (Q14) and design of the shuttle exterior (Q15) and interior (Q25, Q26).

The respondents liked the idea of using automated shuttles in public transport systems (Q30, with a mean of 5.18 on the scale from 1 (strongly disagree) to 6 (strongly agree). They were less satisfied with the practicalities of the shuttle, such as the availability of handholds (Q22), and standing positions (Q21). The lowest ratings were obtained for vehicle speed (Q16; *M* = 3.38), and space for luggage (Q23, *M* = 3.49).

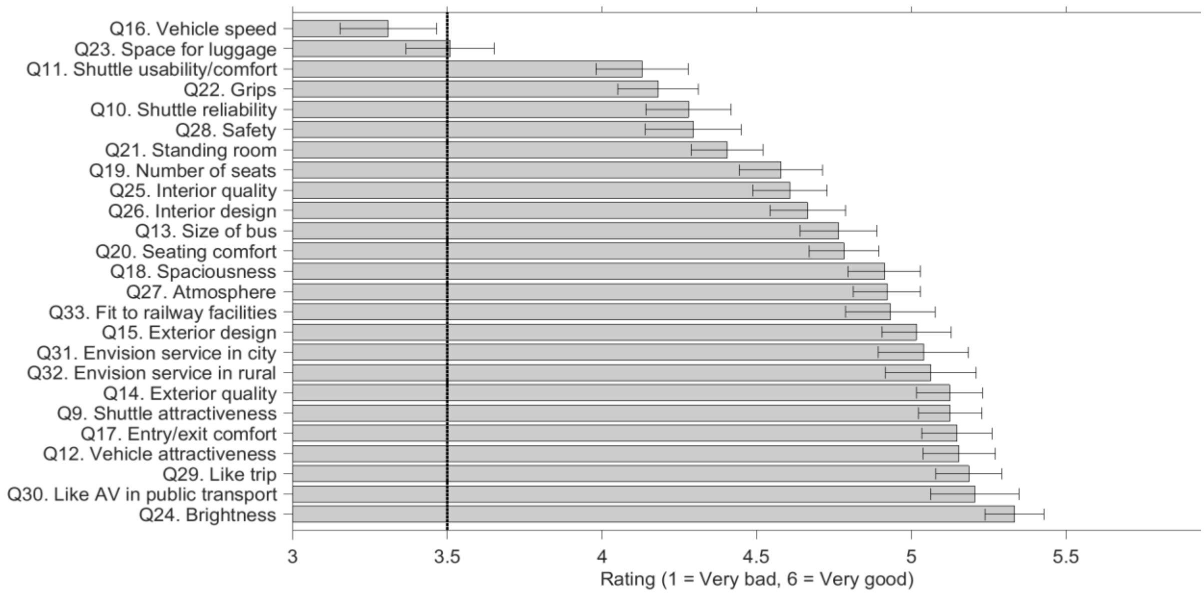

Figure 3. Shuttle and service characteristics, mean and 95% confidence intervals. The items are sorted by mean rating. The vertical line at 3.5 indicates a score in the middle of the range from 1 to 6.

3.4.3. Ratings of attitudinal questions

Figure 4 shows that the respondents gave high ratings to generic questions about the shuttle's usefulness and importance and their own affective state. For example, the respondents considered the shuttle to be useful (Q36, $M = 5.13$), and believed that the shuttle would become an important part of the existing public transport system (Q39, $M = 4.77$). They considered taking a ride in the automated shuttle to be fun and enjoyable (Q34, $M = 5.40$), and disagreed that the trip was boring (Q37, $M = 2.30$).

The respondents liked the idea that a 100% electric driverless shuttle will transport them from the train station to their final destination (Q54, $M = 5.04$), and agreed with the statement that the protection of the environment is crucial for their choice of transportation (Q53, $M = 4.71$). They were inclined to choose a driverless shuttle as a more ecological form of transport, even if it were more expensive than their current travel (Q55, $M = 4.02$). The respondents gave high ratings for sharing the shuttle together with 6–8 passengers having the same destination as them (Q49, $M = 5.34$).

When the respondents were asked to compare automated shuttles to their current travel, their ratings were low. In particular, the respondents did not think that the shuttle was more efficient/faster (Q44), or easier to use (Q40) than their existing form of travel, with means of 2.50 and 2.96 respectively on the six-point scale.

A majority liked the idea of a button inside the shuttle which they could use to stop it (Q60, $M = 5.23$). In terms of vehicle supervision, the most preferred option was supervision from an external control room, followed by having a steward onboard, with no human supervision receiving the lowest ratings (51.6%, 33.5%, and 14.9% of respondents, respectively, Q67).

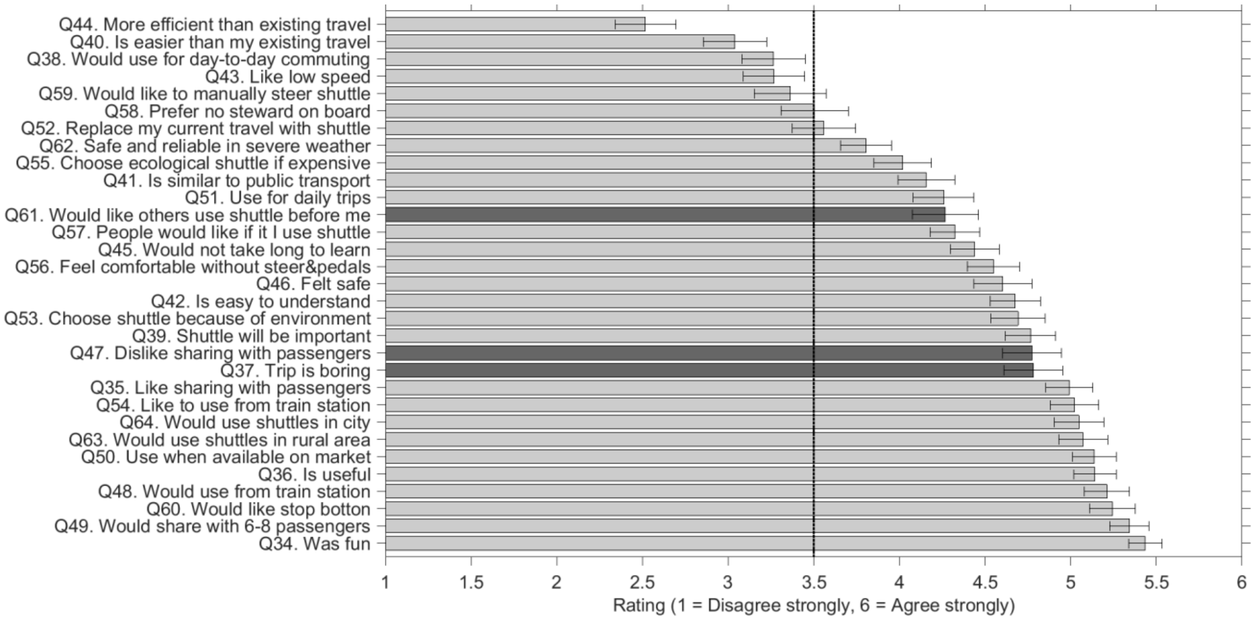

Figure 4. Attitudes towards the shuttle, mean and 95% confidence intervals. The items are sorted by mean rating. The scores for Q37, Q47, and Q61 (as indicated in darker bars) were reversed because these questions were phrased in a negative way. The vertical line at 3.5 indicates a score in the middle of the range from 1 to 6.

An analysis of the standard deviations per item showed substantial differences between items. To illustrate, the lowest standard deviation (0.80) was obtained for Q24 ('Brightness'), with the majority of the respondents giving positive ratings. The highest standard deviation (1.90) was found for Q59 ('I would like to manually steer the driverless shuttle when I want this'), yielding a seemingly bimodal distribution. The distributions of Q24 and Q59 are shown in Figure 5.

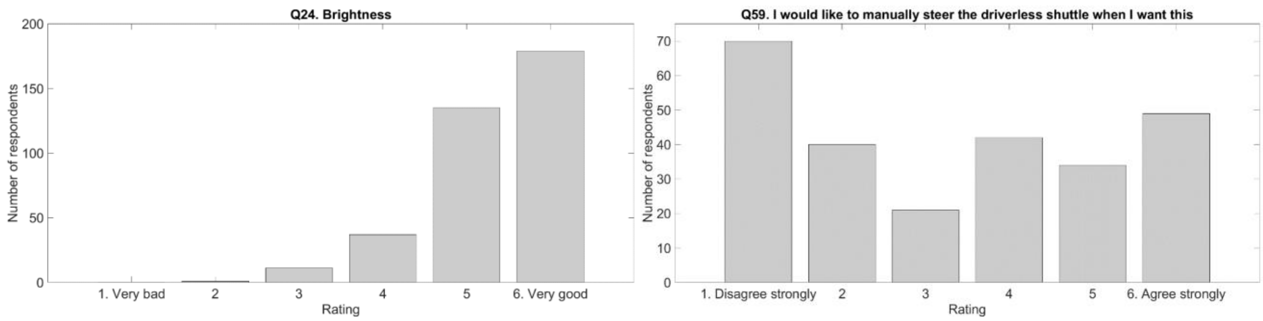

Figure 5. Distribution of the responses for the item with the lowest standard deviation (Q24, left), and the item with the highest standard deviation (Q59, right).

3.4.4. Results from the Van der Laan acceptance questionnaire

Acceptance ratings of the automated shuttle were obtained using a 9-item acceptance questionnaire (Q66-1–Q66-9) (Van der Laan et al., 1997), measuring aspects of usefulness (Q66-1, Q66-3, Q66-5, Q66-7, Q66-9), and satisfaction (Q66-2, Q66-4, Q66-6, Q66-8). Figure 6 shows that the respondents were generally accepting the shuttle, as they gave positive ratings for usefulness and satisfaction. However, they gave higher scores on the satisfaction scale than on the usefulness scale (see the relatively low ratings for Q66-5 and Q66-9).

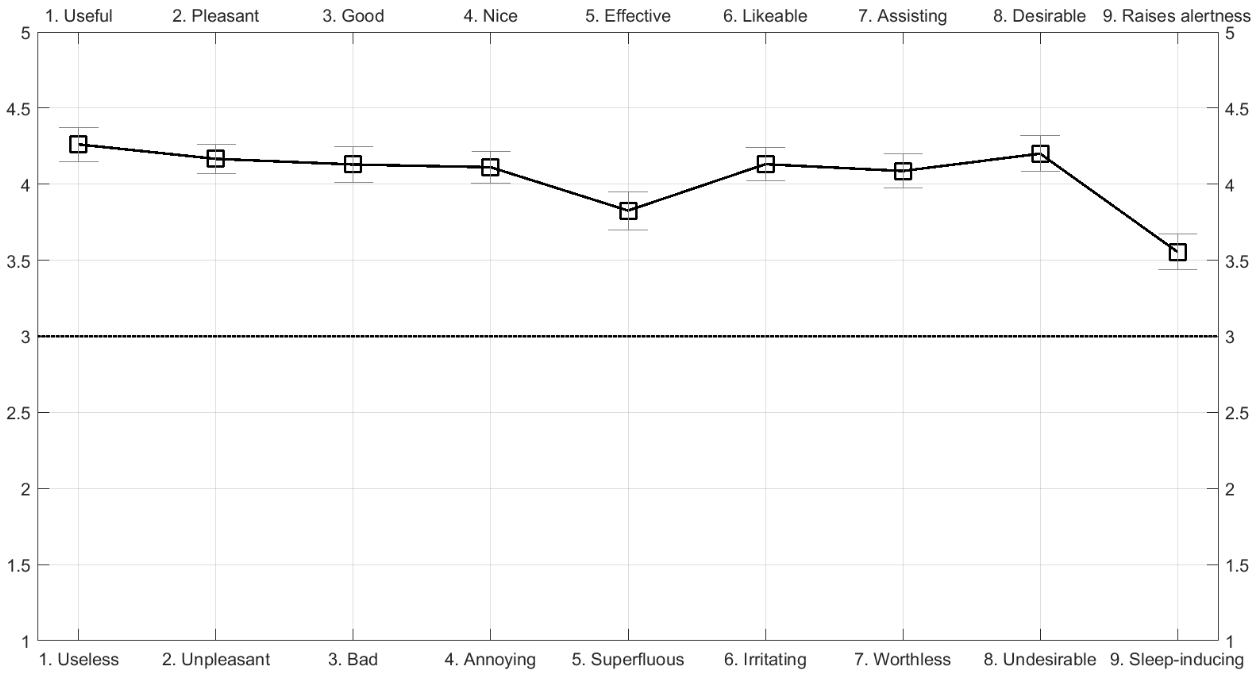

Figure 6. Van der Laan acceptance questionnaire, mean and 95% confidence intervals. The horizontal line at 3 indicates a score in the middle of the range from 1 to 5.

3.4.5. Willingness to pay and intended frequency of use

When the respondents were asked how often they would use automated shuttles on their daily trips (Q65), 33% of the respondents reported the intention to use it daily, 33% on 1 to 3 days a week, 18% on 1 to 3 days a month, 8% less than monthly, and 8% never or almost never.

29% of the respondents indicated that they would be willing to pay for a 10-minute ride (Q67) up to €0.50, 27% reported €0.51–1.00, 17% reported €1.01–1.50, 15% reported €1.51–2.00, 3% reported €2.01–2.50, 2% reported €2.51–3.00, and 7% picked the response option 'nothing'.

3.4.6. Principal component and correlational analysis

A PCA was performed on the responses from 274 respondents on 67 items (i.e., Q9–Q65, Q68, and the Van der Laan scale Q66-1–Q66-9). The Kaiser-Meyer-Olkin (KMO) index of sampling adequacy was 0.907, which is indicative of the suitability of the data for factor-analytic purposes. As suggested by the scree plot (Fig. 7), three interpretable components were retained, explaining 39.4% of the variance (see the Supplementary Material for all component loadings). The three retained components had eigenvalues of 17.8, 5.32, and 3.31, corresponding to 26.6%, 7.9%, and 4.9% of the explained variance. The Cronbach alpha for the three components was 0.942, 0.906, and 0.743 if selecting the 24, 21, and 6 variables that loaded higher than 0.4 on the components, which represents a common cut-off value (Peterson, 2000).

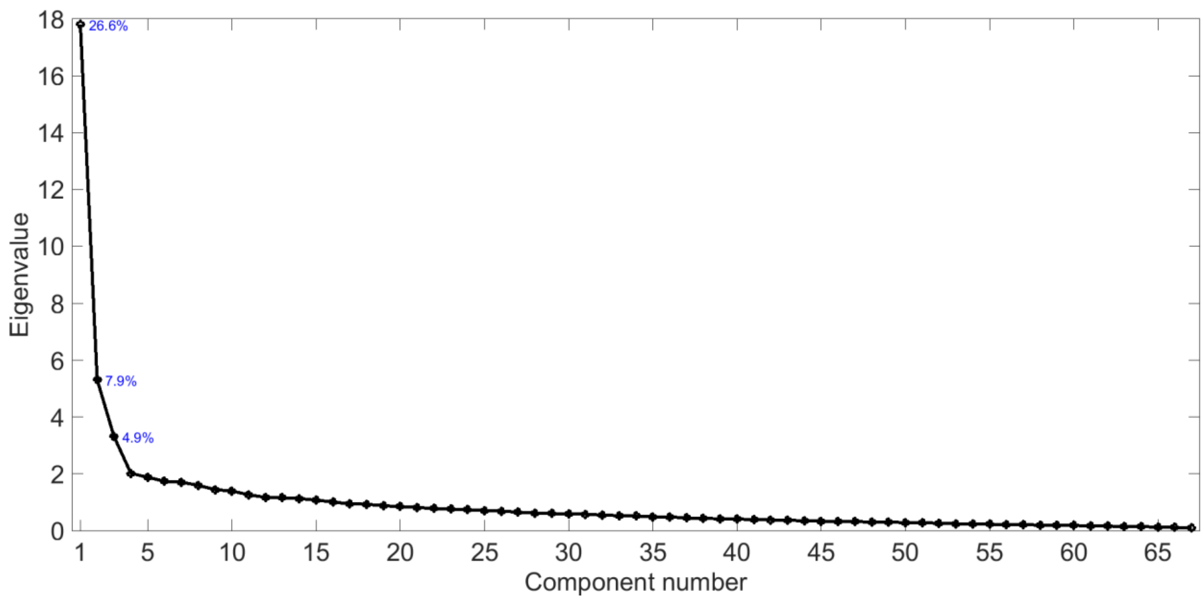

Figure. 7. Scree plot showing the eigenvalues of the correlation matrix, and the corresponding percentages of variance explained.

The first principal component (PCA1), ‘intention to use’, reflects whether the respondents would use automated shuttles (Q30–33, Q36, Q39, Q41, Q42, Q48–Q52, Q54, Q56–Q57, Q63–Q64, Q66-1, Q66-3, Q66-5–Q66-8). The highest loading (0.85) was obtained for Q48 (‘I would use an electric driverless vehicle from the train station or some other public transport stop to my final destination or vice versa’). The second-highest loading (0.84) was obtained for Q31 (‘To what extent can you envision the use of automated busses as mobility service in the city?’).

The second principal component (PCA2), ‘shuttle and service characteristics’, relates to the attitudes towards the physical shuttle itself, represented by Q9–Q10, Q12–Q29 and Q43. The highest PCA2 loading (0.80) occurred for Q26 (‘Design of the bus from the interior’), the second-highest (0.78) for Q18 (‘Spaciousness’).

The third principal component (PCA3), ‘shuttle effectiveness’, pertains to the performance of the automated shuttle in comparison with existing travel modes, represented by Q38, Q40, Q44, Q52, Q59, and Q61. The highest loading (0.75) occurred for Q40 (‘Using the driverless shuttle is easier for me than using my existing form of travel’), the second-highest (0.71) was obtained for Q38 (‘I would use a driverless shuttle in my day-to-day commuting as it is better and more convenient than using my existing form of travel’).

Table 1 shows the correlations between principal components and selected personal characteristics (age, gender, employment on the EUREF) as well as between the components themselves. There were no substantial gender differences between the three PCA scores. There was a positive correlation between age and PCA1 (r = 0.21), with older respondents expressing a higher intention to use automated shuttles (PCA1). However, the negative correlation between PCA3 and age (r = -0.17) indicates that older respondents rated automated shuttles as less effective compared to their existing form of travel. The negative correlation between employment on the EUREF campus and PCA3 (r = -0.19) indicates that people working on the EUREF campus consider the automated shuttle to be less effective compared to their existing form of travel. There were no substantial differences between employees and nonemployees of the EUREF campus concerning their ratings of PCA1 and PCA2. Furthermore, we found a significant positive correlation between PCA1 and PCA2 (r = 0.53) and PCA3 (r = 0.24), as well as between PCA2 and PCA3 (r = 0.28). These positive correlations indicate that there is some degree of redundancy among the three component scores, as each of the three components expresses a positive valence towards the shuttle.

Table 1. Means (*M*), standard deviations (SD) and correlations between principal components and selected personal characteristics

		M	***SD***	1	2	3	4	5
1	Gender (1 = male, 2 = female) (Q2)	1.38	0.49					
2	Age (years) (Q3)	34.90	14.20	-0.06				
3	Working on campus (1 = no, 2 = yes) (Q4)	1.22	0.41	0.04	0.01			
4	PCA1: Intention to use	0.00	1.00	0.01	0.21	-0.06		
5	PCA2: Shuttle and service characteristics	0.00	1.00	0.04	0.08	-0.05	0.53	
6	PCA3: Shuttle effectiveness	0.00	1.00	-0.04	-0.17	-0.19	0.24	0.28

3.5. Discussion

3.5.1. Main findings at the item level

This study showed that the respondents accepted automated shuttles and appreciated their potential use in future public transport systems. The respondents reported positive attitudes towards using the system as a form of transport and were willing to share it with fellow travelers. They agreed most strongly with the item that taking a ride in the shuttle was fun and enjoyable (*M* = 5.40 on a scale from 1 to 6), and so were even more positive than the respondents who experienced an automated shuttle in Trikala as part of the CityMobil2 project (*M* = 3.80 on a scale from 1 to 5; Nordhoff et al., 2017). More than half of our respondents (59.4%) were willing to pay up to EUR1 per 10-minute use.

The respondents were not inclined to replace their current transport mode for the shuttle, which may not be surprising as the shuttle operated under very limited conditions. In Madigan et al. (2016), respondents' ratings of performance expectancy (e.g., 'I think an ARTS would be more efficient/faster than existing forms of public transport') were relatively low (*M* = 3.08 on a scale from 1 to 5), consistent with our findings (*M* = 2.50 on a scale from 1 to 5; Q44). Among the shuttle and service characteristics (Q9–Q28), the speed of the shuttle (Q16) received the lowest ratings (*M* = 3.38 on a scale from 1 to 6). Previous studies showed that a low shuttle speed was positively perceived because of safety (Bekhor et al., 2003; Rodríguez, 2017), but negatively perceived because of travel time concerns (Bekhor et al., 2003). These low ratings may have important implications, as travel time and waiting time are critical determinants of the use and acceptance of shared autonomous vehicles (Krueger et al., 2016). The operation of shuttles at higher speeds, however, necessitates the equipment of shuttles with better sensors and software as well as an adjustment of legal frameworks and an adaptation of infrastructure (Schreurs & Steuwer, 2016). The space for luggage is another shuttle characteristic that received low ratings.

The supervision of the shuttle from an external control room was preferred to the supervision by a steward and no supervision. These findings correspond with findings in the domain of driverless trains where only few people were comfortable without any type of supervision (Fraszczyk & Mulley, 2017). Why the respondents preferred supervision from an external control room to a steward onboard is a question that warrants further investigation. It is possible that the respondents prefer not to encounter a steward, or it is possible that the respondents envisioned a reliable shuttle system where intervention is rarely needed and remote supervision suffices.

3.5.2. Principal components

The PCA resulted in the retention of three components (1. intention to use, 2. shuttle and service characteristics, 3. shuttle effectiveness compared to existing transport), which together accounted for a variance of 39.4%. The first and third components resemble the UTAUT constructs ‘behavioral intention’ and ‘performance/effort expectancy’, respectively (e.g., Venkatesh et al., 2003), whereas the second component resembles the construct ‘service quality’ (e.g., Sánchez Pérez et al., 2007).

We observed positive correlations between the three components. The strong positive relationship between shuttle and service characteristics (PCA2) and intention to use (PCA1) is consistent with studies showing that quality of service is linked to intentions to use public transport systems (e.g., Lai & Chen, 2011; Sánchez-Pérez et al., 2007). The moderate positive relationship between shuttle effectiveness (PCA3) and intention to use (PCA1) also corresponds to previous research. For example, Buckley et al. (2018) found that the intention to use conditionally automated vehicles (SAE Level 3 automation) is associated with perceived usefulness. Similarly, Kaur and Rampersad (2018) identified performance expectancy as a significant predictor of the adoption of driverless cars.

Note, however, that the occurrence of positive correlations can also plausibly be explained by a common cause (e.g., positively minded people giving higher ratings), or method effects such as item wording (i.e., items with the same response options correlate strongly, and therefore cluster on the same component). Further experiments with a control group and objective measures (e.g., actual use rather than intended use) are needed to unravel the causal determinants of the acceptance of automated shuttles.

3.5.3. Individual differences

The standard deviations of the responses were relatively low regarding physical shuttle characteristics (e.g., luggage space, brightness), indicating that the respondents were generally in agreement with each other. However, our study showed higher variability for items pertaining to hypothetical situations. For example, there was a wide distribution regarding whether the respondents want to have the option to steer the vehicle manually (Fig. 6). This finding is consistent with Kyriakidis et al. (2015) who found that some people prefer automated driving, whereas others were against it.

We did not find substantial gender differences regarding the principal component scores. This corresponds with Madigan et al. (2016) who did not find any gender effects on individuals’ behavioral intentions to use automated shuttles. However, our study did find age effects: Older people expressed a higher intention to use the shuttle, but rated the effectiveness of shuttles compared to their existing travel as more negative. Madigan et al. (2017) also found more negative ratings among older shuttle users in Greece, but Madigan et al. (2016) reported more positive ratings among older persons in France and Switzerland. Madigan et al. (2016) further found that age effects in the acceptance of shuttles depend on whether zero-order correlations are assessed, as in the present study, or whether age effects are assessed as part of a multiple regression analysis. The observed inconsistencies in age effects may be due to differences in subcultures (e.g., employees, tourists, visitors), which makes the generalizability of the observed age effects difficult at the moment.

3.5.4. Study strengths & limitations

A limitation of our study is that it may be prone to selection bias, as our study could have attracted people who have a favorable opinion about automated shuttles and were curious about testing them for the first time. This notion is consistent with the fact that employees on the campus rated the shuttle as more negative than outside visitors (Table 1). Campus employees may not have had the same level of excitement about the technology anymore, because they may have seen the shuttle many times before. Similarly, it is possible that the respondents gave high acceptance ratings as a form of cognitive dissonance reduction (i.e., to justify to themselves taking the effort to participate). Although the respondents may have been more positive compared to representative samples, the differences between item responses (e.g., the fact that shuttle speed received relatively low ratings) should be immune to selection bias. Furthermore, current shuttles worldwide operate in similar settings (e.g., office or university campus), which makes our results representative for early-adopter scenarios. Therefore, future research should be conducted using larger samples that are representative of the entire population.

Previous research has used large national or cross-national samples via interviews or online questionnaires and asked them questions about *imagined* automated vehicles (see Eurobarometer method; European Commission, 2015, 2017; Nordhoff et al., 2018). Although these studies target broad and potentially representative audiences, their results may be of limited validity, as respondents had to respond based on their general beliefs (e.g., as obtained via the media or Internet sources). A strength of our survey is that respondents physically experienced an automated shuttle. For example, the fact that respondents gave relatively low ratings to the shuttle speed would probably not have been obtained when the respondents were merely asked to imagine a fully automated vehicle. However, social desirability biases still cannot be ruled out, as individuals in our study may have responded in line with their general beliefs despite having experienced the shuttle. To illustrate, respondents showed agreement (M = 4.02) with the idea of choosing the automated shuttle as a more ecological form of travel if it were more expensive, while the majority (204/274) indicated to be walking (which is arguably the most ecological form of transport possible) on the campus. In other words, it is likely that respondents were overall positive ('yea-saying') without critically reflecting on the meaning of each question. On the other hand, it could be argued that this particular mismatch is sensible as respondents who regularly walk on the campus may be traveling to that campus using the bus or car. To circumvent these limitations, future research should be performed in naturalistic rather than trial-based settings. Furthermore, it is recommended to measure participants' actual usage of the shuttle (e.g., frequency of use), rather than self-reported attitudes towards using the shuttle.

3.6. Acknowledgements

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Chapter 4: What Impressions Do Users Have after a Ride in an Automated Shuttle? An Interview Study

4.1. ABSTRACT

In the future, automated shuttles may provide on-demand transport and serve as feeders to public transport systems. However, automated shuttles will only become widely used if they are accepted by the public. This paper presents results of an interview study with 30 users of an automated shuttle on the EUREF (Europäisches Energieforum) campus in Berlin-Schöneberg to obtain an in-depth understanding of the acceptance of automated shuttles as feeders to public transport systems. From the interviews, we identified 340 quotes, which were classified into six categories: (1) expectations about the capabilities of the automated shuttle (10% of quotes), (2) evaluation of the shuttle performance (10%), (3) service quality (34%), (4) risk and benefit perception (15%), (5) travel purpose (25%), and (6) trust (6%). The quotes indicated that respondents had idealized expectations about the technological capabilities of the automated shuttle, which may have been fostered by the media. Respondents were positive about the idea of using automated shuttles as feeders to public transport systems but did not believe that the shuttle will allow them to engage in cognitively demanding activities such as working. Furthermore, 20% of respondents indicated to prefer supervision of shuttles via an external control room or steward onboard over unsupervised automation. In conclusion, even though the current automated shuttle did not live up to the respondents' expectations, respondents still perceived automated shuttles as a viable option for feeders to public transport systems.

Nordhoff, S., De Winter, J., Payre, W., Van Arem, B., & Happee, R. (2019). What impressions do users have after a ride in an automated shuttle? An interview study. *Transportation Research Part F: Traffic Psychology and Behavior, 63, 252–269.*

4.2. Introduction

Various research projects are pursuing the development and introduction of automated shuttles (e.g., Transport Systems Catapult, 2016; WEpods, 2017). The public's acceptance of automated vehicles has been investigated in a number of questionnaire studies (e.g., Eden, Nanchen, Ramseyer, & Evéquoz, 2017a; Nordhoff et al., 2018a; Nordhoff, De Winter, Kyriakidis, Van Arem, & Happee, 2018b; Vöge & McDonald, 2003). Most studies involved respondents who were asked to *imagine* automated vehicles, while some studies asked respondents to rate *actual* automated vehicles after physically experiencing them.

In Nordhoff et al. (2018a), respondents rated an actual automated shuttle as positive but gave relatively low ratings to the effectiveness of the shuttle compared to their current mode of travel. Eden et al. (2017a) investigated respondents' safety and comfort before and after riding an automated shuttle. Before the ride with the shuttle, 4 out of 17 respondents expressed safety concerns because of news reports of an accident with an automated shuttle that ran into a parked delivery van. These respondents reported that the ride with the automated shuttle mitigated their safety concerns. However, most respondents also indicated that their safety concerns might increase if larger-sized automated buses without steward would operate on public roads at a regular speed. In Vöge and McDonald (2003), respondents indicated that the connection of automated transport systems to an external control room for emergencies, a door-to-door transport service, the option to order automated vehicles on demand via smartphones, and low waiting times are criteria that make automated vehicles attractive for users. In an online questionnaire study by Cyganski, Fraedrich, and Lenz (2015), respondents regarded the possibility of enjoying the landscape and talking to fellow passengers to be advantages of fully automated driving; the ability to work on the move was considered advantageous by only a small proportion of respondents. In another online study in which respondents were asked to imagine automated vehicles, respondents indicated that they would be more inclined to engage in non-driving tasks (e.g., resting, sleeping, watching movies, or reading) with higher automation levels (Kyriakidis, Happee, & De Winter, 2015).

Most studies that examined people's attitudes toward automated vehicles have been based on questionnaires (e.g., Bansal, Kockelman, & Singh, 2016; Kyriakidis et al., 2015; Regan et al., 2017), see Nordhoff et al. (2018a, 2018b) for an overview of prior acceptance studies. A weakness of questionnaires is that little in-depth information is obtained. The present study sought in-depth information from respondents who physically experienced an automated shuttle. Physically experiencing the shuttle is important given that in previous questionnaire studies on automated vehicles, respondents may have been "providing opinions based on a flawed understanding of the technology and its current state of development" (Hyde, Dalton, & Stevens, 2017, p. 3).

We conducted semi-structured interviews with 30 people after they had physically experienced the automated shuttle 'Olli' from Local Motors in Berlin-Schöneberg. The operation of this type of automated shuttle is representative of automated shuttle projects worldwide linked to public transport (Boersma, Van Arem, & Rieck, 2017; Eden, Nanchen, Ramseyer, & Evéquoz, 2017b; Van der Wiel, 2017), but not necessarily of prototype automated driving systems associated with private vehicles or taxi services (e.g., Google, Uber).

This research aimed to contribute to the literature on the acceptance of automated vehicles by acquiring information about respondents' expectations of automated driving technology and whether experiencing an automated shuttle fulfilled these expectations. In particular, factors that might affect respondents' intentions to use automated shuttles as feeders to transport systems were explored.

4.3. Method

4.3.1. Recruitment and procedure

An invitation letter to take part in a test ride with the automated shuttle (Fig. 1) and participate in an interview was sent to 5 groups of people:

- Participants in former experiments of car-sharing or electro-mobility projects of the Innovation Centre for Mobility and Societal Change (InnoZ) in Berlin received the invitation letter via email (Group 1).
- Employees of the EUREF campus (where InnoZ is located) received the invitation letter as part of a newsletter sent on behalf of the EUREF campus (Group 2).
- Students and employees of the Geography department of the Humboldt University, Berlin, received the invitation letter via email on behalf of the department (Group 3).
- Students and employees of the Centre for Entrepreneurship of the Technical University of Berlin received the invitation letter via email on behalf of the centre (Group 4).
- People received the invitation letter from people of Groups 1–4, after which they expressed their interest in participating via email to the researchers of this study (Group 5).

The invitation letter informed the respondents that the ride and the participation in the interview would take around 90 minutes in total. The invitation letter also informed the respondents that the interview would be audio-recorded and that personal data would be treated anonymously. On the day of the interview, the respondents were asked whether they agreed with the conditions stated in the invitation letter and provided their verbal consent. They were offered no financial compensation for participation in the ride and interview.

Figure 1. Automated shuttle Olli by Local Motors at the EUREF campus in Berlin-Schöneberg

In total, 30 shuttle rides with corresponding interviews were performed between March and July 2017. There were 23 participants from Group 1, 1 from Group 2, none from Group 3, 2 from Group 4, and 4 from Group 5. First, the respondent experienced the ride alone. After the ride, the first author of the present study interviewed the respondent individually in a quiet room at InnoZ. With 2 of 30 respondents, the interviewer held telephone interviews a few days after their test ride with the automated shuttle because a personal interview could not be arranged. Twenty-eight interviews were held in German, and two were performed in English. The interviewer guaranteed full anonymity to each respondent. The ride took on average 8 to 12 minutes per trip at an average speed of 8 km/h. The interview took on average 50 minutes per respondent.

The shuttle was fully electric and drove a 700 m route on the EUREF (Europäisches Energieforum) campus in Berlin-Schöneberg. The shuttle shared the road with pedestrians, cyclists, and occasionally with cars and trucks. It operated on ‘virtual tracks’ using lidar, radar, and geo-positioning technology. A steward was present in the shuttle to supervise its operation and intervene in situations that required manual intervention (e.g., use the joystick to overtake obstacles on the ‘virtual tracks’ of the shuttle, or apply an emergency brake in anticipation of approaching road users). In one test ride, an engineer from Local Motors was also present to check the functioning of the shuttle (see the quote of respondent R07 in Section 3.4.3). The shuttle provided space for 12 passengers in total (8 seated, 4 standing). An emergency button inside the shuttle could be used by passengers and the steward to halt the shuttle operation in cases of emergency.

4.3.2. Interviewing procedures and analysis

The interviews were semi-structured and based on a pre-defined protocol that consisted of open-ended questions to investigate the factors influencing the acceptance of automated shuttles as feeders to public transport systems. First, the respondents were asked with which mode of transport they travelled to the campus (Q1), and whether this mode of transport is representative of their daily travel mode choice (Q2). The interviewer asked the respondents about their perceptions and experiences during the ride (Q3), and their associations with automated driving before the ride (Q4). The central part of the interview concerned the identification of factors that influence respondents’ acceptance and use of automated shuttles as feeders to public transport systems (Q5). Here the interviewer asked the respondents to think about their daily mobility needs and to what extent automated shuttles would correspond with their daily mobility as feeders. The interviewer encouraged respondents to assess the practicalities of using shuttles for their daily mobility. Respondents were asked how their close family members and friends perceive automated shuttles (Q6). In the last two questions, the interviewer asked respondents with which travel modes automated shuttles compete (Q7), and how they envisioned the future of mobility (Q8). For the sake of brevity, we will not report the results from Q1–Q2 and Q6–Q8 and concentrate on the examination of the acceptance of automated shuttles as feeders to public transport systems.

A questionnaire was sent to all respondents via email after the interview to obtain background information on their sociodemographic profile, such as age, gender, type of residential situation, labour status, education, having a driver license, and travel behaviour.

The interview was analysed in four steps, primarily performed by the first author, with regular discussions with the second author.

First, the interviews were recorded and transcribed verbatim. The coding process followed the principles of inductive category development (Mayring, 2000). Initial categories (i.e., content themes) were manually developed out of the interview material. The interview transcripts were scrutinized line-by-line applying common steps of text analysis, such as underlining/highlighting in the text, writing notes, searching for keywords in the text, and jumping to different text passages (Mayring, 2000).

In the second step, the transcripts were reread to refine the categories into main categories and subcategories. The categories that emerged from the data represent the factors influencing the acceptance of automated shuttles as feeders to transport systems. These categories were compared to theoretical concepts from the literature (e.g., Eden et al., 2017a, b; Meijkamp & Theunissen, 1996; Nordhoff et al., 2018a, b; Parasuraman, Zeithaml, & Berry, 1985; Parasuraman, Zeithaml, & Berry, 1988; Redman, Friman, Gärling, & Hartig, 2013; Vöge & McDonald, 2003).

In the third step of the analysis, the number of times a subcategory was mentioned per respondent was counted. Multiple mentions (i.e., quotes) of a subcategory by the same respondent equalled a frequency of 1. The difference between the number of respondents in a subcategory (as denoted by *n* in Table 2) and the total number of respondents (*n* = 30) equals the number of respondents who did not address that subcategory. Multiple mentions of a subcategory by the same respondent were not discarded from the analysis but clustered with the other quotes of this respondent. Therefore, some of the quotes presented here are clusters of sentences mentioned by the same respondent at different points in time during the interview. When the quote represented more than one subcategory, the quote was assigned to each of these subcategories. Topics quoted by fewer than five respondents were omitted from the analysis. We assumed that the more respondents spoke on a particular subcategory, the greater the importance of this subcategory as determinant of the acceptance of automated shuttles. Therefore, the number of quotes reported in this paper was decided to be proportional to the number of respondents mentioning the corresponding subcategory. To prevent that a sub-category is dominantly represented by a single respondent, a maximum of one quote per respondent was accepted for each of the subcategories.

In the last step of the analysis, illustrative quotes of each subcategory were selected for presentation in this paper. Here, we used the principle of “prototypical and outlier illustrations” for each subcategory (Graham-Rowe et al., 2012, p. 144). Illustrative quotes were selected as follows:

- Subcategories mentioned by 5 to 10 respondents are represented by a minimum of 1 and a maximum of 3 quotes.
- Subcategories mentioned by 11 to 20 respondents are represented by a minimum of 4 and a maximum of 6 quotes.
- Subcategories mentioned by 21 to 30 respondents are represented by a minimum of 7 and a maximum of 9 quotes.

4.4. Results

4.4.1. Sociodemographic characteristics

Table 1 provides an overview of the respondents’ sociodemographic characteristics. Most responses are based on 27 of 30 respondents because three respondents did not return their questionnaires. Information about age, gender, and being in possession of a valid driver license was available for all 30 respondents, as this information could be extracted from the interviews.Table S1 in the appendix provides a detailed overview of the socio-demographic information of each respondent.

Table 1. Overview of respondents' socio-demographic profile. *n* represents the number of respondents.

Personal characteristic	Response category	*n*
Age	21–25	2
	26–30	4
	31–35	4
	36–40	2
	41–45	5
	46–50	1
	51–55	3
	56–60	3
Gender	Male	24
	Female	6
Living situation	Outside the city in a house in the countryside	0
	In a house on the city outskirts	4
	Within a city, but outside the city centre in a purely residential area	8
	In an apartment in the immediate city centre	15
Highest education	School leaving examination	3
	Completed academic studies	20
	Pupil, student, apprentice	4
Valid driver license	Yes	26
	No	1
Walking >500 meters per trip	Daily or almost daily	17
	1–3 days per week	7
	1–3 days per month	2
	Less than monthly	1
	Never or almost never	0
Biking	Daily or almost daily	8
	1–3 days per week	7
	1–3 days per month	3
	Less than monthly	5
	Never or almost never	4
Moped or motorcycle	Daily or almost daily	0
	1–3 days per week	1
	1–3 days per month	1
	Less than monthly	1
	Never or almost never	24
Car as driver or passenger	Daily or almost daily	5
	1–3 days per week	5
	1–3 days per month	6
	Less than monthly	10
	Never or almost never	1
Public transport <100 km per trip	Daily or almost daily	15
	1–3 days per week	6
	1–3 days per month	4
	Less than monthly	2
	Never or almost never	0
Public transport >100 km per trip	Daily or almost daily	1
	1–3 days per week	2
	1–3 days per month	11
	Less than monthly	13
	Never or almost never	0

4.4.2. Main categories and subcategories

The data analysis resulted in the identification of 320 quotes. Nineteen quotes were assigned to two subcategories and one quote to three subcategories. The total number of classified quotes, therefore, equaled 340. The 340 quotes were assigned to the following six main categories that were regarded as relevant to the intention to use automated shuttles in public transport:

(1) Expectations about the capabilities of the automated shuttle (33 quotes)
(2) Evaluation of the shuttle performance (35 quotes)
(3) Service quality (115 quotes)
(4) Risk and benefit perception (52 quotes)
(5) Travel purpose (84 quotes)
(6) Trust (21 quotes)

Table 2 presents the extracted categories and subcategories, their meaning, and the number of respondents who spoke on a subcategory. A visual presentation of the main categories and their corresponding sub-categories is shown in Figure 2.

Table 2.
Overview of categories and their subcategories, and the number of respondents with a quote in that subcategory (*n*).

Category numbering	**Main category**	**Subcategory**	**Sources**	***n***
1.	Expectations about the capabilities of the automated shuttle	Full automation: Fully automated vehicle that drives in every traffic situation without human input	SAE International (2018)	17
		Comparison of automated shuttles to public transport systems	Newly created	10
		Automated driving as private and not as public transport	Newly created	6
2.	Evaluation of shuttle performance	Braking behaviour: Strong and abrupt braking	Newly created	15
		Incapability to overtake obstacles	Newly created	12
		Manual interventions by the steward	Newly created	8
3.	Service quality	Availability: Instant access to automated shuttles, high frequency of service operation, short waiting times	Shen, Zhang, & Zhao (2018)	20
		Convenience: Accessibility, information provision on routes and interchanges, uncomplicated booking and payment, inclusion in public transport ticket	Lai & Chen (2011), Redman et al. (2013)	20
		Comfort: (More) comfortable and larger number of seats, space for arms, legs, and luggage, having private space, driving in or against the direction of travel, air quality/ventilation, internet access, cleanliness, adequate shuttle size, design of interior	Eboli & Mazzulla (2011), Redman et al. (2013)	19
		Speed	Krueger, Rashidi, & Rose (2016), Redman et al. (2013)	18

		Flexibility: Direct, door-to-door transport or in proximity to respondents' destinations, flexible stop's and go's, no timetable dependence, demand-responsive or on-demand ordering via a smartphone app, being able to drive alternative routes, simple and seamless transfers	Brake, Mulley, Nelson, & Wright (2007), Chowdhury & Ceder (2016), Hine & Scott (2000), Redman et al. (2013)	15
		Creation of advantages through the use of automated shuttles compared to current travel	Rogers (2010)	12
		Reliability: Reliable matching of the actual service with the routing timetable, system reliability	Eboli & Mazzulla (2011), Parasuraman et al. (1985, 1988), Redman et al. (2013)	11
4.	Risk and benefit perception	Traffic safety: Higher traffic safety with automated vehicles than with manually controlled cars	Liu, Yang, & Xu (2018), Pettigrew, Talati, & Norman (2018), Ward, Raue, Lee, D'Ambrosio, & Coughlin (2017)	14
		Not having to drive: Manual driving as a stressful, unpleasant, costly, inefficient, tedious, or environmentally-unfriendly activity	Liu et al. (2018), Pettigrew, Talati, & Norman (2018), Ward et al. (2017)	13
		Environmental protection: Positive environmental effects of automated vehicles equipped with electric propulsion	Eboli & Mazzulla (2011), Liu et al. (2018), Pettigrew, Talati, & Norman (2018), Ward et al. (2017)	10
		Ethical programming	Newly created	5
		Job losses: Job losses will not stop the development of automated driving	Newly created	5
		No productive use of driving time in automated shuttle	Cyganski et al. (2015), Milakis, Van Arem, & Van Wee (2017), Singleton (2018)	5
5.	Travel purpose	Use of automated shuttles in severe weather conditions	Newly created	13
		Use of automated shuttles in suburban and rural areas	Nordhoff et al. (2018a), Vöge & McDonald (2003)	13
		Use of automated shuttles on closed areas	Vöge & McDonald (2003)	12
		Use of automated shuttles for transport of goods	Vöge & McDonald (2003)	11
		Use of automated shuttles in urban areas	Nordhoff et al. (2018a)	10
		Use of automated shuttles in touristic/unfamiliar areas	Vöge & McDonald (2003)	10
		Use of automated shuttles due to temporary physical impairments (e.g., pregnancy, exhaustiveness)	Newly created	5
		One-way trips currently covered by car	Newly created	5

		Suitability of automated shuttles on daily trips	Newly created	5
6.	Trust	Trusting automated vehicles	Choi & Ji (2015), Kaur & Rampersad (2018), Liu et al. (2018)	10
		Preference for supervision of shuttle (i.e., steward onboard, external control room) & halting shuttle operation (i.e., emergency button)	Nordhoff et al. (2018a, b)	6
		Trialability: Putting automated shuttles to trial and expose the public to automated driving	Rogers (2010)	5
Total number of classified quotes				340

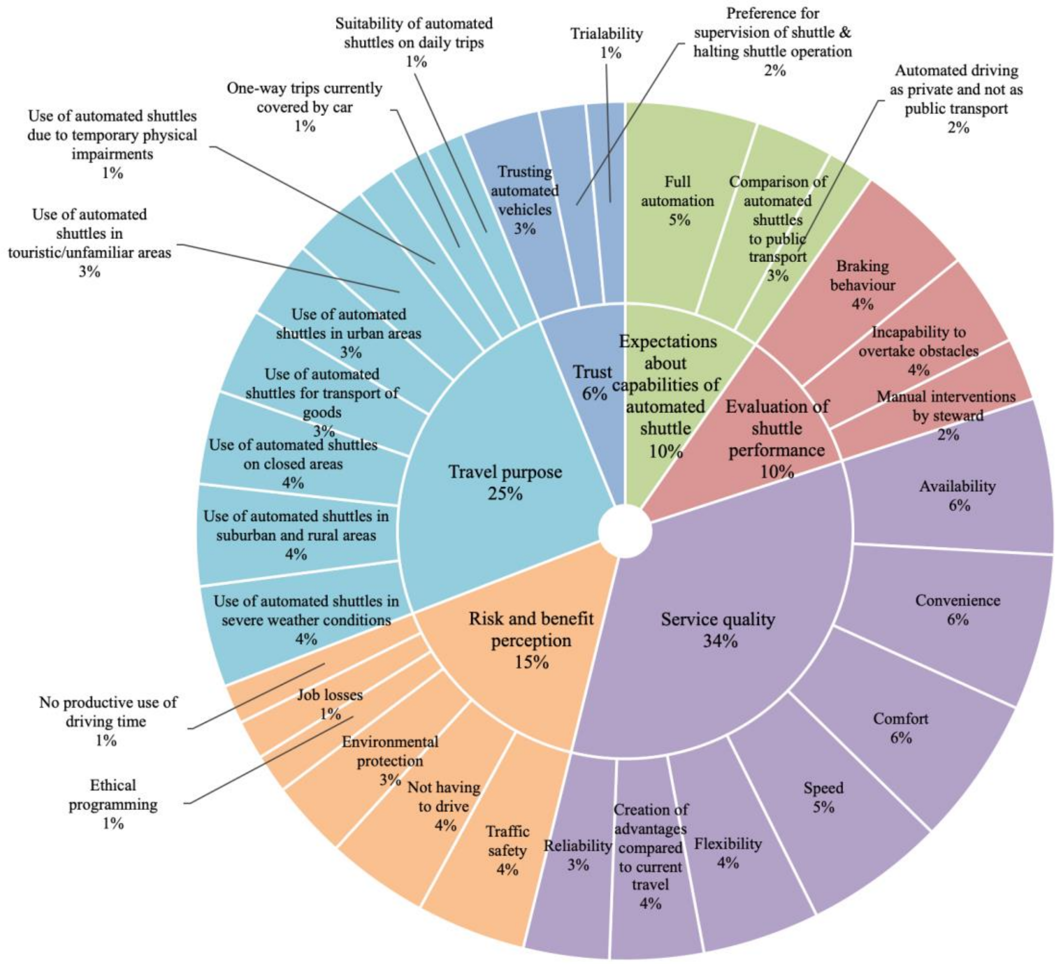

Figure 2. Pie diagram showing the six main categories and their corresponding thirty-one sub-categories.
Note: The arc length of the sectors corresponds to the number of quotes.

4.4.3. Main Category 1: Expectations about the capabilities of the automated shuttle

4.4.3.1. Full automation

Seventeen respondents expected the automated shuttle to be in a more advanced state of technological development. They had an idealized idea of the technological capabilities of an automated vehicle that resembled SAE Level 5 automation (SAE International, 2018). As two interview respondents explained:

> *„I find it rather strange that it is defined as automated driving when a steward is on-board who has to tell the shuttle that there is an obstacle on the road. And the shuttle does not know: Do I need to brake, avoid the obstacle now, or is the obstacle moving such as a car or pedestrian?"* (R01)

> *„I was a bit disappointed that the shuttle is not yet as advanced as I thought. I also found it interesting that the shuttle has to learn the route. I expected it to be much more autonomous."* (R17)

Another respondent referred to the several press releases, technology showcases at exhibitions, and test rides by prominent players in the field (e.g., Google, Tesla) that have contributed to the creation of unrealistic expectations. The respondent expected that automated driving is close to market launch with the technology already being there. The shuttle did not live up to the expectations of the respondent who expected a shuttle operating on every route and performing all driving manoeuvres in automated mode, with the steward intervening only on rare occasions. Instead:

> *„The shuttle was forced to run exactly on the route that was pre-programmed or on virtual tracks as they called it, which also meant that even the smallest deviation from the route prevented the system from continuing on the road in automated mode."* (R02)

Other respondents also blamed the media for creating unrealistic expectations:

> *„I would have expected Olli finding his own way like a private motor vehicle that picks me up from home and brings me to the station. This is the cliché of automated driving, the images of the Google cars which float in conventional traffic, that shape this idea."* (R03)

> *„In the media, automated vehicles are almost on the verge of a breakthrough and that it is great to drive alone in every situation, but we are still a long way away from that. The state of technology tends to be communicated in an exaggerated form. Many are not aware that fully automated driving is not available yet and have different ideas. A common notion is that of being driven; that people give up the largest part of driving, but they do not have sufficient information about what can be technically realized and to what extent. We are far away from a vehicle that can drive 130 km/h on its own and where people can put their feet up."* (R04)

Another respondent described the ride with the shuttle as disillusioning, yet still considered the ride as a valuable experience:

> *„I had a glorified idea and thought that the shuttle could drive alone, and then in the rain, it did not work properly, but I like it now to be aware of this and to come down to earth again. Now I have a more realistic idea. The ride was important for me to discover how far we*

> *are on the timeline of this technological development. This has not worsened my impression of this technology; it just helps me to position it more realistically."* (R06)

4.4.3.2. Comparison of automated shuttles to public transport systems

Ten respondents compared automated shuttles to current public transport systems, with three respondents explaining:

> *„In the end, the trip in the train also happens almost in automated mode. When I get on the train, that's a kind of automated driving. That a human being does this is not transparent to me. In public transport, I am already traveling in automated mode. Covering the last mile with the shuttle would be completely okay for me."* (R15)

> *„If you disregard all the unintentional braking, then that would have been a ride as with the Sky Train at Frankfurt Airport from Terminal 1 to 2."* (R22)

> *„Somehow Olli does not differ from a normal bus except for the fact that no driver is inside. From the user perspective, I do not mind at all whether there is someone in the front or not. If you disregard all the technical details, all the automated parts, then this is a normal bus that needs to drive like every normal bus. The same criteria apply."* (R29)

4.4.3.3. Automated driving as private and not as public transport

Six respondents stated that the idea of automated shuttles was new to them as they mainly perceived automated driving as private and not as public transport, with two respondents explaining:

> *„When I think about automated driving, I think about a car just driving itself. I have not thought about it in the context of like a shuttle. Whenever I think about an automated vehicle, it is a Tesla or a Chevy Volt."* (R08)

> *„It was new to me that it was a large vehicle for many people. I rather expected a Google vehicle or passenger vehicle, an individual vehicle rather than a mass vehicle that you need to share with others."* (R21)

4.4.4. Main Category 2: Evaluation of shuttle performance

4.4.4.1. Braking behaviour

Fifteen respondents mentioned the strong and abrupt braking behaviour of the shuttle, with three of them saying:

> *„I would not dare using the shuttle on public roads after the test ride now. During the ride a few minutes ago, the shuttle abruptly braked, and this is not something that is trustworthy. Before the test ride, I would probably have said yes to testing the shuttle on public roads without a steward onboard. Now I would say: Rather not!"* (R13)

„There was an abrupt braking, which was very uncomfortable." (R15)

„Not much was provided; the speed, the thing was not functioning consistently. Even on straight roads, the shuttle would slow occasionally. At this low speed, there is no reason for Olli to panic. At this speed, Olli could easily slow down and start again." (R19)

4.4.4.2. Incapability to overtake obstacles

Twelve respondents referred to the incapability of the shuttle to overtake obstacles on its trajectory, with five of them saying:

„And maybe because of the growing pains, that it couldn't react to obstacles at the moment. There were obstacles in the way, and the shuttle did not know: 'Do I have to brake or dodge now, or is this a moving obstacle, such as a car or pedestrian?'" (R01)

„A container in the middle of the road, which could have been easily overtaken, but the overtaking was not done autonomously. This is actually the opposite of automated driving." (R11)

„When I imagine that the thing stops every five meters in inner city traffic, then that would definitely be too annoying. If you are already driving at a low speed, then this is not convenient. There should be a smart way to deal with obstacles that is tolerable and adaptive in such a way that you do not have the feeling that everything comes to a standstill when a fly is blowing through." (R16)

„There were some obstacles on the road and the system was really lost. For example, there was a vehicle from the delivery company. I thought the shuttle would recognize this, identify it as a temporary obstacle and be programmed in a way that the chances are high that the vehicle will also move away soon because it is from the delivery company." (R23)

„I was a little bit disappointed by Olli. That he had to be controlled by hand to overtake every little obstacle, I would not have thought that." (R24)

4.4.4.3. Manual interventions

Eight respondents referred to the manual interventions by the steward, with two of them saying:

„Most of the time, the trip with the shuttle did not work. If you start with the expectation that I had before taking a ride with the shuttle: 'A self-driving thing, you sit inside, have no control, don't know exactly what it will do next.' This was not the case, because the shuttle was super slow, and there were two people there. That is, you were not alone, so to speak. They always made sure that nothing happened and that's why it wasn't as stressful of a situation as it could have been." (R07)

„*The trip was very nice, but I had the feeling that it was not so autonomous because the system consistently crashed.”* (R10)

4.4.5. Main Category 3: Service quality

4.4.5.1. Availability

Twenty respondents considered the instant availability of automated shuttles, high frequency of service operation, and short waiting times as factors that could positively affect the acceptance of automated shuttles in public transport. Five respondents explained:

„*It is also a question of availability. Like, my car sits there, and I can take it and just get in immediately. Sure, I can order Olli with a mobile phone an hour before, and it's there, and that works if I can estimate approximately when I finish work. But when I am spontaneously going out or if my plans change, I think that the car is simply more flexible.”* (R02)

„*Availability; that these things are available. What good is it to me if such a thing is basically there, but I have to wait an hour? If I have an appointment at 1 pm, and I don't order the vehicle 3 hours before, but maybe 15 or 5 minutes before and it isn't there, then that's not practical. This means that before I switch from my private car, I expect the vehicle to arrive within a period of 15 minutes. If it takes more than 15 minutes, then I can also easily walk to the next bus stop.”* (R07)

„*I would use Olli from the station if I know that Olli is always available and is running every few minutes or when I need it.”* (R16)

„*When I know upon arrival at the station that there is always a shuttle when I need it, then I would like using it more. Here we talk about waiting times of less than 5 minutes. When it takes the shuttle more than 5 minutes to arrive, I will not use it but try to find a different mode such as the bike or my feet. Assuming that the shuttle would always be available and arrive in less than 5 minutes, then the likelihood is very high that I would use it.”* (R18)

„*Waiting times are all the more important on the last mile because you can also walk the last part of the route easily.”* (R26)

4.4.5.2. Comfort

Having a comfortable journey was mentioned as important by nineteen respondents. Comfort was equated with comfortable seating, travelling in or with the back to the driving direction, access to seating including a place for luggage, free Internet, outside visibility, cleanliness, air conditioning, an attractive interior room, and the size of the shuttle. Three respondents explained:

„*To increase the attractiveness, of course, cleanliness and comfort are important. So, if the vehicle really did look like this vehicle here on the campus, but if I take a look at reality, in the train, I'll think:*

„Oh, I'd rather take the bike because I simply find this uncomfortable. If I have to decide between the underground train and the Olli, I would rather choose the automated shuttle as it makes a more comfortable and cleaner impression if this state corresponds with the real practice." (R01)

„Of course, you also want to sit comfortably, but you do not have to sit like in the car now. If it's similar to the current train, that's fine too. For longer trips, the seats might be too uncomfortable. It can be a bit more comfortable, where you can lean on. I find the seats in our current trains more comfortable." (R20)

„The question is simply how to bring a higher quality in public transport systems today. The higher the quality, the higher the acceptance." (R24)

It was also mentioned that automated shuttles could improve seating space and comfort compared to current public transport, making traveling more convenient, with one respondent explaining:

„I live 300 meters away from the train station; then I would need to travel 3 stops with the train and then I would need to walk 400 meters from the station to my workplace. Actually, it would not be a problem at all traveling by train, but I still take the car because of humans on the train. Hobos lying on the seats. Getting in an automated shuttle of this size will be more comfortable than taking the train." (R11)

4.4.5.3. Speed

Eighteen respondents mentioned the importance of travel time for the use of automated shuttles, with four of them saying:

„For me travel time is decisive. If I travel longer with Olli than with another travel mode such as the bike or bus, then I would choose the fastest travel mode. Even if the use of Olli were for free, I would not use it if it takes me longer than alternative travel modes." (R01)

„I was disappointed by the low speed. If I can travel faster than walking speed, I would use it. If not, I would rather walk." (R15)

„When I compare it with the bus, the bus is much faster. If I was to imagine travelling from A to B in the inner city, then the shuttle would be too slow. But when I'm at the airport and drive from the terminal to the gate, then speed does not matter. It has to be faster than walking. It does not have to be as fast as the car, but if it's going to be fast like, say cycling speed. When I think about riding from Friedrichshain to Schöneberg to visit a friend on a regular basis and the thing is jerking along the road at this tempo and I need 90 minutes to get there, then I would do it once, because I would find it exciting and funny to see the vehicle working, but only once and never again. The train would be faster in all situations." (R16)

> *„My expectations were largely fulfilled. I thought it would go faster. I could imagine using it if it drove faster and was more reliable. I will never get into the Olli if it drives 10 km/h or 30 km/h and that's how fast I get to work. It would definitely have to drive 50 km/h to match normal traffic."* (R25)

4.4.5.4. Convenience

Twenty respondents mentioned that convenience is a factor that would encourage them to use automated shuttles in public transport. Convenience refers to the provision of information about routes and interchanges, as well as functionality, accessibility for people with (temporary) physical impairments, and the ease of booking and payment of the shuttle. Five respondents explained:

> *„Explaining all the different parts of it, the stewards explaining where the sensors are and what they do and what they are supposed to do and what will happen, so giving all this context information really helps. Maybe if there is an obstacle, it could say „obstacle ahead", this is why it is stopping, more context and more explanations about how it generally works would be cool."* (R08)

> *„Sort of monthly ticket because if I just have the option not to think about the price, I would just buy it for convenience."* (R08)

> *„Its use has to be predictable. It should fit as seamlessly as possible into my driving behaviour, and I have to know when Olli is where. If I use the Olli as a shuttle, I need a certainty that I'm really getting on with it. Either there is a large number of Ollis around, so that a schedule is no longer necessary, or I get real-time travel information about departure times. I think I would use it very extensively, regardless of the weather."* (R15)

> *„What I have not seen so far was the interaction with the passenger. Where does the shuttle go to, what happens next? I want to know where the shuttle is driving to, how long will it take, will there be detours? Simply getting in and relying on it that it works would be difficult. Even though I order the shuttle via an app and if I get all the information over this channel or another channel, I think I would still miss a kind of display such as the one we have in trains today saying what comes next."* (R16)

> *„It has to be easy to use. My mother has a smartphone and uses apps on the smartphone. She would be able to do it. Someone without a smartphone should be able to order the shuttle by phone. It has to be orderable."* (R23)

> *„Obstacle-free access; the payment has to be uncomplicated. Its use has to be included in the public transport ticket."* (R29)

4.4.5.5. Flexibility

Fifteen respondents mentioned the provision of door-to-door transport as a positive factor that could enhance the acceptance of automated shuttles. Four respondents explained:

> *„If the shuttle drives a direct route instead of driving detours and is more flexible, demand-oriented, and if you can determine your own destination, this will be very nice."* (R11)

> *„If you can order it there must be a certain flexibility. If you have to wait two hours, that's bad. At best, it ensures that the shuttle takes over the flexibility offered by the private car."* (R23)

> *„If the Olli were to be used now and stops 3 times rather than 30 times like the normal bus, then maybe I drive 5−10 minutes longer than with my car, but that's okay. But if I need twice as long as the public bus. Olli would have to pick me up from home or pick me up nearby, 5 minutes of walking is okay."* (R25)

> *„If I have to decide between automated shuttles and my private car, I would opt for the shuttle if it picks me up at home and if I don't need to walk to the nearby bus stop. But I think it will never completely replace the car unless it works in the same way as my car. Then I do not need to go farther than in front of my doorstep, Olli picks me up exactly there where my parking space would be and drives me at the same speed to my destination. Okay, then I don't need to drive, but I don't mind whether I drive on my own or not. It is mainly a financial issue; the contingency costs are so high with a car. If I could do without it, this would be beneficial."* (R29)

4.4.5.6. Relative advantages of automated shuttles compared to current travel

Twelve respondents mentioned that the use of automated shuttles has to create advantages in comparison with the respondents' current travel. Three respondents explained:

> *„Usage depends on the benefits offered to you. If I have shorter waiting times, or if I get off where I can directly get the connection. You have to do it right, add value to how it works now."* (R11)

> *„It has to be better than the bus. This may mean shorter waiting times or shorter transport routes. Then it may not be more expensive than a cab; a cab is also around the station. The shuttle may take a longer route if it is cheaper than the cab. It should not be more expensive than the cab because the cab brings me to the door. In the worst case, the car smells, and the cab driver is rude."* (R21)

> *„There have to be very clear advantages compared to the status quo. If such a vehicle offers a timely and monetary advantage, then this would certainly help. But if it ends up in the same traffic congestion as the individual private car, then it barely has an advantage."* (R23)

One respondent predicted that automated shuttles would be accepted if their use generates the same advantages as the use of conventional cars:

„If I don't need to drive my own car anymore but have the same advantages as with my car and it does not cost me more, then it would be accepted." (R29)

4.4.5.7. Reliability

The reliability of automated shuttles was mentioned as an important criterion for the choice of automated shuttles by eleven respondents. Four respondents explained:

„Assuming that the current M29 will be replaced by an automated shuttle, then I would also take the shuttle. But I would only consider the shuttle superior to the bus if it was more reliable than the M29." (R18)

„The faster and the more reliable it drives, the higher its attractiveness is.
The thing has to work, no showstopper like today." (R22)

„The system needs to be developed in a way that it works reliably and is safe. This has to be taken for granted." (R23)

„Reliability: That a bus is coming when it should come, and I do not have to wait 20 minutes for the bus. That is one of the biggest factors. Taking the bus to work instead of the car takes me twice as long; I have to walk to the bus, then the bus does not come, then I stand in the rain, that's also an issue of reliability, which is usually not so great in my experience." (R25)

4.4.6. Main Category 4: Risk and benefit perception

4.4.6.1. Traffic safety

Fourteen respondents expected automated vehicles to be safer than manually controlled cars, with five of them explaining:

„There will always be a few people who want to drive their own car, but in the end, it will be like: ‚What? You still drive your car? That's so dangerous. You are not allowed to drive your own car in the city. I don't want my child to be run over by a crazy driver.' At some point, those who want to control their car themselves are socially looked down on, which will eventually encourage them to stop driving. I like technological progress and feel positive about automated driving because once the software works, then accidents can be avoided because accidents are caused by 100% human error and if we can reduce that to 10% human error, then many lives would be saved." (R06)

„I am pretty sure that computers are more trustworthy than humans because we have delayed reactions and can't really process things. And I am sure the computer also doesn't have these things: ‚Oh, my girlfriend broke up with me, and now I am feeling a little bit distracted.' It is really focused on one thing." (R08)

„Sure, driving a car is fun, but when I have the feeling that the automated vehicle can do it, or can do it better, then it can do the driving for me. Giving this up is not the big thing." (R12)

„And if the autonomous vehicles are really good, I think manual driving will be prohibited within the next 5-10 years for safety reasons because autonomous vehicles are substantially safer than human drivers." (R17)

„If traffic is automated, the frequency of accidents will certainly decline. There would not be such a chaotic driving on the streets anymore. That's why I think the trend is quite good." (R28)

4.4.6.2. Not having to drive

Not having to drive and being able to pursue non-driving tasks was considered an important aspect of automated vehicle acceptance by thirteen respondents. They considered driving as a stressful, unpleasant, costly, inefficient, tedious, and environmentally harmful activity, given the time lost while driving, the need to look for a free parking place, or the waste of resources that results from the large number of cars being unused. Three respondents said:

„For me, driving a car is not fun. I was already involved in a car accident, and it is simply stressful for me. Accordingly, I prefer to travel using public transport rather than owning a car, also because the high costs are unappealing to me. I find it harmful for the environment; I would not like the constant search for a parking space. There are so many reasons that completely rule out private car use." (R04)

„In private transport, automated driving is extremely useful, because it offers those people who now have a car the same possibilities. I order the vehicle, input a destination, and have my peace without having to drive myself." (R10)

„My dream is not to drive a car anymore. In fact, I like driving a car, but I don't like physically controlling it because it is stressful and I lose time. I would like to drive everywhere with automated busses and cars, and give up control. It is a desirable goal for the city and society that you can prevent accidents, release the driver and avoid traffic congestion." (R20)

One respondent pointed to his visual impairments and explained:

„I am really looking forward to self-driving cars. I can hardly wait for it because I hate driving cars and I hate owning cars. Driving on the road is stressful for me. Needing to change lanes constantly is stressful for me. I have bad vision because I am almost blind in my left eye, which makes it difficult to estimate the distance to the next car properly. Driving a car gives me no pleasure at all." (R07)

4.4.6.3. No productive use of driving time

Five respondents stated that they could not imagine working in an automated shuttle given the lack of anonymity and privacy, the difficulty to perform cognitively demanding tasks and the necessity to trust the automated driving system. The short trip length, motion sickness, the general liking of driving a car, and the conscious separation of working and private life are also factors. Regarding the short trip length, one respondent explained:

> *„When it comes to Olli, it would make me feel like being in the passenger seat as I would monitor the environment too much rather than being able to sit back and read a book. For this, I will reach my destination too early. I can only imagine doing small things on the smartphone such as replying to emails such as 'Are you attending the meeting on time?' – 'Yes, I will be there', but 'I do not take the bike but instead use Olli, because I can do some reading there' – this I don't see at the moment."* (R03)

One respondent pointed to difficulties to trust the system, and would monitor its operation:

> *„I would prefer more active safety systems in cities to autonomous driving as there won't be a break for the driver if you need to be attentive the whole time anyway. When I imagine using one of these Google cars, I couldn't imagine taking a newspaper because I would watch the road the whole time anyway. I think people would always be attentive because they don't trust the technology 100 percent. With man-made technology, there are always mistakes. I would always feel uneasy about it. It will take generations for people to trust the concept of a driverless car, and not pay attention anymore. As a passenger, you drive in the spirit of watching the road."* (R21)

4.4.6.4. Environmental protection

Ten respondents stated that they liked that the automated shuttle had electric propulsion. Two respondents explained:

> *„I like it that Olli has an electric propulsion. I think that private car use in cities should be restricted because of air pollution. If we want to continue living in large cities, then we need to restrict car use because otherwise, these cities will not be liveable in the long run. When you think about how some countries like China look like in terms of air pollution. I do not want to live here in Germany in such a city. This is why I find it extremely important to develop alternative propulsion systems."* (R04)

> *„In the long run, it is better for all people involved, because these cars produce fewer emissions because they are electric; they make no noise, and there will only be five percent of the current number of vehicles on the roads. Karl Marx Allee would be fantastic.* (R17)

4.4.6.5. Ethical programming and job losses

Five respondents mentioned the ethical programming of automated vehicles, as well as job losses that may arise due to road vehicle automation. These issues were not considered influential enough to halt the development of automated driving technology. Concerning the ethical programming of automated vehicles, two respondents said:

> *„A little girl is crossing the street. Killing the girl or driving against the wall and being killed? How does the vehicle decide? First, we need to realize that these events will occur less frequently because the sensors will definitely react faster than the human being who would definitely kill the girl. It is often overlooked that discussions such as these will occur less frequently because the human driver would definitely kill the girl. Until (s)he reacts, it is already too late. The car has at least the chance to react."* (R07)

> *„The question of acceptance is also related to ethical issues, that's a big point. The ethical and moral question is: A child jumps in front of the car. What should the computer decide? Can you do that at all? Is that morally justifiable? The ethical question is a question that has to be discussed, but it is no reason for me to reject automated vehicles."* (R24)

Concerning possible job losses, one respondent said:

> *„Of course, jobs will be lost. This is a bit critical, but will not stop this trend."* (R05)

4.4.7. Main Category 5: Travel purpose

Respondents envisioned the use of automated shuttles for different trip purposes. Thirteen respondents expressed their intent to use automated shuttles in severe weather conditions, and in suburban and rural areas or areas that are generally unserved by public transport. Twelve respondents indicated they would be willing to use shuttles in closed areas (e.g., exhibitions, large factories, airports, university campuses, retirement homes, hospitals). Eleven respondents indicated to be willing to use shuttles for the transport of goods, ten respondents expressed their interest in using automated shuttles in urban areas, and in touristic/unfamiliar areas. Three respondents explained:

> *„I would use the shuttle when it would be available, in areas where transit is not really good and where the walking distance to public transit is far so that you add mobility."* (R08)

> *„I would want to use it. For example, we had very bad weather on the second day of our tour, and it had soaked me completely. A shuttle like this would fix that. Sometimes I ride a bike in combination with taking the train, and I would actually use the bike less often if I then had the opportunity to use shuttles, especially in rainy weather."* (R15)

> *„If an automated shuttle like Olli is transporting me from where I live in an independent and regular way to the supermarket, I get in and drive five to eight streets to the supermarket, and the way back is equally independent, then I would probably always do this. This would be a very purpose-oriented and practical tool, and this would be a great thing."* (R16)

Another respondent posited that getting to and from the station generally discourages the use of public transport:

> *„Because then I don't need to take the tram to get to the station, the train from the station and from the station I still need to walk to my destination. Taking the direct route through the city is more direct, and it is usually quicker by a factor of 1.5."* (R16)

Five respondents expressed their interest in using automated shuttles because of physical impairments (e.g., pregnancy, early motherhood) or for one-way trips that are currently covered by the car. Five respondents questioned the suitability of automated shuttles on their daily trips. It was explained:

> *„With a travel time of 6 minutes, I would use Olli if I have something difficult to carry, or when I'm exhausted, but these are exceptional cases."* (R06)

> *„I would guess this is suitable for one-way routes. If I go by car to the station, I have to leave the car there somewhere, or if I want the car, it must be there somewhere. So I see it more as a comfortable variant of what I am using now when I arrive with a lot of luggage and use a car2go or drive now or anything else."* (R03)

> *„I was very positive towards automated shuttles in general, but when I think about it, I can't envision at all how I could use these shuttles on my daily trips as I live today in Berlin. Then I realized, I would not use them. The bike and underground system are simply quicker, and it is more practical in daily life. And I have my routines, and my daily trips are already routinized to a large extent; a shuttle would not be able to beat this."* (R18)

4.4.8. Main Category 6: Trust

4.4.8.1. Trusting automated vehicles

The relevance of trust for the use of automated shuttles was emphasized by ten respondents, with two of them saying:

> *„You also need to trust the system, but I also think that this develops over time. It is simply a habitual issue. In Copenhagen, there is also an automated underground train, and the passengers are not afraid anymore that the train is not properly driving or not stopping somewhere as planned."* (R10)

> *„I think the most important factor is trust, especially with the elderly generations, who are afraid of fully or partially automated driving. I believe the most important point is to create trust that the vehicle works. During our ride, the shuttle stopped on the middle of the route and braked abruptly. This is something that does not build trust."* (R13)

Trust might be contingent on the type of environment in which automated vehicles are being trialled, as emphasized by the following respondent:

> *„What has not been properly tested here is the driving in normal traffic. The driving experience will likely be different in a normal traffic situation compared to a closed campus situation where the feeling of safety is likely to be higher.”* (R01)

4.4.8.2. Supervision and control

Six respondents indicated to prefer supervision of automated shuttles via an external control room or a steward onboard over unsupervised automation or to halt the actions of automated shuttles via an emergency button inside the vehicle. According to three respondents:

> *„It needs a human being at the beginning inside the shuttle, who is explaining the system. First, to create trust and second, to provide explanations and understanding and thus dismantling fears because I can imagine that people are still insecure and do not trust the system if they do not have any possibility to control it. I can imagine that some people feel powerless then. The system is driving against the wall. What can I do? Maybe an emergency button would help, but experience also shows that these buttons are often used and misused. I also saw the emergency button and wondered whether I would be able to react in time if sitting in the back seat when the emergency button is at the door in the front.”* (R03)

> *„Having the option to control the vehicle, for example, by pressing an emergency button if there is an obstacle that the car can’t see. Having the option there would be really nice. There is perhaps always the concern that the sensors don’t see something, but the human eye does. Having a steward in the beginning is a good way, without it would be kind of weird because you don’t know what is going on and having a steward there is probably reassuring because I would perceive it like: 'Oh this person knows a lot more about the vehicle than I do, I could ask him stuff about it, it is like asking a human.’”* (R08)

> *„The automated shuttle can be supervised by an external control room. I would not like it if the shuttle isn’t being supervised at all anymore, but if an external control room supervises it, this would not be a problem for me. One person, for example, could control ten shuttles at the same time.”* (R20)

4.4.8.3. Trialability

Five respondents mentioned the importance of putting automated shuttles to trial, and to expose the public to automated driving technology to reduce fear and scepticism, with one of the respondents motivating his view as follows:

> *„Lots of people cannot imagine it. If you have more demos, then more people try it and then more people will probably accept it.”* (R09)

4.5. Discussion

The aim of this interview study was to acquire in-depth knowledge of people’s expectations about automated driving technology and the alignment of those expectations with actual experiences with the automated shuttle during the ride. Also, the factors that affect respondents' intentions to use automated shuttles as feeders to transport systems were explored. Based on the interview quotes, we identified six categories that are relevant to the intention to use automated shuttles in public transport: (1) expectations about the capabilities of the automated shuttle (10% of 340 quotes), (2) evaluation of the shuttle performance (10%), (3) service quality (34%), (4) risk and benefit perception (15%), (5) travel purpose (25%), and (6) trust (6%).

4.5.1. Expectations about the capabilities of the automated shuttle and shuttle performance

Respondents expected a higher level of autonomy of the shuttle in reacting to obstacles and in finding its route independently without the reliance on pre-programmed routes. The majority of our respondents had an idealized expectation of the technological development state and were disappointed by the prototype shuttle they physically experienced during their ride. These findings correspond to Fernández Medina and Jenkins (2017), who found that respondents who took a ride in a driverless shuttle reported that the driverless vehicle/journey did not meet their expectations and had disappointed them, as the vehicle operated at a limited speed and was supervised by a steward onboard.

The results of the interviews suggest that the respondents' idealized expectations were, in part, the result of an ambitious portrayal of automated vehicles in the media. This notion is consistent with Parkhurst and Lyons (2018), who pointed to the existence of positive expectations and a hype about the adoption of automated vehicles and their capabilities. Contrastingly, Shariff, Bonnefon, and Rahwan (2017) mentioned the disproportionate media coverage of crashes involving autonomous vehicles, which may amplify people's fears. The development of incorrect expectations can be harmful to long-term acceptance (Nees, 2016). Incorrect expectations may be mitigated by an accurate portrayal of the benefits and risks of driverless transportation in the media, for example, by emphasizing the safety advantages of automated vehicles compared to manual drivers, while avoiding claims about infallibility (Shariff et al., 2017).

4.5.2. Service quality

The service quality category received a large number of mentions by respondents, which suggests that service quality is an important determinant of the acceptance of automated shuttles. Among the service quality aspects, respondents appreciated the provision of a flexible door-to-door service, which current public transport systems are unable to offer. This finding corresponds with Shen et al. (2018), who postulated that a door-to-door service would make automated vehicles attractive. The positive outlook of respondents is conditional on requirements of speed and reliability: A large number of respondents indicated that the current shuttle speed was too slow to be of real use on their daily mobility trips.

4.5.3. Risk and benefit perception, and travel purpose

Our results showed that respondents supported the idea of using automated shuttles in public transport. They appreciated the idea of not having to drive and the potential of automated vehicles to reduce traffic accidents, which mirrors the literature (e.g., Bansal et al., 2016; Daziano, Sarrias, & Leard, 2017; Portouli et al., 2017).

Studies have shown that passengers perceive the interaction with other people in public transport both positively (e.g., a way for passengers to be entertained) and negatively (e.g., as noise, disturbance) (Beirão & Cabral, 2007; Carreira, Patrício, Natal Jorge, Magee, & Van Eikema Hommes, 2013). Because automated shuttles accommodate passengers in a smaller space compared to conventional public transport (e.g., bus, train), automated shuttles could magnify privacy issues. A number of respondents pointed out that lack of personal privacy in shuttles may discourage them from engaging in cognitively demanding tasks. This finding contradicts the commonly held assumption that travellers will use automated vehicles to make productive use of their travel time (König & Neumayr, 2017; Robertson, Meister, Vanlaar, & Hing, 2017). However, our finding is consistent with Singleton (2018), who argued that users of automated vehicles might not use their newly available travel time for productive in-vehicle activities (see also Cyganski et al., 2015; Milakis et al., 2017). Of course, passengers may still tolerate the lack of privacy and the inability to engage in cognitively demanding activities (e.g., work), if the automated shuttle improves the efficiency of their transport. Kyriakidis et al. (2015) found that there are national differences in public opinion towards automated driving. Their results suggest that people in higher-income countries are more concerned with data privacy of automated vehicles. Future research should investigate the effect of travelling with fellow travellers on the perception of privacy and pleasure of the ride across different cultures and income regions.

Issues related to adverse socioeconomic outcomes (e.g., job losses), and the ethical programming of automated vehicles were addressed by a relatively small number of respondents. Respondents may have found it difficult to speculate on the long-term socioeconomic implications of automated shuttles. Cavoli, Phillips, Cohen, and Jones (2017) pointed out that the long-term effects of automated vehicles are currently unclear. Adnan, Nordin, Bahruddin, and Ali (2018) assumed that ethical questions have not been sufficiently and transparently discussed, and that ethical issues related to accidents are still hypothetical, given that highly or fully automated vehicles are not yet available on the market. Following the recommendations of Adnan et al. (2018), future research should more closely investigate the relationship between the ethical implications of automated driving and user acceptance of automated driving technology.

4.5.4. Trust

Twenty percent of the respondents (6/30) indicated to prefer supervision of the shuttle from an external control room or steward onboard over unsupervised full automation. The desire for human control corresponds to questionnaire studies, where few people were comfortable without any type of supervision. Similarly, Liljamo, Liimatainen, and Pöllänen (2018) reported that 90% of respondents preferred that automated vehicles should also be manually driveable, while 92% of respondents would also like to determine where, when, and which automated functions to use. In this regard, research on automated vehicle acceptance would profit from drawing analogies to other domains, such as driverless trains and even pilotless aircraft. Fraszczyk and Mulley (2017) found that respondents rated having a driver on driverless trains as (very) important and preferred to include a driver cab on driverless trains. Rice et al. (2014), who investigated opinions about autonomous auto-pilots for commercial flights, found that respondents were more comfortable/trusting/willing to use the aircraft with the human pilot in comparison to the auto-pilot (fully autonomous machines that operate without interference with human pilots), or a human pilot in a ground station remotely controlling the aircraft. Control mechanisms inside (e.g., an emergency button to halt the shuttle's operation, S.O.S. button to connect the shuttle to a technical cite centre) or outside the shuttle (e.g., remote supervision of shuttle) could be deployed to compensate for the perceived loss of control and the negative perception of safety.

4.5.5. Comparison with previous questionnaire research

The findings obtained in this interview study are in line with a previous questionnaire study with 384 respondents experiencing the same shuttle ride as in the current study (Nordhoff et al., 2018a). That is, both in the questionnaire study and the interview study, respondents were least satisfied with the shuttle speed. However, in the previous questionnaire study, respondents were overall more positive towards using automated shuttles, as shown by their strong agreement with general questions on their intended use of automated shuttles as feeders to public transport (e.g., “I would use an electric driverless vehicle from the train station or some other public transport stop to my final destination or vice versa”). The questionnaire items may have elicited a so-called “yea-saying behaviour” (Kiesler & Sproull, 1986, p. 404; Nordhoff et al., 2018b) among respondents due to lack of time or willingness for critical reflection. In the present interviews, respondents were given the opportunity to reflect on their experiences and provide insights into their needs and the way automated shuttles should be commercialized. This opportunity for in-depth reflection may explain their critical, albeit still positive, stance toward automated shuttles in public transport.

4.5.6. Study strengths and limitations

So far, there was limited knowledge of the public about automated vehicles (Sanbonmatsu et al., 2018) and an uncertainty of what the public understands about driverless technology and how the technology can form part of their lives in the short- and middle-run (Langdon et al., 2017).

Our interview study is one of the few studies which explored respondents’ critical in-depth reflections on their direct experiences with automated shuttles, their ideas and expectations about automated driving technology, as well as the factors affecting automated vehicle acceptance. Qualitative studies are particularly effective in exploring relatively new or unknown phenomena such as automated vehicles (Fernández Medina & Jenkins, 2017). The knowledge offered by the present interview study improves the understanding of the public’s attitudes towards automated vehicles and inform future quantitative research.

A limitation of our study is that the respondents rode the shuttle alone, and were asked to reflect on using automated shuttles as feeders to transport systems on their daily trips. Thus, respondents were asked to imagine a hypothetical use of shuttles that has not formed a part of their daily mobility lives. Second, the 8–12 minutes test ride may have been insufficient for establishing familiarity and stable attitudes. Some of our findings are thus of a preliminary nature, reflecting initial beliefs around automated vehicles. Third, face-to-face interviews have the risk of producing specific forms of bias, for example, due to the tone of the questions asked and facial expressions of the interviewer (Bowling, 2005). Future interview research could be conducted using a higher degree of anonymity. For example, anonymous telephone interviews could be performed (Knox & Burkard, 2009). A fourth limitation of the present study is its use of a convenience sample that overrepresents males with an academic background, who travel with environmentally-friendly modes of transport (e.g., public transport, walking), and already participated in former experiments of carsharing or electro-mobility projects of the InnoZ (see Table 1). Their attitudes may not be representative of the general population, but of the specific group of early adopters and innovators with a high interest in progressive technologies. We recommend future research using larger gender-balanced samples that are representative of the entire population.

4.6. Conclusions

This interview study classified people’s quotes concerning the acceptance of a driverless shuttle in terms of technological expectations, shuttle performance, service quality, risk and benefit perception, travel purpose, and trust. People had idealized expectations regarding the technical capabilities of an automated shuttle, which did not correspond with the actual technological capabilities of the shuttle. A large number of respondents indicated that the current shuttle speed was too slow to be of real use on their daily mobility trips. The interviews further suggest that respondents' idealized expectations were the result of the ambitious portrayal of automated driving in the media. Respondents regarded service quality as a particularly important determinant of the acceptance of automated shuttles. In general, respondents were positive towards the future use of automated shuttles in public transport. A number of respondents indicated to prefer having a steward on-board or in a control room and did not think that the shuttle allows them to engage in cognitively demanding tasks such as working. We recommend to improve the technical capabilities and service quality of automated shuttles in order to be accepted. The present results provide a sobering outlook on the current hype that surrounds automated public transport and provides various important leads regarding how to make driverless shuttles acceptable to the public.

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4.8. Appendix A. Supplementary material

Table S1. Overview of selected socio-demographic information of respondents R01–R30

Respondent ID	Gender	Age	Living situation	Highest educational qualification	Type of daily transport modes	Access to valid driver license
R01	Female	31–35	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Biking	Yes
R02	Male	26–30	Within the city, but outside the city centre in a purely residential area	Pupil, student, apprentice	Biking, walking > 500 meters per trip	Yes
R03	Male	41–45	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Biking, walking > 500 meters per trip	Yes
R04	Male	21–25	In an apartment in the immediate city centre	Pupil, student, apprentice	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R05	Male	31–35	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Biking, walking > 500 meters per trip	Yes
R06	Male	21–25	In an apartment in	Completed academic studies (university,	Public transport < 100 km per trip	Yes

			the immediate city centre	technical college, academy)		
R07	Male	36–40	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, conventional car, walking > 500 meters per trip	Yes
R08	Female	26–30	Within the city, but outside the city centre in a purely residential area	School leaving examination/qualification	Public transport < 100 km per trip	Yes
R09	Male	56–60	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Biking, walking > 500 meters per trip	No
R10	Male	41–45	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Biking	Yes
R11	Male	26–30	In an apartment in the immediate city centre	Pupil, student, apprentice	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R12	Male	46–50	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Conventional car	Yes
R13	Male	31–35	In a house on the city outskirts	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R14	Male	51–55	In a house on the city outskirts	School leaving examination/qualification	Public transport < 100 km per trip	Yes
R15	Male	41–45	In a house on the city outskirts	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R16	Male	–	–	–	–	–
R17	Male	41–45	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R18	Female	31–35	In an apartment in the immediate	Completed academic studies (university, technical college,	Public transport < 100 km per trip, biking,	Yes

			city centre	academy)	walking > 500 meters per trip	
R19	Male	51–55	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Biking, walking > 500 meters per trip	Yes
R20	Male	36–40	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Biking, public transport < 100 km per trip	Yes
R21	Male	51–55	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R22	Male	–	–	–	–	–
R23	Male	–	–	–	–	–
R24	Male	56–60	In an apartment in the immediate city centre	School leaving examination/qualification	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R25	Female	26–30	In a house on the city outskirts	Completed academic studies (university, technical college, academy)	Conventional car	Yes
R26	Female	–	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Conventional car, walking > 500 meters per trip	Yes
R27	Male	31–35	Within the city, but outside the city centre in a purely residential area	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip, walking > 500 meters per trip	Yes
R28	Male	56–60	In an apartment in the immediate city centre	School leaving examination/qualification	Biking, walking > 500 meters per trip	Yes
R29	Male	41–45	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Public transport < 100 km per trip	Yes
R30	Male	–	In an apartment in the immediate city centre	Completed academic studies (university, technical college, academy)	Conventional car, walking > 500 meters per trip	Yes

Note: The questionnaires on the socio-demographic information of the respondents R16, R22, and R23 were not returned. Respondents R26 and R30 did not provide information on their age.

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Chapter 5: Structural equation modeling discloses interrelationships between predictors of automated vehicle acceptance

5.1. ABSTRACT

The present study investigated the interrelationships between constructs predicting individuals' intentions to use driverless automated vehicles based on the Unified Theory of Acceptance and Use of Technology (UTAUT). Data was gathered from individuals who physically experienced an automated vehicle moving in an open and mixed traffic environment on public roads in Trikala (Greece) as part of the CityMobil2 project. Structural equation modelling showed that behavioural intentions to use automated vehicles are most strongly driven by hedonic motivation, followed by performance expectancy, and social influence. Our findings further revealed that effort expectancy and social influence explained 66.6% of the variance in performance expectancy. Facilitating conditions and social influence accounted for 62.9% of the variance in hedonic motivation. Facilitating conditions explained 70% of the variance in effort expectancy. Social influence explained 13.7% of the variance in facilitating conditions. Car use was a negative predictor of the intention to use automated vehicles in public transport, contributing to a marginal increase in the variance explained in behavioral intention from 68.9% to 71.9%. Technology savviness was a positive predictor of facilitating conditions, and social influence, explaining 8.2% of the variance in facilitating conditions, and 2.4% of the variance in social influence, respectively. It was a negative predictor of performance expectancy, contributing to a slight increase in the variance in performance expectancy from 66.6% to 66.7%. We further found that the relationship between social influence and facilitating conditions changes as a function of technology savviness. Future research should revisit the interrelationships between the UTAUT constructs and apply (quasi-) experimental studies to unravel the temporal interaction between constructs.

Nordhoff, S., Madigan, R., Van Arem, B., Merat, N., & Happee, R. (under review). Structural equation modeling discloses interrelationships between predictors of automated vehicle acceptance.

5.2. Introduction

The debate on how to reduce car ownership and car use has been ongoing for at least four decades (Cullinane, 2002). Governmental policies to encourage the use of public transport tend to yield marginal and temporary reductions in private car use, and often lead to car redistribution rather than reductions in car traffic, congestion and environmental pollution (Cullinane, 2002; Younes, 1995). Hensher (1998, p.193) asserted that *"no public transport system within affordable political budgets is ever likely to provide a level of service of sufficient appeal to attract a large number of car users to switch to public transport"*. The advent of automated vehicles as feeders to public transport systems could instigate a paradigm shift towards more environmentally-friendly mobility by covering both the access and regress end of a public transport trip, thereby increasing the efficiency of public transport (Soteropoulos, Berger, & Ciari, 2019). With driverless operation, smaller vehicles become relatively economic, creating scope for flexible on-demand 24/7 operation.

Automated vehicles as feeders to public transport systems are currently being tested in a number of public trials, mostly in low-speed, controlled, semi-public environments. The commercial deployment of automated vehicles in more dynamic, mixed traffic situations on public roads is expected soon, probably by the end of this decade (Beiker, 2019; Stocker & Shaheen, 2019). These expectations, however, can only be realized if automated vehicles are accepted and used as intended.

A growing body of literature is examining automated vehicle acceptance. This study builds on the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Thong, & Xu, 2012). UTAUT posits that performance expectancy (i.e., degree to which using a technology will provide benefits to consumers in performing certain activities), effort expectancy (i.e., degree of ease associated with consumers' use of technology), social influence (i.e., degree to which consumers perceive that important others believe they should use a particular technology), and facilitating conditions (i.e., consumer's perceptions of the resources and support available to perform a behavior) influence the behavioral intention of an individual to use a technology, while behavioral intention and facilitating conditions determine actual system usage (Venkatesh, Morris, Davis, & Davis, 2003). UTAUT2 suggests that an individual's behavioral intention to use information technology is influenced by three constructs in addition to the original UTAUT, i.e., hedonic motivation (i.e., fun or pleasure derived from using a technology), price value (i.e., monetary cost of technology use), and habit (i.e., degree to which an individual believes the behavior to be automatic) (Venkatesh, Thong, & Xu, 2012, p. 161).

Madigan et al. (2017) showed that the UTAUT constructs performance expectancy, social influence, facilitating conditions, and hedonic motivation predict behavioral intention to use driverless public transport. This paper aims to enhance our understanding of the process leading to behavioural intention investigating the interrelations between the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation. The relevance of examining the relations between technology acceptance constructs has been acknowledged (Karahanna, Agarwal, & Angst, 2006). There is still limited knowledge about the interrelations between the various factors impacting automated vehicle acceptance, including the UTAUT constructs. Acheampong and Cugurullo (2019) argue that automated vehicle acceptance is a complex and multifaceted research theme that can only be fully understood when an interdisciplinary perspective is adopted and the interrelations between different acceptance factors are considered. For example, while the literature on automated vehicle acceptance has identified the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation as predictors of individuals' intentions to use automated vehicles, there is limited knowledge about the factors that determine the UTAUT predictors. Thus, instead of asking *„To what extent do performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation predict the intention to use automated vehicles?"*, we direct our attention to research questions like: *„Which factors predict performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation?*" Examining the interrelations between the UTAUT constructs thus enables us to identify underlying beliefs and devise adequate strategies to promote automated vehicle acceptance.

Madigan et al. (2017) did not consider the influence of car and public transport use, technology savviness and automated vehicle experience on the UTAUT predictor constructs and behavioral intention. Prior research has supported the role of these factors for automated vehicle acceptance (Asgari & Jin, 2019; Bansal, Kockelman, & Singh, 2016; Lavieri et al., 2017; Shabanpour et al., 2017; Nordhoff et al., 2019). For these reasons, the present study examines the relationships between these factors and the UTAUT constructs.

5.2.1. Research objectives

The objectives of the current study, conducted as part of the CityMobil2 project, were therefore to examine:

(i) Relationships between the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions and hedonic motivation;
(ii) Relationships between a person's travel behaviour (i.e., measured by car and public transport use) and the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, hedonic motivation and individuals' behavioural intentions to use automated vehicles in public transport;
(iii) Relationships between a person's technology savviness and the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, hedonic motivation and individuals' behavioural intentions to use automated vehicles in public transport.
(iv) Relationships between a person's automated vehicle experience and the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, hedonic motivation and individuals' behavioural intentions to use automated vehicles in public transport.

5.2.2. Main effects of UTAUT constructs

The relevance of the UTAUT constructs performance and effort expectancy, social influence, hedonic motivation and facilitating conditions to predict behavioural intentions to use automated vehicles has been supported by various studies (Kaur & Rampersad, 2018; Madigan et al., 2016; Madigan et al., 2017; Panagiotopoulos & Dimitrakopoulos, 2018; Xu et al., 2018). In line with these studies we propose the following hypotheses:

> ***H1–H5:*** *Performance expectancy (H1), social influence (H2), facilitating conditions (H3), hedonic motivation (H4) and effort expectancy (ease of use) (H5) will have a positive effect on respondents' ratings of behavioral intention.*

5.2.3. Interrelationships between UTAUT constructs

Zhang et al. (2019) and Panagiotopoulos and Dimitrakopoulos (2018) found positive effects of perceived ease of use on perceived usefulness, which reflects the literature on technology acceptance (Adams, Nelson, & Todd, 1992; Chang et al., 2015; Karahanna, Agarwal, & Angst, 2006; Venkatesh & Davis, 2000). We hypothesize:

> ***H6:*** *Effort expectancy will have a positive effect on respondents' ratings of performance expectancy.*

Empirical evidence for the relationship between facilitating conditions and effort expectancy, performance expectancy, and hedonic motivation is scarce. It is likely that supportive infrastructure will encourage individuals to come to believe that automated vehicles are easy to use, useful and pleasurable. In Merat et al. (2018), respondents showed a preference for automated vehicles travelling in a designated lane, showing the link between the infrastructure provided and people's attitudes towards automated vehicles. Thus, we hypothesize:

> ***H7–H9:*** *Facilitating conditions will have a positive effect on respondents' ratings of performance expectancy (H7), effort expectancy (H8), and hedonic motivation (H9).*

As Venkatesh and Davis (2000) assumed relationships between subjective norm and perceived usefulness, Acheampong and Cugurullo (2019) addressed the interrelationships between the UTAUT constructs and found positive effects of subjective norm (equivalent to social influence) on the perceived benefits (equivalent to performance expectancy, see Xu et al., 2018; Zhang et al., 2019), and ease of use of automated driving technology (equivalent to effort expectancy), and a positive relationship between subjective norm and perceived behavioral control (equivalent to facilitating conditions). Koenig-Lewis et al. (2015) supported the positive relationship between social influence and perceived usefulness and ease of use. The relationship between social influence and hedonic motivation has been under-investigated. We assume a positive relationship between social influence and hedonic motivation. In line with Venkatesh and Davis (2000), the underlying assumptions for all these hypotheses are that if individuals think that people important to them believe they should use automated vehicles, they are more inclined to comply with the referents and believe that automated vehicles are useful, easy to use, that they have the necessary resources, and that automated vehicles are enjoyable. We hypothesize:

> ***H10–H13:*** *Social influence will have a positive effect on respondents' ratings of performance expectancy (H10), effort expectancy (H11), facilitating conditions (H12), and hedonic motivation (H13).*

Studies have further provided empirical evidence for positive effects of perceived enjoyment (equivalent to our construct hedonic motivation) on perceived usefulness (equivalent to performance expectancy) and ease of use (equivalent to effort expectancy) in the field of technology acceptance (Koenig-Lewis et al., 2015; Teo & Noyes, 2011). The underlying assumption is that if automated vehicles are perceived to be enjoyable, individuals will be more inclined to believe that automated vehicles are useful and easy to use. We hypothesize:

> ***H14–H15:*** *Hedonic motivation will have a positive effect on respondents' ratings of performance expectancy (H14) and effort expectancy (H15).*

5.2.4. Car and public transport use

The private car has remained the most attractive mode of transport despite creating serious collective disadvantages, such as traffic congestion, accidents, and environmental pollution (Beirão & Cabral, 2007; Tertoolen, Van Kreveld, & Verstraten, 1998). It has been associated with a source of sensation seeking, power, freedom, status, superiority, convenience, speed, comfort, rapidity, and flexibility (Anable & Gatersleben, 2005; Beirão & Cabral, 2007; Hagman, 2003; Jensen, 1999; Steg, 2005). We would expect a negative relationship between the frequency of car use and the intention to use automated vehicles in public transport, and a positive relationship between public transport use and the intention to use automated vehicles as an extended arm of public transport. In Nielsen and Haustein (2018), individuals with significantly higher concerns regarding self-driving cars reported a higher share of driving on a daily basis compared to individuals who were indifferent and enthusiastic towards self-driving cars. Zmud and Sener (2017) found that car users were less likely and users of other modes of transport (e.g., walking, vehicle passengers) more likely to use automated vehicles, and Nazari, Noruzoliaee, and Mohammadian (2018) found a negative relationship between daily vehicle miles travelled and the inclination towards private and shared automated vehicles. It was further found that individuals who frequently travel with non-car travel modes (i.e., public transport, biking, walking) are more likely to be interested in automated vehicle technology. Haboucha, Ishaq, and Shiftan (2017) revealed that individuals who never use public transport were less likely to use shared automated vehicles, which corresponds with Lilijamo, Limatainen, and Pöllänen (2018) who found that individuals using public transport and who do not have a car had more positive attitudes towards automated vehicles.

There is still a paucity of knowledge about how car and public transport use affect the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation. To the best of our knowledge, our study is the first that investigates such a relationship. We hypothesize that individuals who frequently use a car will find automated vehicles in public transport less useful in attaining their mobility needs than individuals who frequently use public transport. The underlying assumption is that reliability, frequency, accessibility, and competitive costs were the frequently cited reasons that motivate car use and discourage the use of public transport (Redman et al., 2013).

We further hypothesize that individuals who frequently use a car find automated vehicles in public transport less easy to use and are less likely to believe that they have the necessary resources to use automated vehicles in public transport than frequent public transport users. This corresponds with Hine and Scott (2000) who found that car users were more concerned about way-finding through an interchange and their need for information about travel than users of public transport.

We further expect that car users will find automated vehicles in public transport less enjoyable than frequent users of public transport. Asgari and Jin (2019) provide empirical evidence for a negative relationship between the enjoyment of driving and the adoption of automated vehicles and the willingness to pay for automated driving features, which corresponds with Haboucha, Ishaq, and Shiftan (2017) who found that individuals who enjoy driving a car were more likely to use their regular car than an automated vehicle. We hypothesize:

> ***H16–H20:*** *Car use will have a negative effect on respondents' ratings of performance expectancy (H16), effort expectancy (H17), facilitating conditions (H18), hedonic motivation (H19), and behavioural intention to use automated vehicles in public transport (H20).*

> ***H21–H25:*** *Public transport use will have a positive effect on respondents' ratings of performance expectancy (H21), effort expectancy (H22), facilitating conditions (H23), hedonic motivation (H24), and behavioural intention to use automated vehicles in public transport (H25).*

5.2.5. Technology savviness

In MAVA, our multi-level model on automated vehicle acceptance, technology savviness is associated with an individual's innovativeness, the number and type of technologies used, curiosity, technology readiness, openness, interest, or optimism (Nordhoff et al., 2019). On the basis of a literature review of surveys about automated vehicles, Gkartzonikas and Gkritza (2019) defined consumer innovativeness as concept that can potentially influence an individual's intention to take a ride in an automated vehicle. In the study of Asgari and Jin (2019), Lavieri et al. (2017) and Shabanpour et al. (2017), tech-savvy individuals were more likely to be early adopters of autonomous vehicles. Nazari, Noruzoliaee, and Mohammadian (2018) found that mobility-on-demand (MOD) savviness (i.e., owning a smartphone, frequency of using app-based carsharing and ride-sourcing) was positively correlated with an interest in automated vehicle technology, and an interest in commuting with automated vehicles. These studies provide empirical evidence for a positive relationship between technology savviness and the intention to use automated vehicles.

While there is empirical evidence for the relationship between technology savviness and behavioral intention, there is still limited understanding of how technology savviness is related to the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation. Bansal, Kockelman, and Singh (2016) found more positive attitudes towards automated vehicle technologies among technology-savvy individuals. We hypothesize that tech-savvy individuals will be more likely to consider automated vehicles useful (i.e., performance expectancy), and enjoyable (i.e., hedonic motivation) because they are more open towards and interested in new technologies and more likely to see the added value of automated vehicles. Furthermore, due to their technology affinity, they are more likely to believe they have the necessary resources to use automated vehicles (i.e., facilitating conditions), and that it is easy to learn how to use automated vehicles (i.e., effort expectancy). As they are more likely to be surrounded with like-minded peers, they are also more likely to believe that people important to them will appreciate their use of automated vehicles (i.e., social influence). We hypothesize:

> ***H26–H31:*** *Technology savviness will have a positive effect on respondents' ratings of performance expectancy (H26), effort expectancy (H27), facilitating conditions (H28), hedonic motivation (H29), social influence (H30), and behavioral intention to use automated vehicles (H31).*

5.2.6. Automated vehicle experience

The intention to use automated vehicles is a function of an individual's knowledge of and experience with automated vehicles (Nordhoff et al., 2019). Berliner, Hardman, and Tal (2019) found that individuals who reported a higher level of knowledge of automated vehicles were more interested in purchasing them. The scientific literature further supports the relationship between automated vehicle experience and performance and effort expectancy. Liu, Guo, Ren, Wang, and Xu (2019) found that individuals who heard of self-driving vehicles gave higher ratings to the perceived benefits of automated vehicles (equivalent to performance expectancy), and to items that pertain to the trust in automated vehicles, while they gave lower ratings to the perceived dread and perceived risks of automated vehicles. This corresponds with Liu, Xu, and Zhao (2019) who found that respondents' ratings of positive affect, perceived benefit, acceptance of road tests and social trust increased, while their ratings of negative affect and perceived risk decreased. Xu et al. (2018) revealed that experience with automated vehicles increased the perceived usefulness and ease of use of automated vehicles, and increased the strength of the effects of perceived usefulness and ease of use on individuals' intentions to use automated vehicles. These findings correspond with research on the determinants of electronic health records where experience had positive effects on the perceived usefulness and ease of use (Tubaishat, 2017). While empirical research supports the relationship between automated vehicle experience, performance and effort expectancy and behavioural intention, there is a paucity of knowledge how experience affects the UTAUT constructs facilitating conditions and hedonic motivation. We hypothesize:

> ***H32–H36:*** *Experience with automated vehicles will have a positive effect on respondents' ratings of performance expectancy (H32), effort expectancy (H33), facilitating conditions (H34), hedonic motivation (H35), and behavioral intention to use automated vehicles (H36).*

5.3. Method

5.3.1. Procedure

The results reported here were part of a 57–item questionnaire, which was administered to users of an automated vehicle in Trikala (Greece) via tablet computers between December 2015 and February 2016. This demonstration involved six automated vehicles from the French company Robosoft that operated on a dedicated lane on a route of 2.5 km with eight stops in Trikala city centre. The vehicle carried up to 10 passengers per trip and ran at an average speed of around 13 km/h. A steward was onboard the vehicle to intervene in the vehicle operations when requested by the automated driving system. Only individuals who used the automated shuttle were asked to complete the questionnaire, resulting in a total of 315 valid responses. The information was recorded anonymously and no financial compensation was offered to respondents. An image of the automated shuttle that was deployed in the CityMobil2 demonstration is provided in Figure 2. See Madigan et al. (2017) for more detailed information on the study procedure.

Figure 2. Automated shuttle by Robosoft on a public road in a mixed traffic situation in Trikala, Greece

5.3.2. Analyses of responses

Following the recommendations of Anderson and Gerbing (1988), a two-step approach was adopted. In the first step, a confirmatory factor analysis was performed to evaluate the measurement model. This step involves estimating the measurement relationships between the observed variables and their underlying latent variables. Latent variables are theoretical or hypothetical constructs that are not directly measured, which is why they are commonly described as unobserved variables. Latent variables can either be exogenous (i.e., independent), or endogenous (i.e., dependent) variables. The latent exogenous variables in our measurement model are social influence (SI) and facilitating conditions (FC), while the latent endogenous variables are performance expectancy (PE), effort expectancy (EE), hedonic motivation (HM), and behavioural intention (BI). Latent variables are indirectly measured by observed or manifest variables that are directly measured (i.e., questionnaire items). Observed variables can also be exogenous and endogenous (Raykov & Marcoulides, 2006). The observed exogenous variables are SI1–SI3 and FC1–FC2, while the observed endogenous variables in our measurement model include PE1–PE2, EE1–EE3, HM1–HM3, and BI1–BI3 (see Table 2 for descriptions). The psychometric properties of the measurement model were assessed by its indicator reliability, internal consistency reliability, convergent validity and discriminant validity. Convergent validity was assessed by four criteria: 1) All scale items should be significant and have loadings exceeding 0.70 on their respective scales, 2) the average variance extracted (AVE) should exceed 0.50, 3) composite reliability (CR) should exceed 0.70, and 4) Cronbach's alpha values should be greater than 0.70 (Anderson & Gerbing, 1988; Fornell & Larcker, 1981). Discriminant validity of our data was examined with the test of squared correlations by Anderson and Gerbing (1988), which implies that the correlation coefficient between two latent variables is smaller than the square root of the average variance extracted (AVE) of each latent variable.

In the second step of our analysis, a structural equation model, which relates the latent and observed variables to each other, was built in order to test the hypotheses H1–H36 and determine the weighting factors in order to quantify the strength of the relations between our latent variables (Chau, 1997). Covariance-based structural equation modelling was used in this study as it is the default technique in R software lavaan package to run the structural equation models. It is the most prevalent technique and is best suited for confirmatory rather than exploratory factor analyses and theory development (Hair, Gabriel, & Patel, 2014; Hair et al., 2011). In this step, car and public transport use, technology savviness, and automated vehicle experience were added to the model to investigate their relationship with the latent variables. The measurement of these variables is shown in Table 1.

Structural equation modelling is a powerful technique for multivariate data techniques that is particularly suited to investigate multiple indirect and direct effects among variables and to assess the convergence between a theoretical model and empirical data. Evaluating the structural model involves estimating the path coefficients (i.e., standardized regression weights), which indicate the strengths of the relationships between the variables, their level of significance, and the R–square values (i.e., amount of variance explained) (Backhaus, Erichson, & Weiber, 2015). Maximum likelihood estimation (MLE) was used for this calculation. To deal with missing data, we used Full Information Maximum Likelihood (FIML), which is deemed to be superior to other methods of missing data treatment (Schafer & Graham, 2002). With 315 respondents our study meets the suggested minimum sample size requirement of 100 to achieve adequate power in MLE technique (Hair et al., 1998). Multiple fit indices will be reported to account for the weaknesses inherent in different indices: *Comparative Fit Index* (CFI) ≥ 0.90, *Root Mean Square Error of Approximation* (RMSEA) ≤ 0.08, and the *Standardized Root Mean Square Residual* (SRMR) ≤ 0.06 (Hair et al., 2014; Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 2009; Schreiber et al., 2006). Structural equation modelling was estimated with the R package *lavaan* 0.5–20 (Rosseel, 2012).

5.4. Results

5.4.1. Respondents

315 participants completed the questionnaire, of which 54.6% were male and 45.4% female. Respondents had an average age of 33.35 years (SD = 10.76). Most of the respondents used the automated vehicle two times ($M = 2.23$, SD = 1.39), and interacted with it three or four times

(M = 3.64, SD = 1.60). Respondents' reported car use was on average four days a week (M = 3.92, SD = 2.90, Min = 0, Max = 22), and their reported public transport use was on average two days a week (M = 2.05, SD = 5.45, Min = 0, Max = 85). For technology savviness, 36.82% of respondents rated themselves among the first trying a new technology product, 46.35% in the middle, and 16.83% among the last.

5.4.2. Methodology

The measurement model consists of the six latent variables performance expectancy, effort expectancy, social influence, hedonic motivation, facilitating conditions and behavioural intention and their underlying observed variables.

The descriptive statistics of our latent variables and the results of the confirmatory factor analysis are shown in Table 2. Note that we used the same operationalization of our study constructs that was applied in the study of Madigan et al. (2017). Model fit parameters were acceptable for all latent variables (see Table 2).

All scale items exceeded the recommended threshold of 0.7 and were statistically significant. Composite reliability and Cronbach's alpha both exceeded the recommended threshold of 0.7, confirming internal consistency reliability. The average variance extracted (AVE) values exceeded the recommended threshold of 0.5 for all latent variables, ranging between 0.64 and 0.74. The variance inflation factors (VIFs) of our latent constructs reported in Table 2 in line with Dudenhöffer (2013) are all below 5, which represents an accepted rule of thumb to rule out multi-collinearity (Dabholkar, Shepherd, & Thorpe, 2000; Hair, Ringle, & Sarstedt, 2011). As shown by Table 3, which reports the Pearson correlations between the constructs in line with Wu et al. (2019), discriminant validity is acceptable for all latent variables.

Table 1. Measurement of car and public transport use, technology savviness, and automated vehicle experience

Construct	**Measurement**	**Construct & source**
Car use (CU)	CU1: Days a week using a car	Car access and travel patterns, adjusted to the context of this study; Welch, 2015
Public transport use (PTU)	PTU1: Days a week using any form of public transport	Car access and travel patterns, adjusted to the context of this study; Welch, 2015
Technology savviness (TS)	TS1: When it comes to trying a new technology product, I am generally: a) among the last, b) in the middle, c) among the first	Technology savviness; Merat & Barnard (2010); Merat et al. (2018)
Automated vehicle experience (AV–EXP)	AV–EXP1: Number of interactions with the automated vehicle	Usage intensity, adjusted to the context of this study; Karahanna, Agarwal & Angst, 2006
	AV–EXP2: Number of times using the automated vehicle	

Table 2. Descriptive statistics and results of the confirmatory factor analysis

Latent variable	**Observed variable**	***M***	**SD**	**λ**	***p*-value**	**α > 0.70**	**CR > 0.70**	**AVE > 0.50**	**VIF < 5**
Performance expectancy (PE)		3.62	0.84			0.77	0.78	0.64	
	PE1: I find the ARTS a useful mode of transport.			0.83					2.74
	PE2: Using the ARTS to travel helps me to achieve things that are important to me.			0.77	0.000				2.82
		3.92	0.71			0.88	0.89	0.72	

Effort expectancy (EE)	EE1: My interaction with the ARTS is clear and understandable.			0.81					3.53
	EE2: I find the ARTS easy to use.			0.91	0.000				4.24
	EE3: Learning to use an ARTS is easy for me.			0.83	0.000				3.14
Social influence (SI)		3.37	0.79			0.89	0.89	0.74	
	SI1: People who influence my behaviour think that I should use ARTS.			0.83					2.96
	SI2: People who are important to me think that I should I should use ARTS.			0.89	0.000				3.75
	SI3: People whose opinions I value would like me to use ARTS.			0.85	0.000				3.40
Hedonic motivation (HM)		3.82	0.74			0.87	0.87	0.68	
	HM1: Using ARTS is fun.			0.84					3.66
	HM2: Using ARTS is entertaining.			0.86	0.000				3.28
	HM3: Using ARTS is enjoyable.			0.79	0.000				2.90
Facilitating conditions (FC)		3.91	0.75			0.85	0.84	0.73	
	FC1: I have the resources necessary to use ARTS.			0.84					3.09
	FC2: I have the knowledge necessary to use ARTS.			0.87	0.000				3.15
Behavioural intention (BI)		3.74	0.74			0.90	0.90	0.75	
	BI1: Assuming that I had access to ARTS, I predict that I would use it in the future.			0.80					3.18
	BI2: If ARTS become available permanently, I plan to use it.			0.90	0.000				3.92
	BI3: I intend to use ARTS again during the demonstration period.			0.89	0.000				3.82
CFI	0.97								
RMSEA	0.06								
SRMR	0.03								
χ^2/df	2.26								

Note: Measurement of constructs were used from Venkatesh et al. (2012) and adjusted to the context of this study

M = Mean, SD = Standard deviation, ƛ = Lambda, factor loading, α = Cronbach alpha, CR = Composite reliability, AVE = Average variance extracted, VIF = Variance inflation factor, ARTS = Automated Rapid Transit Systems.

Table 3. Inter-construct correlation matrix

Construct	Performance expectancy	Effort expectancy	Social influence	Facilitating conditions	Hedonic motivation	Behavioral intention
Performance expectancy	0.80					
Effort expectancy	0.62	0.85				
Social influence	0.44	0.38	0.86			
Facilitating conditions	0.54	0.68	0.33	0.79		
Hedonic motivation	0.51	0.69	0.45	0.64	0.82	
Behavioral intention	0.60	0.59	0.51	0.59	0.68	0.87

Note: The diagonal values represent the square root of the average variance extracted (AVE)

5.4.3. Structural model testing

We ran two structural models for this study.

In the first structural model, the main effects of the UTAUT constructs on the behavioural intention to use automated vehicles and the interrelationships between the UTAUT constructs.

In the second structural model, car and public transport use, technology savviness and automated vehicle experience were added to the model to test their effect on the UTAUT constructs.

Table 4 presents the results of the structural equation analysis. The significant relations of the second model are shown in Figure 3.

Table 4. Structural equation models: hypothetical path, standardized path coefficients (β), and variance explained (R^2)

Hypothetical path	**Model 1: Effect β**	**Model 2: Effect β**
H1: Performance expectancy → behavioral intention	0.38**	0.37***
H2: Social influence → behavioral intention	0.14*	0.12*
H3: Facilitating conditions → behavioral intention	0.19*	0.21*
H4: Hedonic motivation → behavioral intention	0.49***	0.48***
H5: Effort expectancy → behavioral intention	-0.23, *n.s.*	-0.23, *n.s.*
H6: Effort expectancy → performance expectancy	0.66***	0.66***
H7: Facilitating conditions → performance expectancy	0.15, *n.s.*	0.17, *n.s.*
H8: Facilitating conditions → effort expectancy	0.47***	0.47***
H9: Facilitating conditions → hedonic motivation	0.65***	0.67***
H10: Social influence → performance expectancy	0.27***	0.27***
H11: Social influence → effort expectancy	0.02, *n.s.*	0.00, *n.s.*
H12: Social influence → facilitating conditions	0.37***	0.37***
H13: Social influence → hedonic motivation	0.27***	0.24 ***
H14: Hedonic motivation → effort expectancy	0.41***	0.42***
H15: Hedonic motivation → performance expectancy	-0.14, *n.s.*	-0.13, *n.s.*
H16: Car use → performance expectancy	–	-0.03, *n.s.*
H17: Car use → effort expectancy	–	-0.02, *n.s.*
H18: Car use → facilitating conditions	–	0.08, *n.s.*
H19: Car use → hedonic motivation	–	-0.08, *n.s.*
H20: Car use → behavioral intention	–	-0.16***
H21: Public transport use → performance expectancy	–	-0.03, *n.s.*
H22: Public transport use → effort expectancy	–	0.03, *n.s.*
H23: Public transport use → facilitating conditions	–	-0.09, *n.s.*
H24: Public transport use → hedonic motivation	–	0.03, *n.s.*
H25: Public transport use → behavioral intention	–	0.00, *n.s.*
H26: Technology savviness → performance expectancy	–	0.12*
H27: Technology savviness → effort expectancy	–	0.02, *n.s.*
H28: Technology savviness → social influence	–	-0.16**
H29: Technology savviness → facilitating conditions	–	-0.20***
H30: Technology savviness → hedonic motivation	–	-0.04, *n.s.*
H31: Technology savviness → behavioral intention	–	-0.02, *n.s.*
H32–1: Number of interactions → performance expectancy	–	-0.03, *n.s.*
H33–1: Number of interactions → effort expectancy	–	0.06, *n.s.*
H34–1: Number of interactions → facilitating conditions	–	-0.08, n.s.
H35–1: Number of interactions → hedonic motivation	–	0.08, n.s.
H36–1: Number of interactions → behavioral intention	–	-0.05, *n.s.*
H32–2: Number of uses → performance expectancy	–	0.07, *n.s.*
H33–2: Number of uses → effort expectancy	–	-0.06, n.s.
H34–2: Number of uses → facilitating conditions	–	-0.06, n.s.
H35–2: Number of uses → hedonic motivation	–	-0.01, *n.s.*
H36–2: Number of uses → behavioural intention	–	0.06, *n.s.*
CFI	0.97	0.96
RMSEA	0.06	0.06
SRMR	0.03	0.04
χ^2/df	2.26	1.96
R^2 of BI	0.689	0.719
R^2 of PE	0.666	0.667
R^2 of EE	0.700	0.699
R^2 of HM	0.629	0.639
R^2 of FC	0.137	0.219
R^2 of SI	–	0.024

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, *n.s.* = not significant
Technology savviness was reverse-coded.

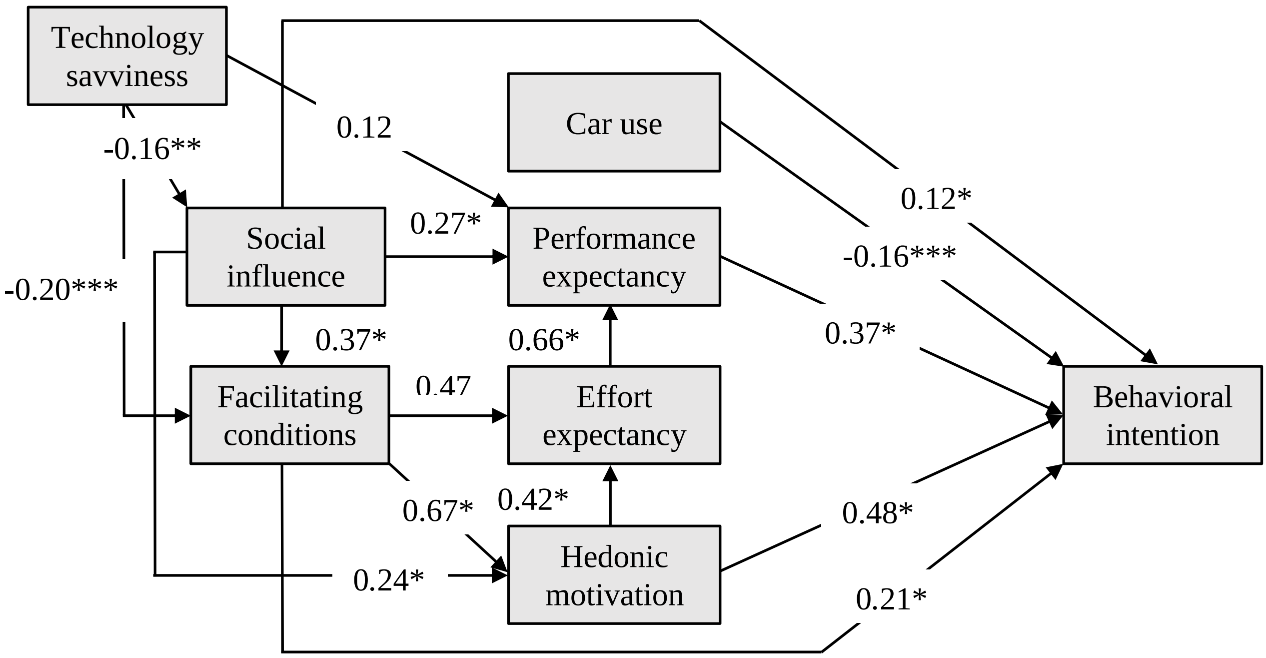

Figure 3. Significant structural path relationships in the second structural model

5.4.4. Moderation analysis

As technology savviness had significant relations with social influence, facilitating conditions, and performance expectancy, we investigated in a next step whether technology savviness moderates the relation between 1) social influence and facilitating conditions, and 2) social influence and performance expectancy. We created mean-centred interaction terms of social influence and technology savviness. The moderation analysis revealed that the relation between social influence and facilitating conditions was moderated by technology savviness. (i.e., the interaction term of social influence and technology savviness was significant) ($\beta = 0.45$, p-value = 0.03* < 0.05). The effect of social influence on facilitating conditions was not significant anymore ($\beta = 0.07$, p-value = 0.59). The relation between social influence and performance expectancy was not moderated by technology savviness ($\beta = 0.22$, p-value = 0.25, *n.s.*).

5.5. Discussion

The present study enhanced our understanding of the factors influencing automated vehicle acceptance and their interrelationships. Structural equation modeling was used to investigate the direct and indirect effects of the UTAUT constructs on the intention to use automated vehicles.

5.5.1. Main effects of UTAUT constructs

In line with Madigan et al. (2017), who used the same dataset, hedonic motivation was the strongest predictor of individuals' behavioral intentions to use automated vehicles in public transport before and after adding car and public transport use, technology savviness and automated vehicle experience to the model. This suggests that one possible strategy to promote the uptake of automated vehicles is to make travelling with automated vehicles enjoyable, for instance through high comfort levels. Furthermore, vehicle manufacturers, public transport companies, operators, policy-makers and the media should advertise the benefits of travelling with automated vehicles and emphasize the hedonic aspects, transforming the "pleasure of driving" – a prominent marketing slogan to increase the attractiveness of the car (BMW, 2013)

– into the “pleasure of *being* driven”. Future research should evaluate whether the pleasure of being driven (or hedonic motivation in more scientific terms) can be enhanced by the possibility of travellers to engage in on-board, non-driving related activities. Research has demonstrated that a positive utility can be derived from using public transport due to the commuters’ ability to listen to music or audio books, browse the internet, enjoy the scenery, talk on the phone, sleep, think and relax (Handy, Weston, & Mokhtarian, 2005; Larson, 1998; Mokhtarian & Salomon, 2001; Salomon & Mokhtarian, 1997). Pudāne et al. (2019) showed that the impact of the engagement in non-driving related activities in automated vehicles on the pleasure of travel is mixed. Pudāne et al. (2019) further proposed that the availability of automated vehicles/limited planning, travel continuity, and comfort have a positive impact on the perceived pleasure of travelling in automated vehicles. More research is necessary to disentangle the relationship between these characteristics and driving pleasure. This shall include trust in automation and perceived safety, which were not investigated in the current survey. Obviously, trust and perceived safety are key factors in the acceptance of automated driving (Choi & Ji, 2015; Nordhoff et al., 2019; Zhang et al., 2019).

5.5.2. Study contributions in addition to Madigan et al. (2017)

5.5.2.1. Interrelationships between UTAUT constructs

While the majority of research studies on automated vehicle acceptance, including Madigan et al. (2017), examined the direct effect of the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions and hedonic motivation on individuals’ behavioral intentions to use automated vehicles, this study examined the interrelationships between the UTAUT constructs. Unlike Madigan et al. (2017), the present study also considered the influence of car and public transport use, technology savviness and automated vehicle experience on behavioural intention. This provides additional insights outlining the ways in which the various acceptance constructs interact to inform individuals’ decisions about whether to use automated vehicles in the future (see Figure 3).

The proposed model explained a substantial amount of variance in the UTAUT constructs. Effort expectancy and social influence together explained 66.6% of the variance in performance expectancy, while facilitating conditions accounted for 70% of the variance in effort expectancy. Social influence and facilitating conditions explained 62.9% of the variance in hedonic motivation. Social influence explained 13.7% of the variance in facilitating conditions. Future research should focus on identifying additional constructs such as personality (Madigan et al., 2016; Yap, Correira, & Van Arem, 2015) and macro-level factors (Nordhoff et al., 2019) to investigate whether these factors can increase the explanatory power of our model and account for the remaining 28% of the variance in behavioral intention that our model left to explain.

We found strong positive effects of facilitating conditions on effort expectancy and hedonic motivation. These findings imply that a supportive infrastructure is more likely to give rise to a positive opinion about automated vehicles in terms of perceived enjoyment and ease of use. A supportive infrastructure could encompass the provision of accessibility to the vehicle using a wheelchair ramp, ensuring an uncomplicated booking and payment process (e.g., including the use of automated vehicles in public transport tickets), and offering information on routes and interchanges either in or outside the vehicle, in close proximity to the stations, and via an app (Nordhoff, De Winter et al., 2019). The strong positive effect of effort expectancy (ease of use) on performance expectancy implies that the complexity of using automated vehicles should be reduced and the clarity of the interaction between humans and automated vehicles increased (Zhang et al., 2019).

Both Madigan et al. (2017) and the present study found a positive correlation between effort expectancy and behavioural intention in a bivariable correlation context (Table 3). When studied in a multivariable context, the relationship between effort expectancy and behavioural intention becomes insignificant in both studies. These findings can be explained with regards to the underlying dynamics of both regression and structural equation modeling, which allow the independent variables to correlate (Hox & Bechger, 1998). Effort expectancy influences behavioural intention indirectly through performance expectancy (see the correlation coefficients > 0.60 in Table 4), with performance expectancy *taking over* or *cannibalizing* the effect of effort expectancy as direct predictor of behavioural intention. Our finding regarding the relationship between effort expectancy and behavioral intention corresponds with research on automated vehicle acceptance, which points to the ambiguous role of effort expectancy in predicting automated vehicle acceptance. Madigan et al. (2016) and Wu et al. (2019) support a positive direct effect of effort expectancy on behavioral intention. In contrast, Wu et al. (2019) and Zhang et al. (2019) reported positive indirect effects of effort expectancy on behavioral intention through performance expectancy and the attitude towards using automated vehicles. Zoellick et al. (2019) did not use perceived ease of use (i.e., equivalent of effort expectancy) as latent construct in their analysis due to the difficulties to apply it to the context of automated driving technology, and Madigan et al. (2017) proposed to exclude effort expectancy from future studies as it was not a significant predictor of the intentions to use automated vehicles.

The current study provides further evidence of the difficulties in understanding how effort expectancy might link to the use automated driving technology. A possible explanation is that respondents are not well able to discriminate between effort expectancy, performance expectancy and facilitating conditions. Future research should investigate whether it is reasonable to merge the constructs effort expectancy and facilitating conditions given 1) the ambiguous role of effort expectancy in research on the acceptance of automated vehicles as highlighted before, and 2) the relatively strong relationship between effort expectancy and facilitating conditions that was detected in our study. Furthermore, we encourage researchers to revisit the operationalization of facilitating conditions. The items measuring facilitating conditions are usually expressed in very generic terms (i.e., resources, knowledge), leaving ample room for respondents to speculate on the meaning of this construct and attach different meanings to it.

5.5.2.2. Car and public transport use

Car use was a negative predictor of the behavioural intention to use automated vehicles in public transport, contributing to a marginal increase in the variance explained in behavioral intention from 69.1% to 72%. This suggests that car users might be among the customer segments with more negative views towards automated vehicles in public transport. This finding corresponds with Krueger, Rashidi, and Rose (2016) who found that car users were less likely to use shared automated vehicles, Berliner, Hardman, and Tal (2019) who found that individuals with a higher number of household vehicles expressed a lower interest in the purchase of automated vehicles, and with Nordfjærn et al. (2015) who found that a strong car habit substantially reduces the intention to use public transport. Future research should investigate the attributes of automated vehicles in public transport that attract car users in order to encourage a switch from the car to automated vehicles in public transport. In line with the findings of König and Neumayr (2017), who over-sampled car-users in their study (i.e., 442 car users versus 47 non-car users), educating car users about the functions, benefits and limitations of the technology in terms of free test rides, comprehensive explanations prior to usage, and free/cheap courses could be further practical recommendations of how the resistance to automated vehicles among car-users could be overcome. Sparrow and Howard (2017) posit that the combination of a rail network with a fleet of autonomous vehicles serving passengers arriving at and departing from each station and offering a door-to-door public transport service could solve the first and last mile problem, thus catering to the needs and preferences of car users.

The effects of public transport use on the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and behavioural intention were not significant. This contradicts the study of Haboucha, Ishaq and Shiftan (2017) who found a negative relationship between public transport use and the use of a shared automated vehicle. As automated vehicles in public transport are supposed to cover small to medium distances between public transport nodes and individuals' destinations (i.e., trips to or from public transport stations), the ability and willingness to pursue recreational or work-related activities may be limited and the full potential of automated vehicles in public transport not leveraged. Future research should address the various user needs along different parts of the journey that most likely yield different implications for vehicle manufacturers, designers, operators and mobility providers to effectively market automated vehicles (Yap, Correira, & Van Arem, 2015).

5.5.2.3. Technology savviness

Technology savviness explained only 2.4% of the variance in social influence, and contributed to an increase in the variance explained in facilitating conditions by 8.2% from 13.7% to 21.9%. The positive relationships between technology savviness and social influence as well as between technology savviness and facilitating conditions correspond with Acheampong and Cugurullo (2019). Our findings suggest that tech-savvy individuals are more likely to believe they are in possession of the necessary resources to use automated vehicles and that people important to them will appreciate their use of automated vehicles. Policy makers, manufacturers and public transport companies should develop strategies to identify the segments who are more amenable to adoption (Pettigrew et al., 2019). As an additional practical recommendation to enhance technology savviness, opportunities for trial should be offered to increase the visibility of usage (Pettigrew, Dana, & Norman, 2019).

The addition of technology savviness to the model led to a decrease in the variance explained in effort expectancy by only 0.1% from 70% to 69.9%. This implies that when technology savviness is defined as predictor of facilitating conditions, it weakens the relationship between facilitating conditions and effort expectancy and thus the importance of facilitating conditions for effort expectancy (see effect size β of facilitating conditions on effort expectancy in Table 4 before and after adding technology savviness). This suggests that for tech-savvy individuals, facilitating conditions are less important for the formation of effort expectancy, probably because technology savviness already subsumes some of the effect of facilitating conditions on effort expectancy. We recommend future research to re-examine the relationship between technology savviness, facilitating conditions and effort expectancy.

The addition of technology savviness increased the variance explained in performance expectancy by only 0.1% from 66.6% to 66.7%. The negative correlation between technology savviness and performance expectancy suggests that technology-savvy individuals are less likely to consider automated vehicles useful. This is a counter-intuitive finding if we contemplate the literature on automated vehicle acceptance that reports a positive relationship between technology savviness and attitudes towards automated vehicles (Bansal, Kockelman, & Singh, 2016; Lavieri et al., 2017). On the other hand, it can be speculated that the expectations of tech-savvy individuals regarding automated public transport are not met by the automated vehicle in the context of this study that was running under very limited and controlled conditions. We encourage future research to investigate the relationship between technology savviness and the UTAUT constructs, using multiple-item scales (see Section 4.6.) to better understand the specific nature of technology savviness, and the consequences of its operationalization for its relationships with the UTAUT constructs.

We further found that technology savviness is a negative moderator of the relationship between social influence and facilitating conditions, implying that the relationship is weaker for tech-savvy individuals. This suggests that tech-savvy individuals rely less on their social network to nurture their belief to be in possession of the necessary resources to use automated vehicles. This finding is not counter-intuitive as tech-savvy individuals may have sufficient confidence in their skills and capabilities to use automated vehicles. Studies model technology savviness as a function of individual demographics, household composition, commute characteristics, and new technology usage (Bansal et al., 2016; Lavieri et al., 2017). Less explored is the relationship between technology savviness and social influence. We encourage future research to fill this gap in research.

5.5.2.4. Automated vehicle experience

Automated vehicle experience did not exert a positive effect on automated vehicle acceptance. This corresponds with studies, which found that familiarity with automated vehicles did not predict willingness to pay for automated vehicles (Bansal & Kockelman, 2018), and did not show positive effects on support for automated vehicles when controlling for other psychological variables (Dixon et al., 2018). However, studies also reveal that experienced and knowledgeable individuals were more positive towards automated vehicles, and more likely to intend to use them in comparison to less experienced and knowledgeable individuals (Liu, Xu, & Zhao, 2019). Distler, Lallemand, and Bellet (2018) found that respondents considered autonomous mobility on demand less useful after they experienced it. Most of the studies on automated vehicle acceptance are based on respondents' imaginations of automated driving technology (e.g., knowledge respondents gain in the context of the study, through media, other information channels, friends/colleagues) rather than direct physical experience with automated vehicles (Nordhoff et al., 2019). Tennant, Stares, and Howard (2019) pointed to the difficulties in researching public opinions towards automated vehicles, and posited that it is speculative to assume that public unease will decline as people become more familiar with automated vehicles. Dixon et al. (2018) suggested that simply experiencing automated vehicles will be ineffective in establishing automated vehicle acceptance. We recommend future research to revisit the relationship between automated vehicle experience and acceptance, making more use of experienced versus non-experienced individuals (Tennant, Stares, & Howard, 2019), and examine not only the amount but also the qualitative experience influencing important aspects of automated vehicle acceptance, such as symbolic-affective (e.g., pleasure, comfort), and domain-specific factors (e.g., performance and effort expectancy, compatibility; Nordhoff et al., prepared for submission).

5.5.3. Study limitations

First, the automated vehicle in this study operated at a low speed, on a dedicated route with fixed stops that had to be shared by multiple passengers at the same time.

Second, car and public transport use, technology savviness and automated vehicle experience were measured by single-item scales, which is a limitation in scientific research (Wanous, Reichers, & Hudy, 1997). Future research should use multiple-item scales, e.g., similar to the scales in the studies of Asgari and Jin (2019), Bansal, Kockelman, and Singh (2016), Haboucha, Ishaq, and Shiftan (2017), Lee and Mirman (2018), and Nazari, Noruzoliaee, and Mohammadian (2018).

Third, while structural equation models are useful to model complex relationships between latent and observed variables, the ability to make causal inferences and establish a clear temporal precedence using cross-sectional data is limited (Bagley & Mokhtarian, 2001). (Quasi-) experimental studies that measure individuals' opinions before and after they are exposed to automated vehicles should be performed, varying attributes of the transport offered, because they are more suitable to isolate the causes from the effects and thus determine the temporal, cause-effect nature of the relationships between two or more variables (Gould & Golob, 1998).

5.5.4. Final conclusions

The present study investigated the interrelationships between the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and hedonic motivation to add to existing research on automated vehicle acceptance that mainly considered the UTAUT constructs as independent antecedents of individuals' behavioural intentions to use automated vehicles. Our model explained 68.9% of the variance in behavioural intentions. The addition of car and public transport use, technology savviness, and automated vehicle experience contributed to an increase of the variance in behavioural intention to 71.9%. The UTAUT predictors effort expectancy and social influence explained 66.6% of the variance in performance expectancy, while facilitating conditions accounted for 70% of the variance in effort expectancy. Social influence and facilitating conditions explained 62.9% of the variance in hedonic motivation. Social influence explained 13.7% of the variance in facilitating conditions. Car use explained 3% of the variance in behavioural intention. Technology savviness explained 8.2% of the variance in facilitating conditions, 2.4% of the variance in social influence, and 0.1% of the variance in performance expectancy. We expect that the findings obtained in this study provide useful insights for policy-makers, vehicle manufacturers, public transport companies, operators and designers to inform the design and implementation of automated vehicles.

5.6. Acknowledgements

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5.7. Supplementary material

During the review process, the dataset can be accessed via the following link: https://www.dropbox.com/s/48wl37ykbhvcbex/Datensatz_neu.sav?dl=0. When the study is accepted for publication, the dataset will be published on the following website: https://researchdata.4tu.nl/en/. The script to perform the statistical analyses can be found in the README file.

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Chapter 6: A multi-level model on automated vehicle acceptance (MAVA): A review-based study

6.1. ABSTRACT

Automated vehicle acceptance (AVA) is a necessary condition for the realisation of higher-level objectives such as improvements in road safety, reductions in traffic congestion and environmental pollution. On the basis of a systematic literature review of 124 empirical studies, the present study proposes MAVA, a multi-level model to predict AVA. It incorporates a process-oriented view on AVA, considering acceptance as the result of a four-stage decision-making process that ranges from the exposure of the individual to automated vehicles (AVs) in Stage 1, the formation of favourable or unfavourable attitudes towards AVs in Stage 2, making the decision to adopt or reject AVs in Stage 3, to the implementation of AVs into practice in Stage 4. MAVA incorporates 28 acceptance factors that represent seven main acceptance classes. The acceptance factors are located at two levels, i.e., micro and meso. Factors at the micro-level constitute individual difference factors (i.e., socio- demographics, personality and travel behaviour). The meso-level captures the exposure of individuals to AVs, instrumental domain-specific, symbolic-affective and moral-normative factors of AVA. The literature review revealed that 6% of the studies investigated the exposure of individuals to AVs (i.e., knowledge and experience). 22% of the studies investigated domain-specific factors (i.e., performance and effort expectancy, safety, facilitating conditions, and service and vehicle characteristics), 4% symbolic-affective factors (i.e., hedonic motivation and social influence), and 12% moral-normative factors (i.e., perceived benefits and risks). Factors related to a person's socio-demographic profile, travel behaviour and personality were investigated by 28%, 15% and 14% of the studies, respectively. We recommend that future studies empirically verify MAVA using longitudinal or experimental studies.

Relevance to human factors/relevance to ergonomics theory

User acceptance is one of the most important human factors constructs to realise the benefits of road vehicle automation. The present study proposes MAVA, a multi-level model on automated vehicle acceptance. Based on 124 empirical studies, MAVA predicts the acceptance of highly (SAE Level 4) and fully automated (SAE Level 5) vehicles. It adopts a procedural view on automated vehicle acceptance and organises the factors of acceptance at the micro and meso level.

Nordhoff, S., Kyriakidis, M., Van Arem, B., & Happee, R. (2019). A multi-level model on automated vehicle acceptance (MAVA): A review-based study. *Theoretical Issues in Ergonomics Science*, *20*, 682–710.

6.2. Introduction

Automated vehicle acceptance (AVA) is a necessary condition for AVs to contribute to improvements in road safety, road capacity, reductions in travel time and/or greenhouse gas emissions. Research on AVA has gained new momentum, creating a need and opportunity to review theories explaining AVA, in order to synthesize a model predicting AVA and to validate this model using published empirical studies.

The idea to integrate theories and models from various influential disciplines is not new, and responds to concerns that erroneous and inconsistent conclusions across studies may be derived if a narrow approach (i.e., not studying the influence of a broad range of the factors affecting the outcome variable, and their interactions) is adopted to study multilevel processes (Alfonzo, 2005; Devine-Wright, 2008; Stern, 2000) such as AVA. Current studies on AVA have not captured this multi-determination, instead they mainly investigate the influence of AVA factors in isolation, and through the lenses of technology acceptance (Hewitt et al., 2019; Kaur & Rampersad, 2018; Leicht, Chtourou, & Youssef, 2018; Madigan et al., 2016; Madigan et al., 2017; Wu et al., 2019; Zhang et al., 2019; Zmud & Sener, 2017). The AVA factors identified by these studies encompass 1) individual characteristics (socio-demographics, differences in one's own personality; Alessandrini et al. 2014; Bansal, 2016; Haboucha et al., 2017; Lavieri et al., 2017; TNS Opinion & Social, 2015), 2) instrumental domain-specific (performance/effort expectancy, physical vehicle and service characteristics; Nordhoff et al., 2018), 3) symbolic-affective (social influence, hedonic motivation; Bansal & Kockelman, 2018; Madigan et al., 2016), and 4) moral-normative factors of AVA (risk and benefit perception of AVs; Daziano, Sarrias, & Leard, 2017; Kyriakidis, Happee, & De Winter, 2015; Moták, et al. 2017; Nordhoff et al., 2018; Tennant et al., 2016).

No comprehensive model exists to date that integrates these different research streams on the basis of empirical evidence to explain and predict AVA. Our conceptual model of the acceptance of driverless vehicles (Nordhoff, Van Arem, & Happee 2016) postulates that AVA is a function of instrumental domain-specific and symbolic-affective factors, ignoring moral-normative factors and the multi-level positioning of AVA factors. The present study fills this gap in research and introduces MAVA – the comprehensive multi-level model of automated vehicle acceptance (AVA) – that accounts for AVA's multi-determination aspect. Based on a review of 124 empirical studies, the model summarises the current knowledge on AVA and serves as a discussion piece for scholars and practitioners who are invited to critically reflect on the factors identified in the model, as well as the relationships between the included factors.

MAVA explains and predicts AVA of driverless Level 4 (L4) and Level 5 (L5) Automated Driving System (ADS)-Dedicated Vehicles (DVs) in line with the definitions provided by the SAE International (2018) taxonomy. ADS-DVs are often designed without standard user interfaces as input devices for braking, accelerating, steering, and transmission, and provide high automation levels (L4 or L5). ADS-DVs will generally not have a driver or operator onboard, but temporary control might be provided by a conventional or remote driver (SAE International, 2018). Throughout this paper, we refer to L4/L5 ADS-DVs as ADS-DVs. Where L4 ADS-DVs can operate in automated mode on limited road sections, L5 ADS-DVs can operate in automated mode on all publicly accessible roadways (including parking areas and private campuses that permit public access) that are navigable by human drivers (SAE International, 2018).

An important class of L4 ADS-DVs is represented by driverless automated shuttles as a hybrid form of individual-public transport that deliver on-demand transport and serve as (last mile) feeder modes to public transport systems (Fraedrich, Beiker, & Lenz, 2015). L5 ADS-DVs might be offered as mobility service operation by taxi companies, or companies that operate a fleet of automated carsharing or ridesharing vehicles on the basis of different parameters (e.g., trip, mile, minute, or a combination thereof). Alternatively, they might be individually-owned (Lavieri et al., 2017). MAVA is constrained to the prediction of AVA of L4/L5 ADS-DVs, and does not cover SAE L2–4 vehicles that are designed to be operated by a human driver during part or all of the trip (SAE International, 2018). Thus, MAVA does not address challenges specific to SAE L2–4 such as transitions of control, and drivers' situation awareness and mental workload as the two most important Human Factors constructs determining safe usage of L2-4 automation (De Winter et al., 2014).

The paper is organized as follows. Section 2 describes our methodology to derive the multi-level model through a systematic literature review. Section 3 first presents and motivates the model structure. It describes the model's meso-level capturing the main effects of instrumental domain-specific, symbolic-affective, and moral-normative factors in addition to the model's micro-level that unites the individual difference acceptance factors. Finally, concluding remarks and potential implications for future research are presented in Section 4.

6.3. Methodology

To perform the literature review, we followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). In correspondence with Zhang et al. (2018), we refrained from generating or registering a protocol.

6.3.1. Information sources and search strategy

To develop a theoretical model that predicts AVA of L4/5 ADS-DVs and explore the determinants of AVA, we thoroughly examined the available Scopus and Web of Science listed peer-reviewed articles up to April 2019. The articles included in the review contained in the title, abstract, or keywords any combinations of the following keywords: acceptance, acceptability, perceptions, attitudes, opinions, automated driving, autonomous driving, self-driving vehicle(s), driverless vehicle(s), automated, and autonomous vehicle(s). Additional searches were performed using Google and Google Scholar to enlarge the pool of selecting suitable studies into our sample. For consistency the same keywords were used. The reference lists of all the studies that met the search criteria were reviewed to retrieve other relevant studies. In line with Zhang et al. (2018), we retrieved all types of studies, including journal publications, papers from conference proceedings, theses, reports, posters, and presentation slides. This enables the identification of grey literature records and minimizes publication bias.

6.3.2. Study selection and data extraction

In the first stage, we retrieved 1537 potentially-relevant full-text records, which were further reviewed for eligibility. We removed 637 duplicate records, and 776 records which did not fulfil our search criteria. Instead, they investigated different types of technologies (e.g., autonomous underwater, micro air, mining, and urban land vehicles, automated highway systems, planes, and driverless trains), SAE Levels 1−2 where the interaction with the human driver is prominent, or technical, legal, ethical, and policy-related aspects of autonomous vehicles. We also excluded review-based studies, which already discussed the results of some of the studies that met our eligibility criteria. 124 records were thus retained in the qualitative analysis in the final stage.

6.3.3. Analysis

Following the procedure presented in Nordhoff et al. (2019), we counted how many studies investigated specific AVA factors. Multiple entries of an AVA factor by the same study equaled a frequency of 1. AVA factors that were investigated by fewer than five studies were not included in the model.

6.4. Theoretical model

Before presenting MAVA, it is important to introduce the underlying theories and assumptions that provide the basis for the model. In correspondence with Kaur and Rampersad (2018), who draw upon the literature on technology adoption and driverless cars to review key factors in the adoption of driverless cars, we synthesize the factors identified by technology acceptance models (i.e., UTAUT, CTAM) in conjunction with our findings from the literature on AVA.

The first theoretical framework that provides the structural foundation for MAVA is the UTAUT3 proposed by Venkatesh, Thong, and Xu (2016), as a result of a critical review of research studies that applied, extended or integrated the former UTAUT1 and UTAUT2 models (Venkatesh et al., 2003; Venkatesh et al., 2012). The UTAUT3 distinguishes between individual-level contextual factors (i.e., individual, technology and task attributes, events), higher-level contextual factors (i.e., environmental, organization and location attributes) and a baseline model that is formed by the main effects of the UTAUT2 model. The strength of the UTAUT3 is its holistic and comprehensive overview of the possible factors impacting technology acceptance, which corresponds with our objective to build a comprehensive model to predict AVA. We follow the proposition of Venkatesh, Thong, and Xu (2016) and locate potentially relevant determinants of AVA at two levels: meso and micro. The meso-level represents the main effects of instrumental domain-specific, symbolic-affective, and moral-normative aspects of AVA. The micro-level captures individual difference factors.

The second theoretical foundation of MAVA is the Car Technology Acceptance Model (CTAM) to predict the acceptance of in-car technology introduced by Osswald et al. (2012). The CTAM posits that in-car technology acceptance is associated with the UTAUT1 constructs (i.e., performance/effort expectancy, social influence, facilitating conditions) along with further factors such as the perceived safety (i.e., belief that using a system will affect his or her well-being).

MAVA adopts a process-oriented view on AVA as supported by literature on technology acceptance (Bagozzi & Lee, 1999; Endsley, 1985b; Rogers, 1983; Schwarz et al. 2014). We build upon these ideas and propose a four-stage-decision-making model capturing the information processing steps behind the adoption or rejection of ADS-DVs, illustrated in Figure 1.

We posit that this process starts with the exposure of the individual to ADS-DVs in stage 1 by the communication about ADS-DVs by an external stimulus (e.g., word-of-mouth communication from family or friends, advertising, media, test ride), or an internal change such as being aware of a problem or perceiving a need. The outcome of stage 1 can either be a resistance or rejection of ADS-DVs or an interest to explore ADS-DVs. In the latter case, the individual moves to stage 2, leading to a favourable or unfavourable attitude towards ADS-DVs on the basis of the evaluation of the instrumental domain-specific, symbolic-affective and moral-normative characteristics of ADS-DVs. In the third stage, the individual makes the decision to either use or reject ADS-DVs, or remains undecided. In the fourth stage, the individual puts ADS-DVs into use, e.g., by using ADS-DVs as part of a carsharing or ridesharing scheme, or as feeder to public transport systems.

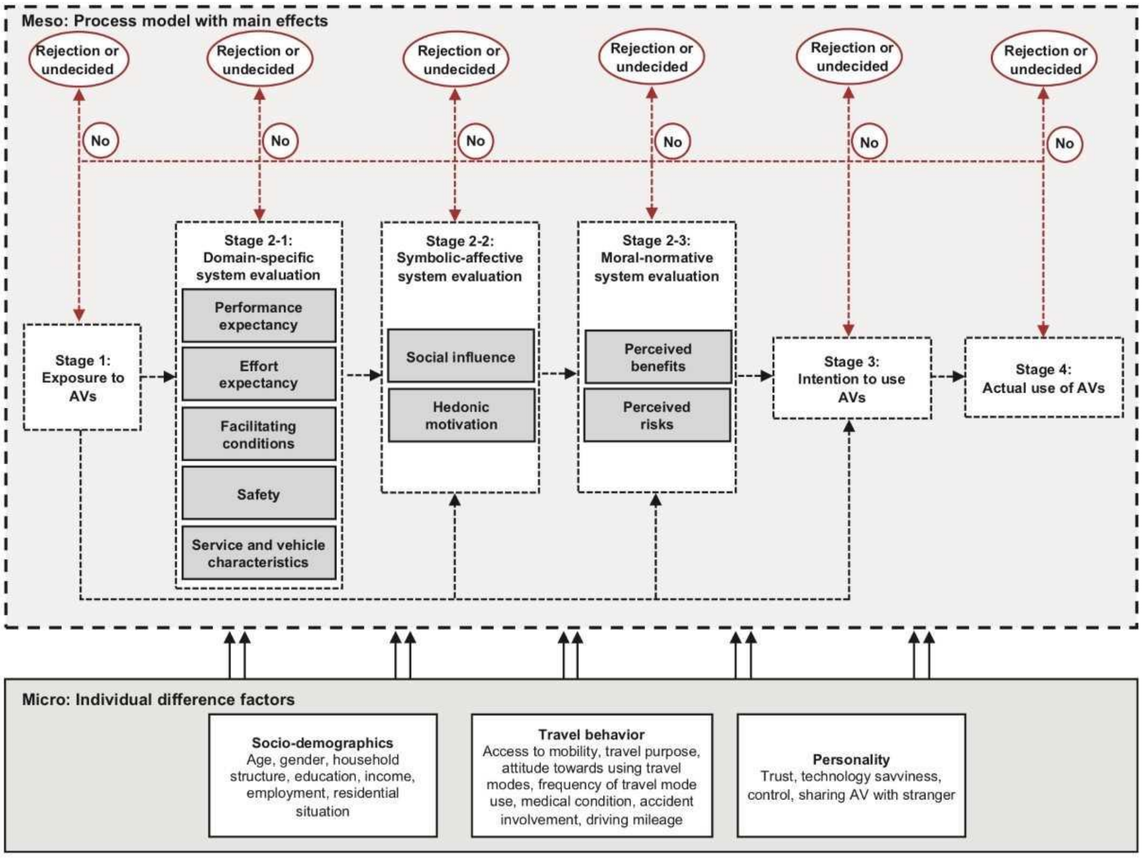

Figure 1. Multi-level model to explain and predict AVA (MAVA)
Note: The individual difference factors at the micro-level influence the factors at the meso-level directly or indirectly through a mediator or moderator effect.

MAVA organizes the factors of AVA hierarchically in line with Maslow's (1954) hierarchy of human needs. As shown in Figure 1, the evaluation of fundamental and basic instrumental domain-specific aspects of ADS-DVs (Stage 2–1) precedes the symbolic-affective (Stage 2–2) and moral-normative appraisal (Stage 2–3) of ADS-DVs. In other words, individuals will first try to realize the fulfilment of basic and fundamental domain-specific aspects of ADS-DVs before they aim for the realization of higher-level symbolic-affective and moral-normative factors of AVA. The relevance of fundamental domain-specific aspects of ADS-DVs corresponds with the literature on road vehicle automation. For example, the system dynamics model to simulate the innovation diffusion of AVs proposed by Nieuwenhuijsen et al. (2018) posits that the attractiveness of AVs is determined by safety and comfort, which are indicators of physical vehicle and service characteristics. Note that in line with the limitations of Maslow's (1954) hierarchy of human needs and Endsley's (1985b) process model on the implementation of technological change, the evaluation of ADS-DVs does not have to proceed in a linear order where each stage in the model is a necessary condition for entering the subsequent stage. Instead, the sequence can also be dynamic and occur in a non-linear, unsystematic, or parallel fashion, where individuals skip stages, jump between stages, or process each stage simultaneously.

6.4.1. Literature study results at micro- and meso- level

From the 124 studies that were included in the literature study, we selected 28 factors in MAVA. As shown in Table 1, these 28 factors form 7 classes:

- Class 1 (factor 1): Exposure to AVs
- Class 2 (factors 2−6): Domain-specific system evaluation
- Class 3 (factors 7−8): Symbolic-affective system evaluation
- Class 4 (factors 9−10): Moral-normative system evaluation
- Class 5 (factors 11−17): Socio-demographics
- Class 6 (factors 18−24): Travel behavior
- Class 7 (factors 25−28): Personality

Acceptance classes 1 − 4 are at the meso-level, while 5 – 7 are at the micro-level.

As the main objective of MAVA is to investigate AVA at the individual level, we discarded the factors 29 – 34 at the macro-level[1]:

- Distance home-workplace, home-downtown, home-public-transit
- GPD/capita
- Employment density/% of families below the poverty line
- Population density
- Policy measures
- Road conditions under which people want to use AVs

Furthermore, as the UTAUT3 on which MAVA is based, does neither include the attitude towards using the technology under investigation nor negative emotions, we further omitted factors 35 – 36 from MAVA:

- Attitude towards using AVs
- Negative emotions

Finally, we omitted factors 37 – 42 that were mentioned by fewer than five studies:

- Sensation seeking
- Big 5 Inventory: Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness
- Political orientation
- Difficulty finding a parking place
- Motion sickness susceptibility
- Values

[1] The macro-level represents higher-level contextual factors in a person's external environment such as environmental, organizational and location factors (Venkatesh, Thong, & Xu, 2016). Environmental factors may encompass legal (e.g., availability of public policies to support the implementation of AVs), economic (e.g., GDP per capita), meteorological (e.g., time of day/week/year), ecologic (e.g., high levels of nitrogen dioxide in cities), social (e.g., urbanization), and the political environment (e.g., political support for AVs). Organizational factors may encompass specific organizational contexts in which AVs are embedded (e.g., rules and policies of public transport organization as operator of shared automated vehicles). Location attributes may capture the physical infrastructure (e.g., availability of parking places or charging stations for automated vehicles) (Grotenhuis, Wiegmans, & Rietveld, 2007; Stern, 2000).

Table 1 presents the extracted factors 1 – 28 at the micro- and meso-level, their meaning, and the number of studies investigating these factors. Factors 29 – 42 that were discarded from the analysis, and miscellaneous items/factors (e.g., items/factors that could not be assigned to a clear factor), can be found in Table S1 in the supplementary material. Table S1 also provides the references of the studies.

Table 1. Overview of AVA factors, and the number of studies that investigated the AVA factor (*n*)

Factor number	**Level**	**Factor class**	**Acceptance factor**	***n***
1.	Meso	Exposure to AVs	Experience with and knowledge about AVs: Awareness of AV technologies, interacting with AVs, satisfaction with in-vehicle technology, familiarity/experience with Advanced Driver Assistance Systems (ADAS)/SAE Level 2 technology, type of information (positive, negative) about AVs	49
2.		Domain-specific system evaluation	Performance expectancy, equivalent to perceived usefulness	31
3.			Effort expectancy, equivalent to perceived ease of use	19
4.			Facilitating conditions, equivalent to perceived behavioural control, helpfulness, technical support, self-efficacy, conceptual compatibility/fit, lifestyle fit, technology confidence	10
5.			Perceived safety, reliability, security (i.e., equipment and system failure, cyber security/fear of terrorism/hacking, system performance in poor/various weather and terrain or unexpected conditions, automated vehicles getting confused by unexpected situations, automated vehicles not driving as well as human drivers in general)	73
6.			Service/vehicle characteristics: Availability, flexibility, costs, convenience, travel time, integration with other modes, comfort, charging time, interoperability, size, quality/design of exterior/interior, brightness, aesthetics, brand/prestige/image, vehicle behaviour/capabilities (identify and react to/overtake objects and events, accelerate and decelerate)	45
7.		Symbolic-affective system evaluation	Hedonic motivation, equivalent to pleasure, enjoyment, fun	13
8.			Social influence	18
9.		Moral-normative system evaluation	Perceived benefits: Benefits for the environment (e.g., reduction of fuel consumptions, emissions and traffic congestion, lower vehicle ownership), increased mobility independence and freedom for the elderly, disabled and others, no need for driver license/no need to spend time and cost on learning how to drive, easier, quicker and less expensive parking, lower repair costs (in case of less accidents), increased jobs, lower insurance premiums, using time for activities other than driving	55
10.			Perceived risks: Legal liability of drivers or owners, data privacy (location and destination tracking), loss of driving skills and pleasure, job losses, interacting with manually controlled cars, pedestrians and bicyclists, lack of assistance for disabled riders/passengers, affordability, traffic delays, ethical/social consequences (job losses, social isolation, loss of human element)	50
11.	Micro	Socio-demographics	Age	65
12.			Gender	58
13.			Household structure: Number of people in household, number/presence of children in household, age of child, number of workers in household, number of dependent people in household,	17

			marital status	
14.			Education	34
15.			Income	29
16.			Employment: Employment status, jobs per household, social class, number of workers in household, flexible work schedule (e.g., offered flextime, permit to compress work schedule)	16
17.			Residential situation: Place of residence, house type, home location, region, ethnicity, nationality, immigration status, cultural influence	28
18.		Travel behavior	Access to mobility: Possessing valid driver license or public transport pass, car/Diesel vehicle/electric vehicle ownership, number of vehicles per household, age of oldest vehicle, number of vehicles sold in 10 past years, vehicle type	29
19.			Travel purpose	10
20.			Attitude towards using transport modes	17
21.			Transport mode use: Commonly used/ preferred mode of transport, rideshare usage/sharing trips, driving habit, access to carsharing, drive alone (for work trips)	40
22.			Medical condition/disability: Having medical condition/disability that prohibits driving, intensity of disability, visual/physical impairment	10
23.			Accident involvement: Involvement in accidents, citation record	15
24.			Driving mileage: Number of kilometers/miles driven (in the last 12 months)	14
25.		Personality	Trust: Being comfortable with idea of removing the steering wheel, being comfortable with travelling in an AV/ with sending an AV on its own, believing that AV drives better than human driver, being concerned about riding in AVs, trusting technology companies	49
26.			Technology savviness: Innovativeness, number and types of technologies used (e.g., own smartphones), technology interest, technology readiness, curiosity, attitudes to robot approval, enthusiasm for technology, knowledge of mobility-related developments, technological optimism and faith in progress, technological openness	34
27.			Control: Internal/external locus of control, preference to have control over things, having the option of manual drive, autonomy preference, desire for control, preference for presence and responsibilities of bus operator/steward/supervisor, and camera, provision of interactive screen for communication with bus operator and visualisation of what AV sees	36
28.			Sharing AV with stranger: Ability to interact with individuals outside immediate social circle, being concerned about riding a self-driving bus with strangers, comfort with other drivers behind the wheel	10

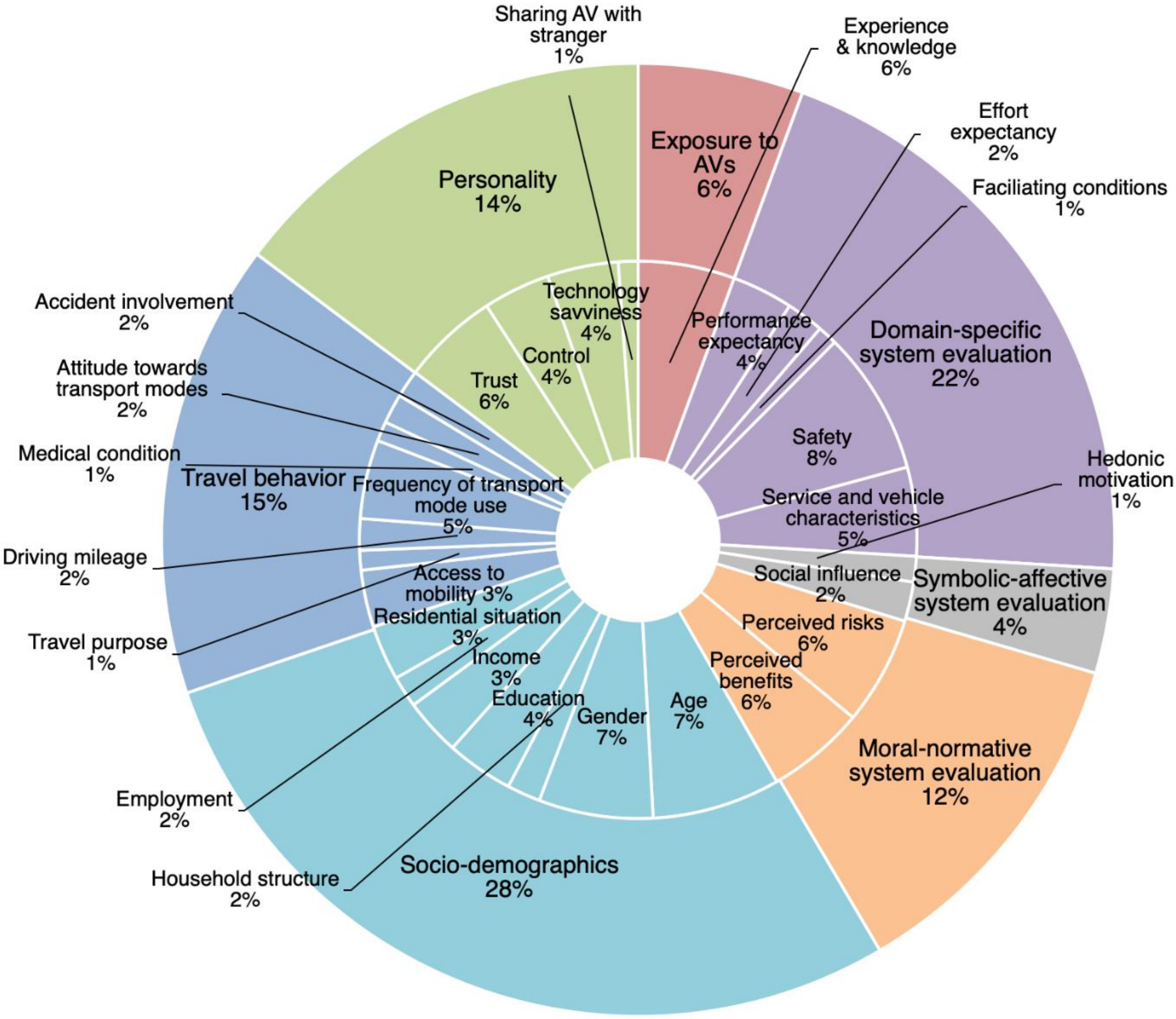

Figure 2. Pie diagram showing the seven main acceptance classes (outer ring) and the corresponding twenty-eight acceptance factors (inner ring). Note: The arc length of the sectors is proportional to the number of studies.

6.4.2. Meso level

6.4.2.1. Exposure to AVs: Knowledge and experience

We expect that AVA is a function of an individuals' knowledge of and experience with AVs. We generally expect that the effect of experience on AVA depends on whether the experience was positive or negative. Tennant et al. (2016) found that the more the respondents reflected on AVs, the more positive they became, and that people using in-car automated technology (e.g., Cruise Control) were more open to accept AVs. In the same vein, Kyriakidis, Happee, and De Winter (2015) found that people currently using Adaptive Cruise Control (ACC) would be willing to pay more for AVs, while they were also more comfortable about driving without a steering wheel. Sanbonmatsu et al. (2018) pointed to the limited knowledge of the public of fully automated vehicles (i.e., only 32.5% was aware that self-driving vehicles would not be equipped with a steering wheel) and found that as knowledge of fully automated vehicles increased, beliefs about driverless cars were more positive. Anania et al. (2018) revealed that, with the exception of Indian females, receiving positive information resulted in a higher willingness to ride in a driverless vehicle compared to receiving negative or no information. Eden et al. (2017) who investigated the opinions and attitudes around safety and comfort of people both before and after riding on an AV shuttle revealed that the safety concerns of people disappeared after the ride. Hartwich et al. (2018) revealed that the initial system experience significantly increased trust and acceptance of highly-automated driving. In contrast, the study of Dekker et al. (2017) did not find a significant influence of experience with AV-DVs on the preferences for AV-DVs. Note that most of the studies on AVA that we retrieved in the process of the literature review are based on respondents' knowledge (e.g., knowledge respondents gain in the context of the study, through media, other information channels, friends/colleagues) rather than direct physical experience with AVs.

6.4.2.2. Domain-specific system evaluation: Performance and effort expectancy, facilitating conditions, safety, and service and vehicle characteristics

As early as 1985, Endsley (1985a, 1985b) discussed the importance of acceptance for the introduction and success of new technologies. Almost twenty years later, Venkatesh et al. (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT), which provides a comprehensive synthesis of research to model technology acceptance and integrates eight influential acceptance models (e.g., Theory of Planned Behavior, Technology Acceptance Model). It postulates that performance expectancy[2], effort expectancy, social influence, and facilitating conditions influence the behavioral intention of an individual to use a technology, while behavioral intention and facilitating conditions determine actual system usage (Venkatesh et al., 2003). Age, gender and experience moderate the relationship between performance expectancy, effort expectancy, social influence and facilitating conditions and behavioral intention. UTAUT2, which follows from UTAUT1, suggests that an individual's behavioral intention to use information technology is influenced by three additional constructs in addition to the original UTAUT, i.e. hedonic motivation (i.e., fun or pleasure derived from using a technology), price value (i.e., monetary cost of technology use), and habit (i.e., extent to which an individual believes the behavior to be automatic) (Venkatesh, Thong, & Xu, 2012, p. 161). The suitability of the UTAUT1/2 to predict the acceptance of ADS-DVs has been supported by Leicht, Chtourou, and Youssef (2018), Kaur and Rampersad (2018), Moták et al. (2017), Zhang et al. (2019), and Zmud and Sener (2017) who revealed that performance expectancy (or its equivalent 'perceived usefulness') was significantly associated with the intention to use AVs. In Nordhoff et al. (2018), performance expectancy and effort expectancy measuring the component 'shuttle effectiveness', which pertained to the performance of L4 ADS-DVs in comparison with respondents' existing travel, significantly correlated with the component 'intention to use', which corresponds with the UTAUT construct 'behavioral intention'. The effect of facilitating conditions (or its equivalent 'perceived behavioral control'[3], 'helpfulness', 'technical support', '(technical) self-efficacy', 'conceptual

[2] Performance expectancy is the degree to which using a technology will provide benefits to users in performing certain activities; Effort expectancy is the degree of ease associated with the use of technology; Social influence describes the extent to which users perceive that important others believe they should use a particular technology; Facilitating conditions refer to users' perceptions of the objective resources and support available in the environment to perform a behaviour.

[3] Perceived behavioral control reflects perceptions about internal and external constraints to perform a behavior and encompasses self-efficacy; Helpfulness reflects perceptions about the provision of adequate and responsive aid; (Technical) self-efficacy reflects perceptions about having the ability and competence to use the technology (Venkatesh et al., 2003). Conceptual compatibility/fit captures beliefs that AVs will work in ways that make sense to the individual user. Lifestyle fit reflect user beliefs that using AVs will fit into the lifestyle of the individual user. Technology confidence is the degree of confidence in the ability to learn and use new technologies (Lee et al., 2017)

compatibility/fit', 'lifestyle fit', and 'technology confidence') on the intentions to use ADS-DVs was supported in the study of Buckley, Kaye, and Pradhan (2018), Brell, Philipsen, and Ziefle (2019a), Hewitt et al. (2019), Jing et al. (2019), and Madigan et al. (2017). Consequently, we conclude that performance/effort expectancy and facilitating conditions are positively correlated with the intention to use ADS-DVs.

Safety is one of the basic human needs and one of the key drivers influencing AVA (Brell, Philipsen, & Ziefle, 2019a; Kaan, 2017; Overakker, 2017; Liu, Zhang, & He, 2019; Piao et al., 2016; Nazari et al., 2018; Xu et al., 2018). At the moment, there seems to be a divide between the opinions of academics and practitioners and the general public regarding the expected safety benefits of AVs. While academics and practitioners do not seem to expect AVs to be error-free (Kalra & Paddock, 2016), the general public does not seem to be willing to accept fatalities that arise due to automation as exemplified by the public reactions to the accidents with the partly-automated vehicles from Tesla and Uber (Eden et al., 2017). Xu et al. (2018) found that perceived safety was significantly correlated with the intention to use and willingness to re-ride in AVs, which aligns with Nazari, Noruzoliaee, and Mohammadian (2018) who revealed that safety concerns reduced interest in shared automated vehicles.

In addition to safety, further vehicle and service attributes have been considered important determinants of AVA. In the interview study of Nordhoff et al. (2019), the majority of respondents' quotes captured service quality aspects (e.g., availability, flexibility, convenience), hinting that service quality is an important determinant of AVA. Krueger, Rashidi, and Rose (2016) found that service quality aspects including travel time, waiting time and travel costs were significant determinants of AVA. Consequently, we conclude that physical vehicle and service characteristics are correlated with the intention to use ADS-DVs.

6.4.3. Symbolic-affective aspects of AVA: Hedonic motivation and social influence

Social influence and hedonic motivation capture the symbolic-affective aspects of AVA, which have been found to play significant roles in consumer adoption behavior and intentions, such as the use of private motorized cars and electric vehicles (Rezvani et al., 2015; Steg et al., 2001). Bansal and Kockelman (2018) corroborated the effect of social influence on the willingness to adopt AVs by showing that some individuals were less likely to rely on the adoption rates of their friends (i.e., disabled, bachelor's degree holders, familiar with car-sharing) than others (i.e., elderly, single, Caucasian ethnicity). Acheampong and Cugurullo (2019) found a positive relationship between subjective norm (equivalent to social influence) and the perceived benefits (equivalent to performance expectancy, see Xu et al., 2018; Zhang et al., 2019), and ease of use of automated driving technology (equivalent to effort expectancy), and a positive relationship between subjective norm and perceived behavioral control (equivalent to facilitating conditions). Hartwich, Beggiato, and Krems (2018) postulate that affective variables are of growing importance for drivers' vehicle choices, and found a significant effect of enjoyment on automated driving. The role of emotions in AVA was substantiated by Rödel et al. (2014) who found that fun[4] declines with higher levels of vehicle automation, and Kyriakidis, Happee, and De Winter (2015), who revealed that respondents considered full automation to be the least enjoyable and manual driving the most enjoyable mode of driving. Hohenberger, Sporrle, and Welpe (2016) observed that pleasure was positively correlated with the willingness to use AVs, while anxiety was negatively correlated with the willingness to use AVs. In light of these findings, we conclude that social influence, and hedonic motivation are correlated with the intention to use ADS-DVs.

[4] Extent to which the activity of using a specific system is perceived to be enjoyable (Rödel et al., 2014).

6.4.4. Moral-normative aspects of AVA: Risk-benefit perception

In line with Kohl et al. (2018) and Raue et al. (2019), we argue that the perception of risks and benefits are important factors for AVA. Similar to Milakis, Van Arem, and Van Wee (2017) in their ripple effect of automated driving model, the moral-normative perception of risks and benefits in our model represents higher-order implications of AVs on energy consumption, air pollution, economy, public health and social equity. Risks that the public tends to associate with the introduction of AVs typically include legal liability in case of an accident, data privacy, unemployment among bus and taxi drivers, the loss of human interaction/control in public transport, and an overreliance on AV technology (Bansal & Kockelman, 2018; Bloom et al., 2017; Brinkley et al., 2017; Kyriakidis et al., 2015; Lavieri et al., 2017; Medina & Jenkins, 2017; Portouli et al., 2017; Regan et al., 2017; Wang & Ankar, 2019; Woldemanuel & Nguyen, 2018). Benefits encompass reduced emissions, congestion, and fuel consumption, lower insurance rates, easier and quicker parking, improvements in traffic safety and productivity due to the engagement in non-driving related tasks (Daziano et al., 2017; Medina & Jenkins, 2017; Portouli et al., 2017; Tennant et al., 2016). Ward et al. (2017) found that the perception of risks and benefits was significantly correlated with the interest in using an AV, with the level of comfort with automation, and with the desire for highly automated driving features in the next vehicle. Piao et al. (2016) found that the expected benefits of AVs were positively correlated and the expected concerns of AVs were negatively correlated with the attitudes of their respondents. Wu et al. (2019) found that people who value the environmental benefits of AVs and who reported to be concerned about the environment were more likely to value the environmental benefits of AVs and showed a higher willingness to use or buy AVs. On the basis of these considerations, we propose that the perception of risks is negatively correlated and the perception of benefits is positively correlated with the intention to use ADS-DVs.

6.4.5. Micro-level: Individual difference factors

Ajzen and Fishbein (2005), Bagozzi and Lee (1999), and Venkatesh, Thong, and Xu (2016), we propose that these individual difference factors are generic AVA factors that influence the intention to use ADS-DVs by mediating or moderating the relationship between the factors at the meso-level. This is confirmed by Zhang et al. (2019) who found that trust (individual difference factor at micro-level) mediated the correlation between perceived safety, usefulness and attitudes towards using AVs, which influenced the intention to use AVs (factors at meso-level). We also expect independent main effects of the individual difference factors on the factors at the meso-level, including the intention to use AVs. For example, Xu et al. (2018) found significant positive effects of trust on perceived usefulness/ease of use and the intention to use AVs.

6.4.5.1. Socio-demographics

Concerning the influence of socio-demographic characteristics on AVA, three patterns are currently observable based on the literature. Men tend to be more accepting of AVs than women: They are more aware of automated driving functions, tend to pay more for automation, are more interested in AV ownership, rate AVs as more useful, seem to be less concerned about safety, are less afraid to drive in AVs and trust AVs more, and are more comfortable to allow a fully automated car to perform all driving tasks (Bhat et al., 2016; Choi & Yi, 2015; Kyriakidis, Happee, & De Winter, 2015; Liu, Zang, & Xu, 2019; Nazari, Noruzoliaee, & Mohammadian, 2018; Regan et al., 2017; TNS Opinion & Social, 2015; Zhang et al., 2019).

The effect of age is ambiguous. Bansal, Kockelman, and Singh (2016), and Schoettle and Sivak (2014, 2015) reported that younger people were more accepting of AVs than older people. In contrast, Rödel et al. (2014) showed that people aged 36 to 65 had a more positive attitude and a stronger intention to use AVs than people aged 18 to 35. Nordhoff et al. (2018) found that elderly people were more likely to express an intention to use automated shuttles and were positive towards the characteristics of the shuttle but rated the effectiveness of the shuttle more negatively in comparison with their existing form of travel.

The statistical effects of gender and age on individuals' behavioral intentions to use AVs are usually weak or disappear when considered with other social-psychological variables being held constant. For example, Madigan et al. (2016) who applied the UTAUT model to understand the predictors of the acceptance and use of AVs in La Rochelle (France) and Lausanne (Switzerland) found that age effects disappeared when they were examined as part of a multiple regression where the influences of all variables under study were held constant. The effect of gender also disappeared in the multiple regression of Payre, Cestac, and Delhomme (2014), when contextual acceptability as measured by four ordinal-scale items (e.g., 'If driving was boring to me, I would rather delegate it to the automated driving system instead of doing it myself') was added to the model in the second step. Kyriakidis, Happee, and De Winter (2015) found neither clear age nor gender effects because the correlations were mostly smaller than 0.10, which corresponds with Regan et al. (2017) whose effect sizes of age and gender were found to be small, and with Webb, Wilson, and Kularatne (2019) who found marginally significant to no significant age effects. These findings also correspond with research unrelated to AVs. For example, Stern (2000) found that socio-demographic variables were unrelated to consumer behavior and policy support when social-psychological variables could simultaneously influence the outcome variable, and with Fernández-Heredia et al. (2016) who found that income and Spanish nationality dropped out of their model when their four latent explanatory variables (i.e., convenience, pro-bike attitude, physical determinants and external restrictions) were included.

Besides age and gender, Liu, Guo, Ren, Wang, and Xu (2019) and Kyriakidis, Happee, and De Winter (2015) observed a positive relationship between income and willingness to pay for vehicle automation. Hardman, Berliner, and Tal (2018) revealed that "Pioneers" and "Pro-automated consumers" had the highest incomes, while "Driverless sceptics" and "Laggards" had the lowest incomes. Hudson, Orviska, and Hunady (2019) found that peoples' degree of comfort with driverless cars increased with their level of education and prosperity, and decreased with being a manual worker, unemployed, retired or a farmer. Bansal, Kockelman, and Singh (2016), and Nazari, Noruzoliaee, and Mohammadian (2018) further revealed that the number/presence of children in a household were positively related to the willingness to pay for automation and the propensity to carpool with AV for commute trips. Hudson, Orviska, and Hunady (2019) revealed that support for driverless cars was lower for those living in villages and small towns, and higher for city dwellers. This corresponds with Regan et al. (2017) who found that residents in the more densely-populated South Australia were more positive towards the potential benefits of fully-automated cars and more agreeable to using fully automated cars compared to residents in the less densely-populated Northern Territory who had more negative perceptions and were less agreeable.

6.4.5.2. Personality

Personality-related factors that are considered pivotal for AVA are technology savviness, trust, locus of control and sharing an AV with a stranger.

As regards the effect of technology savviness, Bansal, Kockelman, and Singh (2016) found that technology-savvy individuals were more positive towards AVs, which is in agreement with Lavieri et al. (2017) who found that tech-savvy individuals are likely to be early adopters of

AVs, and with Haboucha, Ishaq, and Shiftan (2017) who found that individuals with a higher interest in technology were more likely to choose AVs.

Trust has been considered a valid foundation for human-machine interaction (Hengstler et al., 2016), and plays a leading role in determining the willingness of humans to rely on automated systems (Hoff, & Bashir, 2015), and accept AVs (Haspiel et al., 2018; Molnar et al., 2018; Wintersberger et al., 2016; Zhang et al., 2018). Choi and Li (2015) observed that individual generic trust levels positively influenced the perceived usefulness of AVs and the intentions to use them, while it reduced any related perceived risks. Zmud and Sener (2017) revealed that lack of trust in the technology was cited by 41% of the respondents as one of the reasons for being unlikely to ride in self-driving vehicles for everyday use. Abraham et al. (2016) found that higher trust in the different entities to build a self-driving car and more comfort with higher levels of automation were associated with the willingness to pay more for a self-driving car. The focus group analysis of Brinkley et al. (2017), however, identified issues related to risk and trust as the themes that were the least discussed by members of their focus groups. We hypothesize that the relevance of trust will be especially strong in the early stages of AVs' deployment, when people would still have limited experience with and knowledge of AVs. Hartwich et al. (in press) support this by showing that the acceptance and trust in automation significantly increased after the primary system experience with highly-automated driving vehicles, but remained stable after the initial system exposure. Trust has to be calibrated (i.e., individuals' level of trust matches the capabilities of automation) to prevent misuse with overtrust and disuse with undertrust of AVs (Hoff & Bashir, 2015; Lee & See, 2004). Overtrust can have profound negative consequences for safety. In an on-road study using a Tesla Model S operating in Autopilot mode, drivers showed behaviors of complacency and overtrust (Banks et al., 2018). These safety-critical behaviors can negatively impact the acceptance of AVs as inferred by the decrease in the publics' level of trust in AVs after the occurrence of fatal and serious accidents with AVs (Claybrook & Kildare, 2018).

The notion of locus of control captures individuals' assumptions regarding responsibility for the outcome of events (Rotter & Hochreich, 1975; Rudin-Brown & Parker, 2004). Locus of control was one of the main variables in a psychological model of driving automation (Stanton & Young, 2000), which was updated in a later study (Heikoop et al., 2015). People with an internal locus of control ("Internals") are more likely to rely on their own skills and abilities and maintain direct involvement with the system regardless of how safe or reliable it is. In contrast, people with an external locus of control ("Externals") are more likely to relinquish control to an external device and rely on it to perform a task (Payre, Cestac, & Delhomme, 2014; Rotter, 1966; Rudin-Brown & Parker, 2004). There is still a paucity of knowledge regarding the extent to which AVs are accepted by "Internals" and "Externals". We expect that "Externals" are more likely to surrender control to AVs, while "Internals" are more inclined to prefer manual controls to intervene in the vehicle's operations rather than surrendering control entirely. So far, studies generally reveal a preference of individuals to maintain some degree of control over the AV rather than relinquishing complete control to the AV. For example, Hassan et al. (2019) found that the large majority of their respondents (81%) preferred to be in control of their vehicle because autonomous technologies cannot be foolproof. In a questionnaire study (Nordhoff et al., 2018), we found that the majority of our respondents agreed on being able to take over control from an AV by using a button inside the vehicle, which corresponds with Schoettle and Sivak (2015), who found that about 96% of the respondents preferred the availability of vehicle controls.

Research has explored the role of the private car in maintaining privacy and personal space and enabling movement amongst people without jeopardizing personal space boundaries

(Ibrahim, 2003; Petkewich, 2005). The automobility frame "Cocooning and Fortressing" proposed by Sovacool and Axsen (2018), which has dominated the literature, considers the car as cocoon, fortress or isolated enclave similar to a mobile living room where drivers are isolated from the world and relax, listen to music, and engage in other (private) leisure activities. Sharing an AV with a stranger is an important factor for AVA, especially for AVs that are shared rather than personally-owned such as driverless automated shuttles as feeder modes to public transport systems, or AVs that are used as taxi, carsharing or ridesharing vehicles. Cunningham, Ledger, and Regan (2018) found that "travelling in public transport in which the vehicle is driverless" and "sharing a driverless vehicle" received the lowest agreement among respondents. In the study of Bansal, Kockelman, and Singh (2018), 50% of respondents reported being comfortable in sharing a ride with a stranger for short durations during the day or with a friend of one of their Facebook friends. Sanguinetti, Ferguson, and Kurani (2019) posit that there is still a paucity of knowledge regarding who will be willing to share rides, with whom, and under what circumstances. Therefore, we strongly encourage future research to investigate the capability and willingness of individuals to share rides with strangers in AVs and its role for AVA.

While the above considerations provide evidence for the relationships between personality-related factors at the micro-level and factors at the meso-level, we also expect relationships between the factors within the micro-level. Abraham et al. (2016), for instance, revealed that younger people have higher levels of trust in traditional automakers and the Silicon Valley technology companies than older people. These findings point to possible correlations between socio-demographics (e.g., age, gender) and personality-related factors (e.g., trust), which deserve further investigation.

6.4.5.3. Travel behavior

The relevance of individuals' travel behavior for AVA has been supported by the literature. For example, with respect to individuals' access to mobility, Bansal, Kockelman, and Singh (2016) found that licensed drivers would be less likely to frequently use shared AVs. With respect to individuals' driving experience, Kyriakidis, Happee, and De Winter (2015) revealed that people who drive more are willing to pay more for AVs, while Bansal, Kockelman, and Singh (2016) found that individuals who experienced more accidents are more likely to embrace AVs. With regard to the use of daily modes of transport, Zmud and Sener (2017) found a significant effect of the commuting mode on the intention to use self-driving vehicles with private passenger car drivers seeming to be more reluctant to use AVs than users of other transport modes (i.e., public transport vehicle passengers, walkers or telecommuters). Winter et al. (2016) corroborated the influence of current travel mode choices on the preferences for AV technology: Early adopters (i.e., users of the ride-sourcing company Uber, or members of households with at least one subscription to a carsharing company) found modes requiring parking and driving (car, free-floating carsharing) the least attractive and prefer demand-responsive modes that allow for the productive use of in-vehicle travel time by task engagement during the ride (taxi, shared AVs). Nielsen and Haustein (2018) revealed that people who are sceptic towards AVs ("Sceptics") are more likely to drive their car just for the fun of it. In contrast, people being indifferent towards AVs ("Indifferents") tend to use the car for travel purposes, while people being enthusiastic about AVs ("Enthusiasts") use the car to get to their holiday destination. Additionally, 45% of Sceptics use the car daily as compared to 41% of "Enthusiasts, and 29% of "Indifferents".

6.5. Discussion

This study presents a comprehensive, theoretically motivated, multi-level model on AVA, referred to as MAVA. MAVA is based on 124 empirical studies that were retrieved in a systematic literature review. The literature review revealed that 6% of the studies investigated the exposure of individuals to AVs (i.e., knowledge & experience). 22% of the studies investigated domain-specific factors (i.e., performance/effort expectancy, safety/reliability/security, service/vehicle characteristics), 4% symbolic-affective factors (i.e., hedonic motivation, social influence), and 12% moral-normative factors (perceived benefits/risks). Factors related to a person's socio-demographic profile, travel behaviour, and personality were investigated by 28%, 15% and 14% of the studies, respectively. MAVA incorporates a process-oriented view on AVA, as a function of factors located at two different levels, i.e., meso, micro. The meso-level merges domain-specific, symbolic-affective and moral-normative factors. It is influenced by factors at the micro-level, representing individual difference factors. The model explains acceptance as a sequential, four-stage decision-making process that ranges from the exposure of the public to AVs in stage 1, the formation of favorable or unfavorable attitudes towards AVs in stage 2, making the decision to adopt or reject AVs in stage 3, to the use of AVs in stage 4.

The model can be operationalised in two ways. First, when the research goal is to understand AVA, the full model could be applied and adapted to the research context. Second, when the research goal is to explain or predict, a more parsimonious and directive (mathematical) model would be more suitable. The meso-level or factors at the meso-level could then be used together with factors at the micro-level to suit the context at hand. Previous studies mostly applied linear regression analyses to investigate the correlations between AVA factors and the acceptance construct itself. MAVA can be implemented as a non-linear multilevel model, capturing the four stages of acceptance in time. It represents a conditional model where actual acceptance will depend on all four stages as well as a probabilistic model with probability functions capturing the relationship between the factors at the micro level and the factors at the meso-level. Multivariate analysis methods such as regression or structural equation modelling can be applied to test and quantify mathematic relations between the factors in the model. Qualitative techniques (e.g., focus groups and interviews) could also be employed to explore the relevance of each factor and adjust the model by new factors that have not been identified yet. Finally, the model indicates the extent to which the factors in our model are causally related. Future studies should, therefore, examine the causal nature of these relationships using longitudinal and experimental studies.

While a strength of the model is its profound grounds in empirical research, the empirical evidence on AVA should be interpreted with regards to its current caveats. That is, while the rapid growth in AVA research has undoubtedly been gratifying, researchers expressed some concerns regarding the current state of the literature. For example, Fraedrich and Lenz (2014) pointed out that most of the respondents who participated in the numerous surveys lack broad knowledge of or actual experience with AVs, which may pose a threat to the validity of results. Further, Lavieri et al. (2017) stated that the datasets used to investigate people's attitudes towards AVs are mainly based on surveys with a variety of different assumptions and specifications to describe automated vehicle technologies and scenarios. Finally, Langdon et al. (2017) argued that despite comparable findings it is not clear yet to what extent the public understands the driverless technology and how this technology can form a part of their lives in the short- and middle-run. A second weakness of MAVA is its relatively low parsimony as it contains a large number of factors, which could make the model cumbersome at times for researchers to use. Potential critics could refer to previous research, which has shown that only a small number of factors are needed to explain most of the variance in the outcome variable and where the explanatory power of these models could only be marginally increased by virtue of additional factors. For example, a 13-factor-model increased the variance in behavioral intention by only 2% over a 5-factor model (Taylor & Todd, 1995). Yet, the 13-factor-model in this case provided a better understanding by showing which factors are *less* influential in predicting the intention to use technology. On the other hand, it can be argued that in previous AVA studies (Böhm et al., 2017; Madigan et al., 2016; Madigan et al., 2017), instrumental domain-specific and symbolic-affective factors explained between 19.6% to 58.6% of the variance in individuals' behavioral intentions to use AVs. This implies that a substantial amount of variance has not been captured so far, which again justifies the development of MAVA that contains additional predictors of AVA. Furthermore, previous studies mostly applied linear regression analyses to investigate the correlations between factors of AVA and the acceptance construct itself. MAVA can be implemented as a non-linear multilevel model, capturing the four stages of acceptance in time. It represents a conditional model where actual acceptance will depend on all four stages as well as a probabilistic model with probability functions capturing the relationship between the factors at the micro level and the factors at the meso-level. A further limitation of MAVA is that for the sake of brevity and a paucity of knowledge, it only concentrates on the micro- and meso-level and refrains from detailing the macro-level as an assembly of higher-level external contextual factors (i.e., environment, organization, location). Future research should not neglect the role of the factors that were discarded from the analysis of the present study. The macro-level is a potentially relevant determinant of AVA. As Sanbonmatsu (2018, p. 114) posited: *„Consumer opinions will also determine the support for the legal and physical infrastructure needed to put the technology on our roads."* On values Moták et al. (2017, p. 271) stated that: *„Values represent such a major research trend that it would be difficult to neglect them when seeking to apply as broad an approach as possible to automated shuttles' acceptability."* Moták et al. (2017) found that personal values significantly impacted the intentions to use ADS-DVs. Future research should investigate the value basis of beliefs or behavior (Steg & Vlek, 2009; Steg et al., 2014), and explore how self-enhancement and self-transcendence values[5] influence AVA.

Finally, MAVA does not specify the relative importance or weight of the factors on the intention to use AVs as the specific nature of the relationships between the factors in the model is still relatively unknown and will probably be adjusted as research on AVA grows in the coming years. However, in line with the propositions of Ajzen and Fishbein (2005), we would assume that the relative importance of these factors varies as a function of the specific behavior and the population under consideration. Finally, the model indicates the extent to which the factors in our model are causally related. Future studies should, therefore, examine the causal nature of these relationships using longitudinal experimental studies.

6.6. Final conclusions

In conclusion, the present paper proposes a multi-level model to predict AVA, named MAVA. Building on UTAUT3 and CTAM, MAVA incorporates a process-oriented view and contemplates acceptance as a four-stage decision-making process. The process starts with the exposure of the individual to ADS-DVs in stage 1, and moves to the formation of either a favorable or unfavorable attitude towards ADS-DVs in stage 2, to deciding whether to use or reject ADS-DVs, or remain undecided in stage 3, and to putting ADS-DVs into use in stage 4.28 acceptance factors that were identified in the literature review are located at two levels, i.e., micro, and meso. The factors at the meso-level represent the procedural view on acceptance with the exposure of individuals to AVs in terms of 'experience with/knowledge about AVs' preceding the domain-specific factors 'performance/effort expectancy', 'facilitating conditions', 'safety/reliability/security', and 'service/vehicle characteristics', the symbolic-affective factors 'hedonic motivation', and 'social influence' and the moral-normative factors

[5] Self-enhancement values reflect a key concern with one's own individual interests, while self-transcendence values reflect a key concern with the collective interest (Steg et al., 2014).

'perceived risks' and 'perceived benefits'. The individual difference factors 'socio-demographics', 'travel behavior', and 'personality' at the micro-level influence the factors at the meso-level. We expect our model to provide useful insights to policy makers and other actors involved in the deployment of ADS-DVs. We recommend future research to revisit the model for empirical verification and adaptation and further explore the nature of these factors as well as relationships using longitudinal or experimental studies.

6.7. Declaration of interest statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

6.8. References

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Chapter 7: A structural equation modeling approach for the acceptance of driverless automated vehicles based on constructs from the Unified Theory of Acceptance and Use of Technology and the Diffusion of Innovation Theory

7.1. ABSTRACT

The present study investigated the attitudes and acceptance of automated vehicles in public transport among 340 individuals physically experiencing the automated vehicle 'Emily' from Easymile in a mixed traffic environment on the semi-public EUREF campus in Berlin. The highest mean rating was obtained for believing that automated vehicles are easy to use, while the lowest mean rating was obtained for feeling safe inside the automated vehicle without any type of supervision. The analysis revealed a preference for supervision of the automated vehicle via an external control room to supervision by a human steward onboard. Automated vehicle acceptance was modelled as a function of the Unified Theory of Acceptance and Use of Technology (UTAUT) constructs performance and effort expectancy, social influence, and facilitating conditions, the Diffusion of Innovation Theory (DIT) constructs compatibility and trialability, as well as trust and automated vehicle sharing. The results show that after adding the DIT constructs, automated vehicle sharing, and trust to the model, the effects of performance expectancy and social influence on the behavioral intention are no longer significant. Instead, compatibility with current travel was the strongest predictor of behavioral intention to use automated vehicles, followed by automated vehicle sharing. It was further found that individuals who are willing to share rides in an automated vehicle with fellow travelers (i.e., automated vehicle sharing) are more likely to intend to use automated vehicles (i.e., behavioral intention). We recommend future research to investigate the hypothesis that compatibility could serve as an even stronger predictor of the behavioral intention to use automated vehicles in public transport than performance expectancy.

Nordhoff, S., Malmsten, V., Van Arem, B., & Happee, R. (under review). A structural equation modelling approach for acceptance of driverless automated vehicles based on constructs from the Unified Theory of Acceptance of Use of Technology and the Diffusion of Innovation Theory.

7.2. Introduction

Automated vehicles can substantially contribute to the attractiveness of public transport. As these vehicles feed public transport on the first and last end of a public transport trip and can be ordered on-demand, they can provide a flexible door-to-door transport service around the clock, and are more affordable due to decreases in labor costs (Shen, Zhang, & Zhao, 2018). As a hybrid form of individual-public transport, automated vehicles can enhance the inter-modality and individualization of public transport due to smaller-sized vehicles (Fraedrich & Lenz, 2015; Shen et al., 2018). Given the large investments in the development of automated vehicles, forecasting the acceptance of automated vehicles in public transport and collecting feedback on prototypes from potential users as early as possible is desirable to increase the chance of acceptance and reduce the likelihood of rejection (Davis, 1993; Gould, Boies, & Lewis, 1991; Rosson, Maas, & Kellogg, 1987).

The examination of automated vehicle acceptance has received ample attention in the past few years. The Unified Theory of Acceptance and Use of Technology (UTAUT) is one of the most comprehensive theories to model technology acceptance that is based on eight influential acceptance models. It posits that the intention to use technology is influenced by its perceived usefulness (i.e., performance expectancy), ease of use (i.e., effort expectancy), the influence of the individuals' social network (i.e., social influence), and facilitating conditions (i.e., objective factors in the individual's environment supporting usage) (Venkatesh et al., 2003). Roger's Diffusion of Innovation Theory (1995, 2003) posits that an individual's adoption decision is influenced by six characteristics: relative advantage, image, compatibility, observability, complexity and trialability. Relative advantage, image and complexity correspond with the UTAUT constructs performance expectancy, social influence and effort expectancy, respectively (Venkatesh et al., 2003). Previous studies have modelled the behavioral intention to use automated vehicles as a function of the UTAUT constructs (Hewitt et al., 2019; Kaur & Rampersad, 2018; Kettles & Van Belle, 2019; Madigan et al., 2016; Madigan et al., 2017; Panagiotopoulos & Dimitrakopoulos, 2018; Xu et al., 2018), and trust (Choi & Ji, 2015; Kaur & Rampersad, 2018; Zhang et al., 2019). However, there is a paucity of knowledge on the role of Roger's (2003) Diffusion of Innovations Theory (DIT) constructs trialability and compatibility, and automated vehicle sharing for predicting AVA. Research studies in other domains have integrated technology acceptance models and the DIT (Min, So, & Jeong, 2018). As previous studies on automated vehicle acceptance explained around 70 percent of the variance in the intention to use automated vehicles (Nordhoff et al., 2019), identifying and testing further predictors can account for additional variance in behavioral intention in order to provide a richer understanding of automated vehicle acceptance (see Venkatesh et al., 2003).

Venkatesh (1999) posits that there has been limited research on the interventions that stimulate acceptance and use of information technology. In his study (Venkatesh & Bala, 2008), Venkatesh cites Lee, Kozar, and Larsen (2003) who posit that one of the most common criticisms of the technology acceptance model has been the lack of actionable guidance to practitioners: *„Imagine talking to a manager and saying that to be adopted, technology must be useful and easy to use. I imagine the reaction would be 'Duh!' The more important questions are what makes technology useful and easy to use"* (Lee et al., 2003, p. 766). The same reasoning Venkatesh and Bala (2008) applied to the domain of the acceptance of information technology also applies to the field of automated vehicle acceptance: The mechanisms that indirectly promote automated vehicle acceptance are not well understood so far. Knowledge on the interventions necessary to promote automated vehicle acceptance indirectly can be obtained by examining the interrelationships between the acceptance factors.

There is a paucity of knowledge on the interrelationships between the UTAUT constructs performance and effort expectancy, social influence, and facilitating conditions, the DIT constructs trialability and compatibility, and trust and automated vehicle sharing. The study of interrelationships has received renewed interest in the domain of automated driving in the past few months (Nordhoff et al., under review). This knowledge can be used to inform the strategic decision-making of policy-makers and practitioners regarding the prioritization of acceptance factors, and the derivation of corresponding strategies and policies to promote automated vehicle acceptance. In line with Venkatesh and Bala (2008) we assume that unless effective interventions are developed to enhance automated vehicle acceptance, the practical utility of our rich understanding of automated vehicle acceptance is limited. Furthermore, the study of interrelationships between variables is important to identify the ability of variables to predict the outcome variable in a multivariable context, while identifying redundancy. While a variable can have a strong bivariate correlation with the outcome variable, its effect on the outcome variable can disappear when it is considered together with additional variables in a model. This would then imply that this particular variable is not needed and thus redundant to produce the optimal prediction of the outcome variable (Hair et al., 2014). The knowledge on variable redundancy can contribute to the development of more economic measures to investigate attitudes towards and acceptance of automated vehicles.

7.2.1. Research objectives

The main objectives of the present study therefore are:

(i.) To examine the effect of the UTAUT constructs performance and effort expectancy, social influence, and facilitating conditions, and DIT constructs trialability, compatibility, as well as trust and automated vehicle sharing on the behavioral intention to use automated vehicles in public transport

(ii.) To examine the interrelationships between the UTAUT and DIT constructs, as well as trust and automated vehicle sharing

7.2.2. Hypothesis development

In previous studies on automated vehicle acceptance (Kaur & Rampersad, 2018; Madigan et al., 2016; Madigan et al., 2017; Panagiotopoulos & Dimitrakopoulos, 2018; Xu et al., 2018) positive effects of performance and effort expectancy, and social influence on individuals' behavioural intentions to use automated vehicles were found. The underlying assumption is that individuals who consider automated vehicles useful (i.e., performance expectancy), easy to use (i.e., effort expectancy), and who believe that important others in their social networks support the use of automated vehicles (i.e., social influence) are more likely to intend to use automated vehicles (i.e., behavioural intention). Note that the effect of facilitating conditions on usage behavior is contingent on the moderators age and experience (Venkatesh et al., 2003). We posit the following hypotheses:

> ***H1–H3:*** *Performance expectancy (H1), effort expectancy (H2), and social influence (H3) will have a positive effect on the behavioural intention to use automated vehicles.*

We further expect that the relationships between performance and effort expectancy, social influence and behavioural intention are moderated by age and gender in line with Venkatesh et al. (2000, 2003).

> ***H4:*** *The relationships between performance and effort expectancy, social influence and behavioural intention to use automated vehicles are moderated by age and gender.*

In line with the literature on automated vehicle acceptance (Nordhoff et al., under review; Wu et al., 2019; Zhang et al., 2019), we further expect a positive effect of effort expectancy on performance expectancy. The underlying assumption is that individuals who consider automated vehicles easy to use (i.e., effort expectancy) are more likely to consider automated vehicles useful (i.e., performance expectancy). Hence, we hypothesize:

> ***H5:*** *Effort expectancy will have a positive effect on performance expectancy.*

Acheampong and Cugurullo (2019) found positive effects of subjective norm (equivalent to social influence) on the perceived benefits (equivalent to performance expectancy, see Xu et al., 2018; Zhang et al., 2019), and the ease of use of automated driving technology, and a positive relationship between subjective norm and perceived behavioral control (equivalent to facilitating conditions). In our study (Nordhoff et al., under review) social influence was related to performance expectancy, facilitating conditions, and hedonic motivation. We further expect positive effects of social influence on trust, compatibility, automated vehicle sharing, and trialability. The underlying assumption is that individuals who believe that important others in their network will appreciate their use of automated vehicles (i.e., social influence) are more likely to trust automated vehicles (i.e., trust), to consider automated vehicles compatible with their existing mobility needs and routines (i.e., compatibility), to share automated vehicles with fellow travellers (i.e., automated vehicle sharing), and to appreciate trialling automated vehicles before adoption (i.e., trialability). Thus, we posit the following hypotheses:

> ***H6–H12:*** *Social influence will have a positive effect on performance expectancy (H6), effort expectancy (H7), facilitating conditions (H8), trust (H9), compatibility (H10), automated vehicle sharing (H11), and trialability (H12).*

There is a paucity of knowledge about the relationship between facilitating conditions, and effort and performance expectancy, respectively. In our study (Nordhoff et al., under review), we found positive effects of facilitating conditions on effort expectancy, while the relationship between facilitating conditions and performance expectancy was not significant. We expect positive effects of facilitating conditions on performance expectancy under the assumption that individuals who believe to be in possession of the necessary resources to use automated vehicles (i.e., facilitating conditions) are more likely to consider automated vehicles useful (i.e., performance expectancy). We hypothesize:

> ***H13–H14:*** *Facilitating conditions will have a positive effect on performance expectancy (H13) and effort expectancy (H14).*

Compatibility is defined as the degree to which an innovation is perceived to be consistent with existing values, needs and experiences of potential adopters (Rogers, 2003). It has been consistently related to technology adoption together with relative advantage and complexity and is considered an important salient belief contributing to technology acceptance (Karahanna, Agarwal, & Angst, 2006). There is still a paucity of knowledge how compatibility influences the behavioural intention to use automated vehicles in public transport. We expect a positive relationship between compatibility and the behavioural intention to use automated vehicles under the assumption that individuals who consider automated vehicles to be compatible with their existing mobility routines and needs are more likely to intend to use automated vehicles. This assumption is supported by the scientific literature. Moore and Benbasat (1991) found that compatibility had the highest influence on the attitude towards using technology, which in turn influenced technology usage. Similarly, Rezvani et al. (2015) showed that the compatibility of electric vehicles in everyday lives and habits is an important factor for potential adopters of electric vehicles. Ozaki and Sevastyanova (2011) identified perceived benefits and compatibility with green values and practices and needs as one of the five factors determining UK consumers' purchase motivations of hybrid vehicles. We therefore hypothesize:

> ***H15:*** *Compatibility will have a positive effect on the behavioural intention to use automated vehicles.*

We further expect positive effects of compatibility on performance and effort expectancy and facilitating conditions. The underlying assumption is that individuals who consider automated vehicles to be compatible with their exiting mobility needs (i.e., compatibility) are more likely to believe that automated vehicles are useful (i.e., performance expectancy), easy to use (i.e., effort expectancy), and that they have the necessary resources using automated vehicles (i.e., facilitating conditions). Our assumptions are supported by literature on technology acceptance in other domains (Oliveira et al., 2016; Tavares & Oliveira, 2018; Zhang et al., 2015). We hypothesize:

> ***H16–H18:*** *Compatibility will have a positive effect on performance expectancy (H16), effort expectancy (H17) and facilitating conditions (H18).*

Trialability is the extent to which an innovation can be trialled and experienced before the adoption (Rogers, 1995; 2003). Experiencing automated vehicles in a trial can be regarded as a suitable means to increase the acceptance of automated vehicles. Individuals can test automated vehicles and their benefits whereby uncertainty can be reduced and knowledge and trust gained. Exposing the public to automated vehicles in trials is pivotal given that vehicles operating at the SAE level 3 and higher have not yet been available for either commercial or private use, which may explain the limited knowledge of the public about automated vehicles (Berliner et al., 2019; Pettigrew et al., 2019; Sanbonmatsu et al., 2018). Liu, Xu, and Zhao (2019) posit that the investigation of the acceptance of road tests is a pressing research need that has to be addressed, especially after the occurrence of the first pedestrian fatality caused by an automated vehicle. We expect a positive relationship between trialability and the behavioural intention to use automated vehicles under the assumption that individuals who value experiencing automated vehicles in trials prior to adoption (i.e., trialability) are more inclined to use automated vehicles in public transport (i.e., behavioural intention). We hypothesize:

> ***H19:*** *Trialability will have a positive effect on the intention to use automated vehicles.*

Furthermore, we expect that trialability influences the extent to which automated vehicles are considered useful (i.e., performance expectancy), easy to use (i.e., effort expectancy), and compatible with their existing mobility needs (i.e., compatibility). Liu, Xu, and Zhao (2019) supported a positive relationship between perceived benefits (equivalent to performance expectancy) and road test acceptance, implying that individuals who value the perceived benefits of automated vehicles are more likely to accept road tests with automated vehicles. To the best of our knowledge, this study is the first examining the relationship between trialability, performance and effort expectancy and compatibility. We expect that individuals who value the importance of trialing automated vehicles before adoption (i.e., trialability) are more likely to consider automated vehicles useful (i.e., performance expectancy), and easy to use (i.e., effort expectancy), are more likely to believe to be in possession of the necessary resources to use automated vehicles (i.e., facilitating conditions), and consider automated vehicles compatible with their existing mobility needs and routines (i.e., compatibility), and to trust automated vehicles (i.e., trust).

> ***H20–H24:*** *Trialability will have a positive effect on performance expectancy (H20), effort expectancy (H21), facilitating conditions (H22), compatibility (H23), and trust (H24).*

Trust is a key driver of automated vehicle acceptance (Choi & Ji, 2015; Du et al., 2018; Roche-Cerasi, 2019). Choi and Ji (2015) found statistically significant effects of trust on the intention to use automated vehicles, which corresponds with Herrenkind et al. (2019). The study of Brell, Philipsen, and Ziefle (2019) revealed that respondents preferred the option of being able to control the actions of an autonomous vehicle at all times as it was difficult for them to envision a complete surrender of control to the technology. Woldeamanuel and Nguzen (2018), who studied the perceived benefits and concerns of millennials vs. non-millennials towards autonomous vehicles, found that 95% of millennials were most concerned about riding in a vehicle without driver controls such as a steering wheel, brake and gas pedals. Lee and Mirman (2018) revealed that the perceived concern ‘I would not know how the autonomous vehicle will protect my child if there are aggressive or dangerous vehicles nearby’ received the highest agreement among parents. On the basis of these results, we expect that individuals with higher levels of trust in automated vehicles (i.e., trust) are more likely to intend to use automated vehicles (i.e., behavioural intention). We hypothesize:

> ***H25:*** *Trust will have a positive effect on the intention to use automated vehicles.*

Zhang et al. (2018) found that trust had significant and positive relations with the attitude towards automated vehicles, which in turn was positively related to the intention to use automated vehicles. Xu et al. (2018) found positive effects of trust on performance and effort expectancy. Positive effects of social trust on the perceived benefits of automated vehicles have been supported by Liu, Xu, and Zhao (2019). These findings feed into our hypothesis that trust has positive effects on performance and effort expectancy and facilitating conditions. The underlying assumption is that individuals who have a higher level of trust in automated vehicles (i.e., trust) are more likely to believe that automated vehicles are useful (i.e., performance expectancy), easy to use (i.e., effort expectancy), and that they are in possession of the necessary resources to use automated vehicles (i.e., facilitating conditions). Trust is further related to compatibility on the assumption that individuals who have a higher level of trust in automated vehicles (i.e., trust) are more likely to consider automated vehicles compatible with their existing mobility needs and routines (i.e., compatibility). We hypothesize:

> ***H26–H29:*** *Trust will have a positive effect on performance expectancy (H26), effort expectancy (H27), facilitating conditions (H28) and compatibility (H29).*

Even though sharing an automated vehicle with strangers as part of public transport is an ubiquitous part of the user experience, it has received surprisingly little attention from scientific scholars so far. Axsen and Sovacool (2019) and Sanguinetti, Ferguson, and Kurani (2019) posit that there is still a paucity of knowledge regarding who will be willing to share rides, with whom, and under what circumstances. Cunningham, Ledger, and Regan (2018) found that “travelling in public transport in which the vehicle is driverless” and “sharing a driverless vehicle” received the lowest agreement among respondents. In the study of Bansal, Kockelman, and Singh (2018), 50% of respondents reported to be comfortable with sharing a ride with a stranger for short durations during the day or with a friend of one of their Facebook friends. We propose that sharing an automated vehicle with strangers is positively related to performance and effort expectancy, facilitating conditions, and the behavioural intention to use automated vehicles. The underlying assumption is that individuals who are willing/capable to share automated vehicles (i.e., automated vehicle sharing) are more likely to believe that automated vehicles are useful (i.e., performance expectancy), easy to use (i.e., effort expectancy), that they have the necessary resources to use automated vehicles (i.e., facilitating conditions), and are more likely to intend to use automated vehicles (i.e., behavioural intention). We hypothesize:

> ***H30–H33:*** *Automated vehicle sharing will have a positive effect on performance expectancy (H30), effort expectancy (H31), facilitating conditions (H32), and the behavioural intention to use automated vehicles (H33).*

7.3. Method

7.3.1. Automated vehicle, respondent recruitment, and procedure

The results reported here were part of a 45-item questionnaire, which was administered to users of the automated vehicle “Emily” on the EUREF office campus in Berlin-Schöneberg (Germany) via tablet computers between March and December 2018. The automated vehicle that was involved in the trial is shown in Figure 1.

Figure 1. AV ‘Emily’, EZ10, by Easymile on the EUREF campus in Berlin, Germany

The vehicle carried up to 12 passengers per trip (6 sitting, 6 standing) and ran at a maximum speed of 13 km/h. A steward was onboard the vehicle to intervene in the vehicle operations when requested by the system. For example, obstacles that were on the trajectory of the vehicle had to be overtaken manually. Our previous trial at the EUREF campus involved an automated vehicle running on the basis of fixed stops, where stewards braked and accelerated manually (Nordhoff et al. 2018a). In the current study, Emily operated on the basis of virtual stops to simulate that the future hop-on and hop-off situation can be dynamic and without the constraints of fixed stops. Emily now braked and continued to drive at stops in automated mode.

At the end of the ride, the stewards handed out the tablet computers with a questionnaire to individuals. Only individuals who took a ride with the automated vehicle were asked to complete the questionnaire. The questionnaire was offered in German and English, depending on the preference of the respondent. The information was recorded anonymously and no financial compensation was offered to respondents.

7.3.2. Questionnaire content

With the first six questions (Q1–Q6), the respondents were asked to assess their level of agreement with items pertaining to the perceived usefulness and ease of use (equivalent to performance and effort expectancy) of automated vehicles in public transport on a scale from strongly disagree (1) to strongly agree (6). The next question (Q7) asked respondents to rate the user-friendliness, adequateness for daily use, reliability, environmental friendliness, affordability and innovativeness of the automated vehicle on a scale from very negative (1) to very positive (6). Next, respondents were asked to rate their level of satisfaction with automated vehicles on a scale from very unsatisfied (1) to very satisfied (6) (Q8). Question Q9 asked respondents to indicate how their personal view on automated vehicles has changed since their personal test ride on a scale from very negative (1) to very positive (5).

Nine questions (Q10–Q18) were presented to assess the agreement of respondents with items capturing the availability of facilitating conditions to support the use of automated vehicles (i.e., facilitating conditions), their reliance on the opinions of others (i.e., social influence) as well as the importance of their desired level of privacy in automated vehicles (i.e., automated vehicle sharing) on a scale from strongly disagree (1) to strongly agree (6).

The respondents were asked to rate the level of comfort for the driving maneuvers of the automated vehicle on a scale from comfortable (1) to uncomfortable (5) (Q19). Question Q20 asked respondents to rate the amount of effort required to maintain a posture/balance during the ride on a scale from no effort at all (1) to a high amount of effort (5). Question Q21 asked respondents to rate the amount of effort required to carry out a task (if respondents were carrying out a task) on a scale from no effort at all (1) to a high amount of effort (5). Question Q22 asked respondents to rate the level of comfort felt for specific vehicle characteristics on the scale from comfortable (1) to uncomfortable (5).

Next, questions Q23–Q30 asked respondents to rate their level of trust in and acceptance of automated vehicles on a scale from strongly disagree (1) to strongly agree (6). More specifically, Q26 asked respondents to indicate whether they would expect a large user acceptance of automated vehicles, whether they plan to abolish the car in favor of public transport and automated vehicles as feeders in public transport systems (Q27), whether they predict (Q28) and plan to use automated vehicles in public transport systems when they are available (Q29), and whether they intend to use automated vehicles from the train station or some other public transport stop to their final destination or vice versa when available (Q30).

Questions Q31 and Q32 asked respondents to rate the importance of having a steward inside the vehicle (Q31), and supervising the automated vehicle from an external control room to provide manual control (Q32) on a scale from not at all important (1) to very important (6), respectively. Question Q33 asked respondents whether they would feel safe without any type of supervision on a scale from strongly disagree (1) to strongly agree (6). Questions Q34–Q41 asked respondents to indicate their level of agreement with items capturing the importance of experiencing automated vehicles in the context of trials (i.e., trialability) as well as the compatibility of automated vehicles with respondents' existing mobility needs and behavior (i.e., compatibility) on a scale from strongly disagree (1) to strongly agree (6).

With the final questions Q42–Q45, respondents were asked to provide information on their socio-demographic profile such as their gender (Q42), age (Q43), access to a valid driver license (Q44), and transport pass (Q45).

The questions pertaining to the UTAUT and DIT constructs Q1–Q6, Q10–Q12, Q15–Q18, Q28–Q30, and Q34–Q41were used from Venkatesh et al. (2003) and Rogers (2003) and adjusted to the context of this study. Q7–Q9, Q13–Q14, and Q26 were adapted from the WOB Emobility cube questionnaire that was conducted by the InnoZ to assess the acceptance of electric vehicles. Q23–Q25 were adapted from Choi and Ji (2015). Q27, and Q31–Q33 were newly created.

7.3.3. Analyses of responses

A two-step approach was adopted (Anderson & Gerbing, 1988). First, a confirmatory factor analysis was performed to assess the measurement relationships between the latent and observed variables. Latent variables are hypothetical or theoretical constructs that are indirectly measured by the observed variables (i.e., questionnaire items). The psychometric properties of the measurement model were assessed by its indicator reliability, internal consistency reliability, convergent validity and discriminant validity. Convergent validity was assessed by four criteria: 1) All scale items should be significant and have loadings exceeding 0.70 on their respective scales, 2) the average variance extracted (AVE) should exceed 0.50, 3) construct reliability (CR) and 4) Cronbach's alpha values should exceed 0.70 (Anderson & Gerbing, 1988; Fornell & Larcker, 1981). Discriminant validity of our data was examined with the test of squared correlations by Anderson and Gerbing (1988), which implies that the correlation coefficient between two latent variables should be smaller than the square root of the average variance extracted (AVE) of each latent variable to demonstrate sufficient discriminant validity

The second step of the analysis involves testing the structural model, which relates the UTAUT and DIT constructs with trust and automated vehicle sharing. Maximum-likelihood (ML) estimation used to estimate the measurement and structural model, which has proven robust to violations of the normality assumption (Hair et al., 2014). Full Information Maximum Likelihood (FIML) was used to deal with missing data.

7.4. Results

7.4.1. Respondents

Responses were gathered between April and December 2018. Respondents completed the questionnaire after their ride with the automated vehicle in a building of the InnoZ. When the respondents did not have time to fill out the questionnaire at the InnoZ, they were provided with an online link to access the questionnaire at a convenient place and time. In total, 340 individuals completed our questionnaire. To enhance data quality, we deleted individuals who responded to less than 5 questions (i.e., 10% rule, see Hair et al., 2014), and individuals who took an unreasonable amount of time to complete the questionnaire, leaving valid responses from 270 individuals in the analysis. The mean age of respondents was 30.33 years (SD = 9.98). 140 respondents were female, 135 respondents were male, and one respondent picked the gender option "Other". 224 respondents indicated to be in possession of a public transport ticket, while 52 specified they were not. 237 respondents reported to have access to a valid driver license, while 37 respondents specified they did not.

Table 1. Means (*M*), standard deviations (SD), and distribution of questionnaire items on a scale from 1 (disagree strongly) to 6 (agree strongly)

Questionnaire item	***M***	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
Q1. My interaction with the automated shuttle would be clear and understandable.	4.827	1.093	4	11	11	50	120	74
Q2. I think that automated shuttles would be useful for my daily travel.	4.362	1.491	12	34	22	60	70	77
Q3. Learning to use automated shuttles would be easy for me.	5.457	0.911	3	4	3	17	76	172
Q4. I think that an automated shuttle would be more useful than my existing form of travel.	3.620	1.448	25	42	56	71	52	29
Q5. I think that automated shuttles would be a useful extension of our current transport systems.	5.119	1.051	3	8	7	39	97	122
Q6. I would find automated shuttles easy to use.	5.163	0.921	1	2	11	43	98	120
Q7.1. According to your experiences: How would you rate automated shuttles? User-friendly	4.305	1.244	2	3	87	75	33	75
Q7.2. According to your experiences: How would you rate automated shuttles? Adequate for daily use	4.055	1.129	0	17	76	96	45	60
Q7.3. According to your experiences: How would you rate automated shuttles? Reliable	4.022	1.097	2	16	68	108	46	33
Q7.4. According to your experiences: How would you rate automated shuttles? Environmentally-friendly	4.647	1.391	3	7	69	52	18	126
Q7.5. According to your experiences: How would you rate automated shuttles? Affordable	3.865	1.190	4	31	61	103	37	31
Q7.6. According to your experiences: How would you rate automated shuttles? Innovative	5.120	1.275	1	2	55	22	21	175
Q8. Please let us know to what extent you are unsatisfied or satisfied with automated shuttles.	3.767	1.194	2	20	121	71	19	42
Q9. To what extent has your personal view on automated shuttles changed since your personal test ride?	3.690	0.823	0	12	111	102	51	0
Q10. I have the knowledge necessary to use automated shuttles.	4.515	1.401	13	14	30	57	78	81
Q11. Given the resources, opportunities and knowledge it takes to use automated shuttles, it would be easy for me to use automated shuttles.	4.942	1.123	3	9	17	47	96	103
Q12. I have the resources necessary to use automated shuttles.	4.343	1.456	10	29	34	57	65	75
Q13. Even when I am in public space, privacy is important for me.	4.396	1.322	10	16	40	68	82	61
Q14. I feel comfortable sharing the space of the automated shuttle with fellow travellers at the same time.	4.909	1.040	2	6	15	61	99	92
Q15. People whose opinion I value would like me to use automated shuttles.	3.907	1.425	27	16	43	88	56	38
Q16. I intend to share an automated shuttle with around 6-8 fellow travelers who have the same route like me.	4.736	1.208	6	9	23	64	86	87
Q17. People who influence my behavior would think that I should use automated shuttles.	3.668	1.425	30	22	56	79	52	25
Q18. People who are important to me think that I should use automated shuttles.	3.653	1.449	29	27	58	77	46	30
Q19.1. Please rate the discomfort felt for the following maneuvers from a scale of 1 to 5, 5 being uncomfortable and 1 being comfortable. Braking	2.424	1.938	131	64	20	13	7	28

Q19.2. Please rate the discomfort felt for the following maneuvers from a scale of 1 to 5, 5 being uncomfortable and 1 being comfortable. Accelerating	2.336	1.976	145	61	15	6	8	28
Q19.3. Please rate the discomfort felt for the following maneuvers from a scale of 1 to 5, 5 being uncomfortable and 1 being comfortable. Turning	2.362	1.948	133	68	26	4	2	27
Q20. Please rate from a scale of 1 to 5, the amount of effort required to maintain posture/balance during the ride, 5 being high amount of effort and 1 is no effort at all.	3.040	2.171	89	65	30	12	45	8
Q21. If you were carrying out a task during the ride, please rate from a scale of 1 (no effort at all) to 5 (high amount of effort) the amount of effort required to carry out the task. The task can be something like reading/writing an email or playing a game.	2.707	1.912	92	67	40	21	7	23
Q22.1. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Inside temperature	2.585	2.007	130	46	22	19	18	25
Q22.2. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Available leg space	1.884	1.683	183	46	13	2	2	22
Q22.3. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Available arm space	2.681	2.066	111	58	39	11	5	23
Q22.4. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Seating	2.777	2.101	106	54	45	13	6	21
Q22.5. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Vehicle noises	2.018	1.744	164	52	19	6	3	18
Q22.6. Please rate the discomfort felt for the following features on a scale from 1 being comfortable to 5 being uncomfortable. Air quality/ventilation	2.591	1.976	119	61	23	16	9	30
Q23. I think that automated shuttles would be reliable.	4.473	1.150	2	16	33	78	92	55
Q24. I think that my interactions with this type of vehicle would be predictable.	4.562	1.015	0	8	34	77	106	49
Q25. I would trust this type of vehicle for my everyday travel.	4.402	1.166	4	13	41	78	89	50
Q26. For automated shuttles I would expect a large user acceptance.	4.322	1.150	2	17	46	79	89	42
Q27. I plan to abolish my own car in favor of public transport and automated shuttles as feeder systems as soon as automated shuttles are available.	3.352	1.611	45	41	51	55	36	32
Q28. Assuming that I had access to automated shuttles, I predict that I would use them when they are available.	4.693	1.146	3	11	27	60	102	73
Q29. I plan to use automated shuttles in public transport systems when they are available.	4.880	1.073	1	10	16	59	98	91
Q30. I intend to use automated shuttles from the train station or some other public transport stop to my final destination or vice versa when they are available.	4.931	1.052	1	10	10	63	95	97

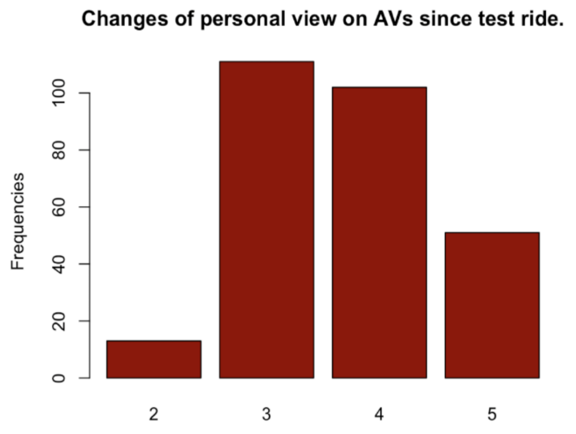
Q31. Please rate the importance of having a steward inside the vehicle that would provide manual control if necessary.	3.838	1.672	32	46	26	54	65	53
Q32. Please rate the importance of the supervision of a driverless shuttle by an external control room to provide manual control if necessary.	4.834	1.297	8	13	16	53	77	109
Q33. I would feel safe without any type of supervision.	2.902	1.547	66	57	55	49	29	19
Q34. Being able to try out automated shuttles was important for me in deciding whether I should use them in the future or not.	4.333	1.486	16	26	26	62	72	73
Q35. I want to be able to use automated shuttles on a trial basis.	4.690	1.292	8	11	30	51	87	89
Q36. I am more likely to want to use automated shuttles because of being part this pilot test.	4.094	1.476	18	29	39	67	68	54
Q37. I want to be permitted to use automated shuttles on a trial basis long enough to see what they can do.	4.574	1.390	11	17	28	55	77	88
Q38. Using automated shuttles would be compatible with all aspects of my mobility behavior.	4.256	1.317	11	20	34	86	72	53
Q39. I think that using automated shuttles fits well with the way I like to travel.	4.185	1.303	8	24	45	77	74	46
Q40. I expect to be able to handle all my mobility trips well with automated shuttles.	3.687	1.486	32	25	61	67	58	31
Q41. Using automated shuttles is completely compatible with my current situation.	3.663	1.424	22	43	54	69	61	26

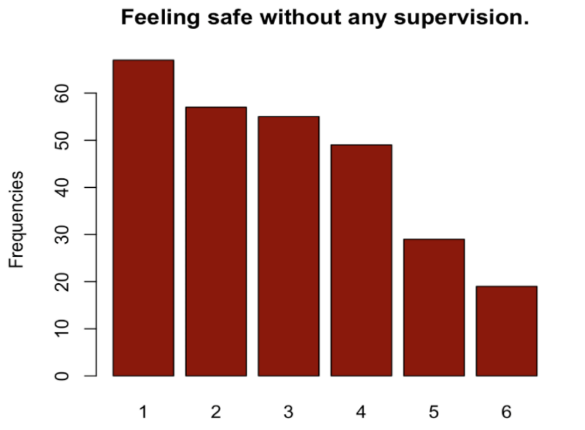
7.4.2. Ratings of attitudinal questions

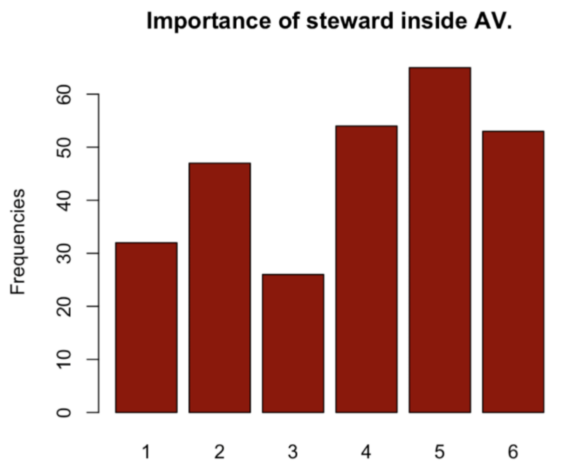
As shown in Table 1, on a scale from very negative (1) to very positive (6), respondents rated the automated vehicle as innovative (Q7.6, *M* = 5.12, SD = 1.41), environmentally-friendly (Q7.4, *M* = 4.64, SD = 1.42), user-friendly (Q7.1, *M* = 4.30, SD = 1.29), adequate for daily use (Q7.2, *M* = 4.05, SD = 1.41), reliable (Q7.3, *M* = 4.02, SD = 1.11), and affordable (Q7.5, *M* = 3.86, SD = 1.21) (Q7). The respondents indicated to be slightly satisfied with the automated vehicle (Q8), with a mean of 3.77 (SD = 1.19) on a scale from very unsatisfied (1) to very satisfied (6) (Q8). As shown by Figure 2, 42% of respondents indicated that taking a ride with the automated vehicle has produced no change of their view on automated vehicles in public transport, while 37% reported a rather positive change of their view on automated vehicles (Q9, *M* = 3.69, SD = 0.82, on a scale from very negative (1) to very positive (5)).

On a Likert scale from strongly disagree (1) to strongly agree (6), the highest mean rating was obtained for the item pertaining to the belief that learning to use automated vehicles would be easy (Q3, *M* = 5.457, SD = 0.91). The lowest mean rating was obtained for feeling safe without any type of supervision (Q33, *M* = 2.902, SD = 1.55) (see Figure 3). A moderate rating was obtained for abolishing the own car in favor of public transport and automated vehicles as feeder systems to public transport (Q27, *M* = 3.352, SD = 0.91).

As shown by Figures 4 and 5, respectively, on a scale from not at all important (1) to very important (6), respondents considered a steward inside the automated vehicle moderately important (Q31, *M* = 3.838, SD = 1.67), and favor the supervision of the automated vehicle from an external control room (Q32, *M* = 4.834, SD = 1.30).







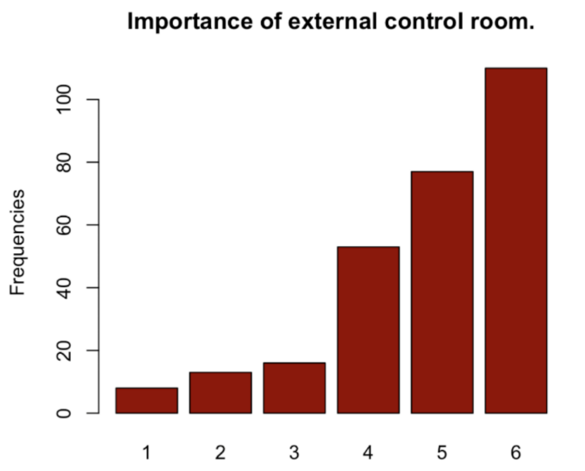


Figure 2. Left, top, frequency distribution of the responses for the questionnaire item Q9 *"To what extent has your personal view on automated shuttles changed since your personal test ride?"* on scale from very negative (1) to very positive (5), *n* = 277

Figure 3. Right, top, frequency distribution of the responses for the questionnaire item Q33 *"I would feel safe without any type of supervision"* on scale from strongly disagree (1) to strongly agree (6), *n* = 276

Figure 4. Left, bottom, frequency distribution of the responses for the questionnaire item Q31 *"Please rate the importance of having a steward inside the vehicle that would provide manual control if necessary"* on scale from not at all important (1) to very important (6), *n* = 277

Figure 5. Right, bottom, frequency distribution of the responses for the questionnaire item Q32 *"Please rate the importance of the supervision of a driverless shuttle by an external control room to provide manual control if necessary"* on scale from not at all important (1) to very important (6), *n* = 277

7.4.3. Results of confirmatory factor analysis

The results of the confirmatory factor analysis are shown in Table 2. The items PE3, EE1, TRU2 & TRU4, TRIAL1 & TRIAL3, AVS1, and BI1 & BI2 were omitted from the analysis as their loading was below the recommended threshold of 0.70. Model fit parameters were acceptable for all latent variables. The CFI (= 0.95 ≥ 0.95), RMSEA (0.05 ≤ 0.08), SRMR (= 0.05 ≤ 0.06), and chi-square statistic ($\chi^2/df = 1.14 < 3$) were acceptable. With the exception of EE2 and AVS2, the loadings of all observed variables exceeded the recommended threshold of 0.70 and were statistically significant. AVS2 and EE2 were maintained in the analysis to prevent that their latent constructs are measured by a single observed variable. Composite reliability and Cronbach's alpha both exceeded the recommended threshold of 0.70, confirming internal consistency reliability. All average variance extracted (AVE) values exceeded the recommended minimum threshold of 0.50 for all latent variables, ranging between 0.58 and 0.78. As shown by Table 3, which reports the inter-construct correlations, discriminant validity is acceptable for all latent variables.

Table 2. Results of confirmatory factor analysis

Latent variable	Observed variable	λ	α	CR	AVE
Performance expectancy (PE)			0.80	0.79	0.65
	PE1: I think that automated shuttles would be useful for my daily travel.	0.821			
	PE2: I think that an automated shuttle would be more useful than my existing form of travel.	0.800			
	PE3: I think that automated shuttles would be a useful extension of our current transport systems.	Removed from the analysis due to factor loading < 0.7			
Effort expectancy (EE)			0.73	0.76	0.62
	EE1: My interaction with the automated shuttle would be clear and understandable.	Removed from the analysis due to factor loading < 0.7			
	EE2 Learning to use automated shuttles would be easy for me.	0.671			
	EE3: I would find automated shuttles easy to use.	0.890			
Social influence (SI)			0.91	0.91	0.78
	SI1: People whose opinion I value would like me to use shuttles	0.837			
	SI2: People who influence my behavior would think that I should use automated shuttles.	0.892			
	SI3: People who are important to me think that I should use automated shuttles.	0.915			
Trust (TRU)			0.78	0.80	0.67
	TRU1: I think that automated shuttles would be reliable.	0.676			
	TRU2: I think that my interactions with this type of vehicle would be predictable.	Removed from the analysis due to factor loading < 0.7			
	TRU3: I would trust this type of vehicle for my everyday travel.	0.950			
	TRU4: I would feel safe without any type of supervision.	Removed from the analysis due to factor loading < 0.7			
Facilitating conditions (FC)			0.80	0.80	0.58
	FC1: I have the knowledge necessary to use automated shuttles.	0.809			
	FC2: Given the resources, opportunities and knowledge it takes to use automated shuttles, it would be easy for me to use automated shuttles.	0.753			
	FC3: I have the resources necessary to use automated shuttles.	0.732			
			0.71	0.74	0.59

Trialability (TRIAL)	TRIAL1: Being able to try out automated shuttles was important for me in deciding whether I should use them in the future or not.	Removed from the analysis due to factor loading < 0.7			
	TRIAL2: I want to be able to use automated shuttles on a trial basis.	0.682			
	TRIAL3: I am more likely to want to use automated shuttles because of being part this pilot test.	Removed from the analysis due to factor loading < 0.7			
	TRIAL4: I want to be permitted to use automated shuttles on a trial basis long enough to see what they can do.	0.857			
Compatibility with existing mobility needs (COMPAT)			0.84	0.85	0.58
	COMPAT1: Using automated shuttles would be compatible with all aspects of my mobility behavior.	0.771			
	COMPAT2: I think that using automated shuttles fit well with the way I like to travel.	0.821			
	COMPAT3: I expect to be able to handle all my mobility trips well with automated shuttles.	0.727			
	COMPAT4: Using automated shuttles is completely compatible with my current situation.	0.745			
Automated vehicle sharing (AVS)			0.65	0.72	0.58
	AVS1: Even when I am in public space, privacy is important for me.	Removed from the analysis due to factor loading < 0.7			
	AVS2: I feel comfortable sharing the space of the automated shuttles with fellow travelers at the same time.	0.537			
	AVS3: I intend to share an automated shuttle with around 6-8 fellow travelers who have the same route like me.	0.944			
Behavioural intention (BI)			0.88	0.90	0.75
	BI1: For automated shuttles I would expect a large user acceptance.	Removed from the analysis due to factor loading < 0.7			
	BI2: I plan to abolish my own car in favor of public transport and automated shuttles as feeder systems as soon as automated vehicles are available.	Removed from the analysis due to factor loading < 0.7			
	BI3: Assuming that I had access to automated shuttles, I predict that I would use them when they are available.	0.837			
	BI4: I plan to use automated shuttles in public transport systems when they are available.	0.925			
	BI5: I intend to use automated shuttles from the train station or some other public transport stop to my final destination or vice versa when they are available.	0.847			

Note: λ (i.e., lambda) = Loading of the observed variable on the latent variable.
α (Cronbach alpha) and CR (construct reliability) = Internal consistency measure defined as the extent to which the observed variables measure the same construct on the basis of their interrelations.
AVE = The average variance extracted in the observed variable accounted for by the latent variables.

Table 3. Inter-construct correlation matrix

Construct	PE	EE	SI	FC	TRU	COMPAT	TRIAL	AVS	BI
Performance expectancy (PE)	**0.65**								
Effort expectancy (EE)	0.30	**0.62**							
Social influence (SI)	0.38	0.19	**0.78**						
Facilitating conditions (FC)	0.21	0.47	0.14	**0.58**					
Trust (TRU)	0.39	0.27	0.32	0.28	**0.67**				
Compatibility (COMPAT)	0.59	0.18	0.29	0.02	0.40	**0.58**			
Trialability (TRIAL)	0.22	0.04	0.16	-0.08	0.05	0.35	**0.59**		
Automated vehicle sharing (AVS)	0.18	0.23	0.39	0.18	0.23	0.22	0.20	**0.58**	
Behavioral intention (BI)	0.48	0.34	0.31	0.27	0.42	0.48	0.21	0.31	**0.75**

Note: The diagonal values represent the square root of the average variance extracted (AVE)

7.4.4. Moderation analysis

To examine the moderating effects of age and gender, we performed a multiple hierarchical regression analysis. As shown by Table 4, age and gender did not have significant moderating effects on the relationships between performance and effort expectancy, social influence, and the behavioral intention to use automated vehicles in public transport. The effects of age and gender on the behavioral intention to use automated vehicles were not significant either.

Table 4. Results of moderation analysis

Independent/moderator variable (IV)	Dependent variable (DV)	Effect β	p-value
Performance expectancy	Behavioral intention	0.267	0.218, *n.s.*
Effort expectancy		-0.285	0.355, *n.s.*
Social influence		0.061	0.754, *n.s.*
Compatibility		0.197	< 0.001***
Trust		0.123	0.029*
Automated vehicle sharing		0.170	0.003**
Trialability		0.064	0.166, *n.s.*
Age		-0.043	0.354, *n.s.*
Gender		0.120	0.872, *n.s.*
Performance expectancy × age		-0.004	0.362, *n.s.*
Effort expectancy × age		0.017	0.077, *n.s.*
Social influence × age		-0.003	0.457, *n.s.*
Performance expectancy × gender		-0.004	0.962, *n.s.*
Effort expectancy × gender		-0.025	0.858, *n.s.*
Social influence × gender		0.036	0.672, *n.s.*

Note: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, *n.s.* = not significant

7.4.5. Results of the structural equation models

We ran four structural models for this study. First, the effects of the UTAUT constructs performance and effort expectancy, and social influence on the behavioral intention to use automated vehicles as well as their interrelationships were investigated (model 1). In the second and third structural model, we added the construct compatibility (model 1a) and trust (model 1b), respectively. In the fourth model (model 2), the constructs trialability and automated vehicle sharing were added to the model. The results of the structural equation modeling are shown in Table 5, and interpreted in the discussion.

Table 5. Structural Equation Models, standardized path coefficients (*β*), p-values (*p*), variance explained (R^2), and model fit parameters

Variable type		Model 1		Model 1a adding compatibility		Model 1b adding trust		Model 2 adding sharing and trialability	
Independent variable (IV)	**Dependent variable (DV)**	***β***	***p***	***β***	***p***	***β***	***p***	***β***	***p***
Performance expectancy	Behavioral intention	0.397	< 0.001***	0.102	0.387, *n.s.*	0.104	0.374, *n.s.*	0.110	0.344, *n.s.*
Effort expectancy		0.197	0.009**	0.217	0.003**	0.182	0.018*	0.173	0.025*
Social influence		0.132	0.050, *n.s.*	0.092	0.162, *n.s.*	0.074	0.257, *n.s.*	0.001	0.990, *n.s.*
Compatibility		–	–	0.404	< 0.001***	0.336	0.001**	0.316	0.006**
Trust		–	–	–	–	0.147	0.056, *n.s.*	0.134	0.082, *n.s.*
Automated vehicle sharing		–	–	–	–	–	–	0.179	0.014*
Trialability		–	–	–	–	–	–	-0.002	0.977, *n.s.*
Effort expectancy	Performance expectancy	0.332	0.001**	0.176	0.066, *n.s.*	0.170	0.071, *n.s.*	0.171	0.068, *n.s.*
Social influence		0.323	< 0.001***	0.147	0.020*	0.135	0.033*	0.145	0.038 *
Facilitating conditions		0.038	0.692, *n.s.*	0.098	0.266, *n.s.*	0.099	0.274, *n.s.*	0.103	0.266, *n.s.*
Compatibility		–	–	0.624	< 0.001***	0.593	< 0.001***	0.599	< 0.001***
Trust		–	–	–	–	0.069	0.377, *n.s.*	0.067	0.391, *n.s.*
Automated vehicle sharing		–	–	–	–	–	–	-0.022	0.754, *n.s.*
Trialability		–	–	–	–	–	–	-0.004	0.962, *n.s.*
Facilitating conditions	Effort expectancy	0.572	< 0.001***	0.596	< 0.001***	0.560	< 0.001***	0.555	0.000***
Social influence		0.182	0.007**	0.118	0.090, *n.s.*	0.102	0.140, *n.s.*	0.079	0.297, *n.s.*
Compatibility		–	–	0.224	0.003**	0.170	0.042*	0.119	0.211, *n.s.*
Trust		–	–	–	–	0.120	0.161, *n.s.*	0.142	0.098, *n.s.*
Automated vehicle sharing		–	–	–	–	–	–	0.037	0.634, *n.s.*
Trialability		–	–	–	–	–	–	0.076	0.359, *n.s.*
Social influence	Compatibility	–	–	0.106	0.120, *n.s.*	0.121	0.075, *n.s.*	0.133	0.050, *n.s.*
Trust		–	–	0.455	< 0.001***	0.430	< 0.001***	0.421	< 0.001***
Trialability		–	–	0.407	< 0.001***	0.410	< 0.001***	0.423	< 0.001***
Social influence	Trust	–	–	–	–	0.330	< 0.001***	0.321	< 0.001***
Trialability		–	–	–	–	-0.025	0.750, *n.s.*	-0.024	0.753, *n.s.*
Social influence	Trialability	–	–	0.212	0.008**	0.213	0.008**	0.205	0.009*
Social influence	Automated vehicle sharing	–	–	0.462	< 0.001***	0.463	< 0.001***	0.461	< 0.001***
Trialability	Facilitating conditions	–	–	–	–	–	–	-0.133	0.151, *n.s.*
Trust		–	–	–	–	0.415	< 0.001***	0.361	< 0.001***

Compatibility		–	–	-0.041	0.617, *n.s.*	-0.244	0.008**	0.076	0.067, *n.s.*
Automated vehicle sharing		–	–	–	–	–	–	0.266	0.003**
Social influence		0.125	0.084, *n.s.*	0.135	0.089, *n.s.*	0.066	0.398, *n.s.*	-0.034	0.696, *n.s.*
Model fit	CFI	0.98		0.94		0.95		0.95	
	RMSEA	0.05		0.06		0.054		0.05	
	SRMR	0.04		0.07		0.052		0.05	
	χ^2/df	1.71		1.85		1.73		1.73	
R^2	Behavioral intention	0.338		0.401		0.404		0.435	
	Performance expectancy	0.228		0.614		0.613		0.614	
	Effort expectancy	0.381		0.459		0.460		0.460	
	Compatibility	–		0.453		0.438		0.425	
	Trust	–		0.115		0.106		0.101	
	Trialability	–		0.045		0.045		0.042	
	Automated vehicle sharing	–		0.214		0.215		0.216	
	Facilitating conditions	0.016		0.016		0.144		0.198	

Notes: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, *n.s.* = not significant

7.5. Discussion and conclusion

Prior research has applied the Unified Theory of Acceptance and Use of Technology (UTAUT) and Roger's Diffusion of Innovation Theory (DIT) to predict automated vehicle acceptance in isolation. Our study fills this gap in research and integrates the UTAUT and DIT constructs into one model to predict automated vehicle acceptance in public transport. Trust was further added to the model to tailor it to the context of automated driving technology and respond to research studies that corroborated the role of trust in determining automated vehicle acceptance. Automated vehicle sharing was integrated into our model to account for the fact that sharing space with fellow travellers in automated vehicles will become a relevant part of the user experience of shared automated vehicles, which in the end might determine whether people will use automated vehicles in public transport or not. The interrelationships of these constructs can inform and guide the decision-making of practitioners regarding the identification of the determinants and the development of the corresponding strategies to enhance automated vehicle acceptance.

7.5.1. Ratings of attitudinal questions

Our results have shown that the highest mean rating was obtained for believing that automated vehicles are easy to use. This finding is not surprising as the role of the respondents who experienced the automated vehicle in the trial was simply to enter the vehicle and enjoy the ride while being driven. When automated vehicles are part of functional public transport, using automated vehicles will involve the booking, ticketing, identifying, entering the vehicle, getting seated, and leaving the vehicle. This implies that the ratings of the perceived ease of use of automated vehicles in trials might differ from the ratings of the perceived ease of use in future operational systems. We recommend research to revisit the operationalisation of effort expectancy, which is equivalent to the perceived ease of use, as effort expectancy tends to be operationalised in very generic terms. It could be assessed which associations respondents have with the perceived ease of use of automated vehicles; whether it relates to the actual use of the

automated vehicle, and/or the processes that precede the actual use (e.g., booking, ticketing, entering, getting seated, leaving the vehicle).
The lowest mean rating was obtained for feeling safe without any type of supervision of the automated vehicle, suggesting that respondents do not entirely trust the automated vehicle to execute the entire driving task on its own. However, they questioned the presence of a steward onboard the vehicle. One possible explanation is that respondents question the presence of physical supervision onboard in an automated vehicle that is supposed to be driverless. They preferred the supervision of the automated vehicle from an external control room, which corresponds with our study (Nordhoff et al., 2018) where respondents favoured the supervision of the automated vehicle from an external control room to the human steward onboard and no human supervison. In contrast, Roche-Cerasi (2019) found that 54.9% of respondents indicated that automated buses should still have drivers, while only 8.5% preferred that buses are monitored and remotely controlled by a control room operator. Lee et al. (2019) revealed that 71.3% of the respondents reported to be comfortable with automation levels in which the human driver remains in control, while 27.7% of respondents indicated to be comfortable with automated driving features that placed the vehicle in control. As the automated vehicle in the present study was supervised by the steward as well as the interviewer, future research should be conducted in automated vehicles that are supervised from an external control room or not at all rather than relying on physical human supervision onboard.

A moderate rating was obtained for abolishing the private car in favour of public transport and automated vehicles feeding public transport. This suggests that while respondents are positive towards the idea of using automated vehicles in public transport, it is questionable whether automated vehicles in public transport will lead to substantial reductions of the use of private cars. It is likely that a substantial reduction of private car use can only be realised when automated vehicles provide all or most of the benefits of the private car (Nordhoff et al., 2019).

7.5.2. UTAUT model

The first structural model examined the main effects of the UTAUT constructs performance and effort expectancy, social influence and facilitating conditions on the behavioural intention to use automated vehicles, and the interrelationships between the predictor constructs. In line with several studies on automated vehicle acceptance (Madigan et al., 2016, 2017; Kaur & Rampersad, 2018), performance expectancy was the strongest predictor of the intention to use automated vehicles, followed by effort expectancy. The effect of effort expectancy on the behavioral intention to use automated vehicles was robust across all four models, which corresponds with Buckley, Kaye, and Pradhan (2018), Xu et al. (2018), and Wu et al. (2019), but is contradictory to the studies of Madigan et al. (2017), and Zhang et al. (2019). However, when we modelled behavioral intention as a function of the UTAUT constructs performance and effort expectancy, social influence, and facilitating conditions, effort expectancy became insignificant and performance expectancy remained as the main predictor, similar to Madigan et al. (2017) and Nordhoff et al. (under review). Note that the results of this model were not reported. Social influence was not predictive of the behavioural intention to use automated vehicles, which does not correspond with Madigan et al. (2016, 2017), and Nordhoff et al. (under review). Note, however, that the effect of social influence on the behavioral intention of information technology was insignificant in voluntary usage contexts (Venkatesh et al., 2003).

Effort expectancy and social influence were predictive of performance expectancy and thereby predictive of behavioral intention, which corresponds with previous research on automated vehicle acceptance (Nordhoff et al., under review; Xu et al., 2018; Zhang et al., 2018). The effect of effort expectancy and social influence on performance expectancy has been supported

in the literature on automated vehicle acceptance (Nordhoff et al., under review). It suggests that designers, operators and policy-makers should increase the ease of use of automated vehicles, and promote the image of automated vehicles to make automated vehicles useful.
Age and gender did not moderate the relationships between the UTAUT constructs performance and effort expectancy, social influence, facilitating conditions, and the behavioural intention to use automated vehicles nor did they have significant effects on behavioural intention. This finding mirrors the literature on automated vehicle acceptance, which has either shown non-significant or small effects of age and gender on people's attitudes towards and acceptance of automated vehicles (Cunningham et al., 2019; Madigan et al., 2016, 2017). Cunningham et al. (2019) posit that despite the small effects of age and gender on their study variables, the importance of age and gender for automated vehicle acceptance should not be neglected. We recommend future research to re-examine the effects of age and gender, and assess whether they serve as better predictors of automated vehicle acceptance when they interact with other variables such as emotions (Hohenberger, Spörrle, & Welpe, 2016).

7.5.3. UTAUT model with DIT constructs, trust and automated vehicle sharing

7.5.3.1. Effect on the behavioural intention to use automated vehicles

When the DIT constructs compatibility and trialability, automated vehicle sharing and trust were added (model 2), the effect of performance expectancy on the behavioural intention to use automated vehicles became insignificant. Instead, compatibility was the strongest predictor of the intention to use automated vehicles in public transport, implying that individuals who consider automated vehicles to be compatible with their existing mobility needs and routines are more likely to intend to use automated vehicles. This contradicts the study of Rahman et al. (2019) who did not find significant effects of compatibility on automated vehicle acceptance.

According to models 1b, 1c, and 2, compatibility is a more important predictor of behavioral intention to use automated vehicles in public transport than performance expectancy. This corresponds with scientific research in other domains (Ifinedo, 2012; Schaper & Pervan, 2007), which has shown that the effect of performance expectancy on behavioral intention was insignificant when it is considered along with compatibility in a model. The effect of compatiability on behavioral intention was robust across our models 1b, 1c, and 2, where the effect of performance expectancy on behavioral intention was insignificant. One possible explanation is that performance expectancy involves a more general appraisal of the usefulness of automated vehicles without necessarily linking usefulness to the mobility lives of individuals. Compatibility, on the other hand, has a direct linkage with individuals' mobility routines: The compatibility of automated vehicles with individual's mobility routines and practices may imply that individuals are not required to make substantial changes to their mobility habits, while this remains entirely untouched by performance expectancy. Note that compatibility is rooted in the construct facilitating conditions (Venkatesh et al., 2003). We propose to treat compatibility with existing mobility needs and practices to be conceptually distinct from facilitating conditions. Facilitating conditions is defined as the degree to which infrastructure exists to support the use of the system (Venkatesh et al., 2003), in our case automated vehicles, which, in our view, does not address the compatibility of automated vehicles with the mobility patterns of individuals. We encourage future research to investigate more closely the similarity between compatibility and performance expectancy, and examine whether these constructs can be possibly merged. A hypothesis *tentatively* derived from this finding is that compatibility may even substitute performance expectancy as the strongest predictor of the behavioral intention to use automated vehicles. We invite scientific scholars to examine this further.

The moderately strong relationship between performance expectancy and compatibility suggests redundancy and conceptual similarity between these constructs. Compatibility was the strongest predictor of performance expectancy, which implies that individuals who believe that automated vehicles are compatible with their existing mobility needs and routines are more likely to regard automated vehicles as useful. This corresponds with theoretical and empirical research showing that compatibility has direct relations with perceived usefulness (equivalent to performance expectancy) (Ghazizadeh, Lee, & Boyle, 2012; Karahanna, Agarwal, & Angst, 2006).

Automated vehicle sharing was the second-strongest positive predictor of the behavioral intention to use automated vehicles. This suggests that individuals who are willing to share space with strangers are more likely to intend to use automated vehicles. This finding corresponds with Bhat (2018) who found that the success of shared automated vehicles hinges on the willingness of travellers to share rides with strangers, where privacy-sensitivity reduced the likelihood to share a ride in an automated vehicle, and with Amirkiaee and Evengelopoulos (2018), and Morales Sarriera et al. (2017) who have shown that travellers are concerned about taking a ride with unfamiliar people due to a lack of trust, security and privacy concerns. In Nordhoff, Stapel et al. (under review) respondents considered sharing the automated vehicle with fellow travellers an uncomfortable aspect of automated vehicle use. In line with Bhat (2018), we encourage future research to identify the population segments that differ in their propensity to use shared automated vehicles. Future research should further investigate the hypothesis that social network-based services could alleviate privacy and security concerns in automated vehicles (Bhat, 2018). Vehicle manufacturers and public transport companies should consider the deployment of smaller-sized vehicles to mitigate privacy concerns and simulate the "private cocoon" effect that has contributed to the attractiveness of the private car (Fraedrich, Beiker, & Lenz, 2015; Fraedrich & Lenz, 2016; Pudāne et al., 2019; Sovacool & Axsen, 2018). Our study further shows positive effects of social influence on automated vehicle sharing, implying that one's own social network supporting the adoption of automated vehicles can positively contribute to an individual's willingness to share automated vehicles with fellow travelers.

7.5.3.2. Effect on compatibility

Trust was the strongest predictor of compatibility, implying that individuals who are more likely to trust automated vehicles are more likely to consider automated vehicles compatible with their existing mobility needs and routines. This finding suggests that enhancing an individual's level of trust in automated vehicles could promote the individual's belief that automated vehicles are compatible with their existing mobility needs and routines.

Trialability was the second-strongest predictor of compatibility, implying that individuals who consider trialing automated vehicles prior to adoption important are more likely to believe that automated vehicles are compatible with their existing mobility needs and routines. A possible explanation is that trialing automated vehicles prior to more permanent usage enables individuals to assess the fit between automated vehicles and their mobility needs. Kaye et al. (2019) posit that the successful implementation of automated vehicles depends upon the outcomes of trials with automated vehicles, and that it is important to evaluate automated vehicle acceptance by public trials. In the context of these trials, the public can be educated about the expected benefits and risks of automated vehicles and the reactions and acceptance of all types of road users. Furthermore, they learn to interact with automated vehicles as vulnerable road users and human drivers (Kaye et al., 2019). Pettigrew and Cronin (2019) found that trials with automated vehicles was the main recommendation of governmental stakeholders to successfully implement them as trials enable the refinement of the technology while making the public familiar with automated vehicles. The operationalization of compatibility in very generic terms creates the need to investigate more closely what individuals associate with the compatibility of automated vehicles with their existing mobility needs and practices.

It was also found that trust and trialability can be further enhanced by social influence, implying that promoting automated vehicles in the social networks of individuals can enhance individual's levels of trust in automated vehicles, and contribute to the importance of trialing automated vehicles before usage.

Policy makers and public transport companies should design strategies to increase the compatibility of automated vehicle usage with the existing mobility needs of individuals. Performance expectancy, in turn, was determined by social influence, implying that individuals who appreciate the use of automated vehicles in public transport in their social networks are more likely to consider automated vehicles useful.

7.5.3.3. Effect on effort expectancy

The positive effect of facilitating conditions on effort expectancy suggests that effort expectancy can be enhanced by providing a supportive infrastructure to facilitate the use of automated vehicles. This finding corroborates the results of our recent study (Nordhoff et al., under review) where we propose that a supportive infrastructure can entail the provision of accessibility to the vehicle using a wheelchair ramp, ensuring an uncomplicated booking and payment process (e.g., including the use of automated vehicles in public transport tickets), and offering information on routes and interchanges either in or outside the vehicle, in close proximity to the stations, and via an app. We recommend future research to investigate the role of effort expectancy and facilitating conditions together with other latent variables in a multivariate context to examine the conditions under which the effect of these constructs on the intention to use automated vehicles can be maintained, and when they become insignificant. Furthermore, it is also likely that the effect of effort expectancy and facilitating conditions on the behavioral intention to use automated vehicles is stronger for automated vehicles that still require the human input to a larger extent (SAE Level 2–4), and weaker for automated vehicles in public transport that do require less human input.

Effort expectancy, in turn, was determined by social influence, meaning that promoting automated vehicles in individual's social networks contributes to the perceived ease of use of automated vehicles. As demonstrated by the positive effects of social influence on performance expectancy, trust and trialability mentioned before, strengthening the reliance on the individual's social networks promoting the use of automated vehicles can be a valuable avenue to promote automated vehicle acceptance.

7.5.3.4. Effect on facilitating conditions

Trust was the strongest, and automated vehicle sharing was the second-strongest predictor of facilitating conditions, implying that individuals who trust automated vehicles, and are willing to share automated vehicles are more likely to believe they are in possession of the necessary resources to use automated vehicles. Litman (2018) postulates that automated vehicles (i.e., autonomous micro-transit) can introduce new stresses and discomforts such as reducing security since passengers may need to share space with strangers. Our finding suggests that in addition to the physical resources individuals have to possess for automated vehicle usage, psychological resources (i.e., capability and willingness to share; trusting automated vehicles) to share automated vehicles with strangers are also relevant.

7.5.4. Limitations

The results of the present study have to be interpreted with regards to its caveats. First, the automated vehicle operated at a limited speed in a controlled environment, which could bias the safety and trust perceptions of respondents. Second, the sample was not representative of the general population but consisted of more highly-educated, tech savvy individuals, which could bias results. We recommend future research to use more representative samples.

7.5.5. Final conclusions

In conclusion, our questionnaire showed that respondents considered automated vehicles in public transport easy to use, but most did not feel safe without any type of human supervision. They favored the supervision of the vehicle from an external control room to a human steward onboard, and no supervision. A moderate mean rating for planning to abolish the private car in favor of public transport and automated vehicles feeding public transport suggests that respondents are undecided about whether automated public transport will lead to substantial reductions in their use of the private car. The effect of performance expectancy and social influence on the behavioral intention to use automated vehicles became insignificant with the addition of the DIT constructs compatibility and trialability, automated vehicle sharing and trust to the model. Instead, compatibility was the strongest predictor of the behavioral intention to use automated vehicles. We recommend future research to examine the importance of compatibility for automated vehicle acceptance, and assess whether compatibility can substitute performance expectancy as strong and robust predictor of automated vehicle acceptance.

7.6. References

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Chapter 8: Passenger opinions of the perceived safety and interaction with automated shuttles: A test ride study with 'hidden' safety steward

8.1. ABSTRACT

A necessary condition for the effective integration of automated vehicles in our daily lives is their acceptance by passengers inside and pedestrians and cyclists outside the automated vehicle. 119 respondents experienced an automated shuttle ride with a 'hidden steward on board' in a mixed traffic environment in Berlin-Schöneberg. A mixed-method approach was applied gathering qualitative interview data during the ride and quantitative questionnaire data after the ride. Responses were classified into three main categories: (1) Perceived safety, (2) interactions with automated shuttles in crossing situations, and (3) communication with automated shuttles. Respondents associated their perceptions of safety with the low speed, dynamic object and event identification, longitudinal and lateral control, pressing the emergency button inside the shuttle, their general trust in technology, sharing the shuttle with fellow travellers, the operation of the shuttle in a controlled environment, and the behaviour of other road users outside the shuttle. Respondents pressed the emergency button inside the automated shuttle on 28 out of 62 test rides in order to test its behavior. They further expected to be more cautious in crossing the road before an automated shuttle due to the lack of eye contact with the human driver and a lack of trust in the behavior of the automated shuttle, and expected road users testing the automated shuttle due to the conservative driving behavior of automated shuttles. We recommend future research into the hypothesis that the acceptance of automated shuttles will be associated with the perceived safety of and their effective and intuitive interaction and communication with both passengers and other road users.

Nordhoff, S., Stapel, J., Van Arem, B., & Happee, R. (under review). Passenger opinions of the perceived safety and interaction with automated shuttles: A test ride study with 'hidden' safety steward.

8.2. Introduction

The past years have shown a dramatic upsurge of scientific publications in the field of automated driving. Ample studies focused on automated vehicle technology, and examined impacts on transport, mobility and society. The user acceptance of automated vehicles is gaining attention as exemplified by our multi-level model on automated vehicle acceptance (MAVA) that summarizes current trends of acceptance research on the basis of 124 empirical studies (Nordhoff, Kyriakidis et al., 2019). The acceptance of automated vehicles does not only depend on occupants inside automated vehicles – the car drivers and passengers – but also on vulnerable road users such as pedestrians and cyclists outside automated vehicles. Managing safe and efficient interactions between automated vehicles and pedestrians and cyclists provides a necessary condition for the successful deployment and acceptance of automated vehicles by vehicle occupants inside and pedestrians and cyclists outside automated vehicles (Merat et al., 2019).

Safety is one of the basic human needs and a key requirement of automated vehicle acceptance (Fagnant & Kockelman, 2015; Garidis et al., 2020; Nordhoff et al., 2019; Xu et al., 2018). Several passenger cars now provide SAE Level 2 automation, which requires the permanent supervision of human drivers (SAE International, 2018). Similarly, SAE Level 4 automated shuttles are being tested at low speeds in semi-public controlled environments under the supervision of safety stewards on board. Higher automation levels (SAE Level 3+) will gradually reduce the level of supervision, allowing the engagement in eyes-off road activities, and ultimately allowing driverless operation. This sacrifice of self-control, however, requires vehicle occupants to exhibit more trust in the automation, which increases the relevance of perceived safety for automated vehicle acceptance.

Several studies investigated perceived safety from the perspective of human drivers in private automated cars. Using an online survey to investigate perceived safety of SAE Level 5 private automated vehicles, Moody, Bailey, and Zhao (2020) revealed that perceived safety is a function of a person’s awareness of automated vehicle technology, socio-demographic characteristics (e.g., age, gender, education, employment, income, car ownership and use, residential area), and country-level variables. Xu et al. (2018) investigated the influence of direct experience with SAE Level 3 cars and found that trust served as determinant of perceived safety. Vehicle occupants, however, also consider others in their assessment of safety and acceptance. In the interview study of Nordhoff et al. (2019) respondents considered sharing an automated shuttle with fellow travellers an uncomfortable aspect of automated vehicle usage. Sanguinetti, Kurani, and Ferguson (2019) posit that sharing a ride with fellow travellers in automated vehicles poses a risk to the physical and emotional safety of its passengers. Besides fellow occupants, occupants’ automated vehicle acceptance may further depend on concerns towards the safety of pedestrians and cyclists as vulnerable road users.

Pedestrians and cyclists will have to interact with automated vehicles – whether private automated passenger cars or public automated shuttles – in complex and mixed traffic situations (Habibovic et al., 2018; Hagenzieker et al., 2020). Little is known about how pedestrians and cyclists perceive the safety of and interact and communicate with automated vehicles (Habibovic et al., 2018; Hagenzieker et al., 2020; Mahadevan, Somanath, & Sharlin, 2018; Merat et al., 2018; Palmeiro et al., 2018; Rasouli & Tsotsos, 2018; Vissers et al., 2016). Filling these gaps in research is important as vulnerable road users constitute more than half of all traffic deaths on the road (WHO, 2018). In the survey study of Pyrialakou et al. (in press), the awareness of automated vehicles, level of automation, attitudinal variables, mode-choice related and socio-economic factors were associated with perceptions of safety of travelling near an automated vehicle. Merat et al. (2018) revealed that the presence of road markings and the type of environment affected perceptions of safety of pedestrians and cyclists: Respondents indicated to feel less safe in a shared space environment without road markings, and felt safest in a university campus environment rather than in an urban environment. In their study, pedestrians felt less safe when interacting with automated shuttles in comparison to manually driven vehicles. In Penmetsa et al. (2019), 6% of respondents who interacted with private automated cars on open streets considered automated cars safer than humans, 71% did not experience a difference between a human driver or experienced no negative interaction with an automated car, 12% considered automated vehicles more cautious or slower, or had difficulties anticipating their movements, and 7% indicated to have witnessed a negative interaction with an automated car.

The interaction between human drivers and vulnerable road users is often regulated by informal cues such as gestures, eye contact and braking (Ackermann et al., 2019; Hagenzieker et al., 2020). In driverless automated vehicles these common forms of communication become obsolete due to the absence of a human operator (Hagenzieker et al., 2020; Merat et al., 2018, 2019). This may induce additional risks, such as when vulnerable road users become hesitant or over-reliant in their interactions with an automated vehicle due to a lack of clarity on whether the vehicle they encounter is automated or manually driven (Hagenzieker et al., 2020). It is also likely that automated vehicles are being tested or blocked intentionally or unintentionally by vulnerable road users, e.g., to see how they react in near collision situations or because it is expected that these vehicles will always stop (Ackermann et al., 2019; Hagenzieker et al., 2020; Liu et al., 2020; Madigan et al., 2019; Merat et al., 2018). These situations can be avoided if automated vehicles and vulnerable road users effectively interact with each other, communicating their intentions to one another and agreeing on future motion trajectories (Merat et al., 2018, 2019). It has been suggested that a communication framework between all actors interacting with automated vehicles can compensate for the absence of a physical driver (De Clercq et al., 2019; Malmsten Lundgreen et al., 2017; Merat et al., 2018). External human machine interfaces can inform other road users on the automated vehicle’s driving mode and intention, cooperation manoeuvres, and perception of the environment, providing safe and intuitive interactions with automated vehicles (Habibovic et al., 2018; Schieben et al., 2018).

8.2.1. Research objectives

The above challenges were addressed investigating opinions of passengers experiencing an automated shuttle in a mixed traffic environment in Berlin-Schöneberg that was accompanied by a ‘hidden’ steward onboard. The research objectives were:

- (i.) To explore the safety perceptions of passengers of automated shuttles and how passengers perceive the safety of pedestrians and cyclists interacting with automated shuttles as external vulnerable road users
- (ii.) To explore how pedestrians and cyclists envision their interactions with automated shuttles
- (iii.) To explore the communication needs of pedestrians and cyclists interacting with automated shuttles

A mixed-method approach was adopted triangulating qualitative interview data that was collected during the ride with questionnaire data obtained after the ride. The interview and questionnaire addressed occupants’ perceived safety from a vehicle, individual and environmental perspective, their envisioned interactions and communication needs with an automated shuttle in crossing scenarios from the perspective pedestrians and cyclists.

8.3. Method

8.3.1. Automated shuttle, route and procedure

The automated shuttle ‘Emily’ from Easymile (2nd generation EZ10) operated on a 1500m route on the EUREF office campus in Berlin-Schöneberg, sharing the road with conventional vehicles, pedestrians, cyclists and electric scooters (Figure 1 *A*). It was electrically powered and controlled the steering, braking, and acceleration on the basis of a pre-programmed map using Lidar (Light Detection and Ranging) and geo-positioning technology. It ran at an average speed of 10 km/h and at a maximum speed of 13 km/h. A safety steward had to be on-board the shuttle to supervise its operations and intervene when necessary. For example, obstacles on the trajectory of the shuttle (e.g., parked bicycles or cars) had to be removed or overtaken manually by the steward.

Respondents were accompanied in the automated shuttle by the interviewer and the ‘hidden steward’. The steward was introduced to respondents as ‘minute writer’ (Figure 1 *B*) to hide the true purpose of the steward and improve the respondents’ sense of autonomy inside the shuttle. At the beginning of the test ride, respondents were instructed to interact with the shuttle to get acquainted with its characteristics such as the display showing the route (Figure 1 *C*), the operator interface (Figure 1 *D*), and the buttons to open the door, pull out the wheelchair ramp and connect the shuttle to an external control room (Figure 1 *E*). Respondents were also allowed to press the emergency button inside the shuttle (Figure 1 *F*). When respondents pressed the emergency button, the interviewer asked them why they pressed the button. To simulate a more realistic public transport experience, respondents shared the ride with fellow travellers ($n > 1$), or took the ride alone ($n = 1$). After the accompanied test ride, respondents were asked to complete a questionnaire that consisted of the same set of questions that were asked during the test ride by the interviewer. Respondents were offered no financial compensation for participation in the study.

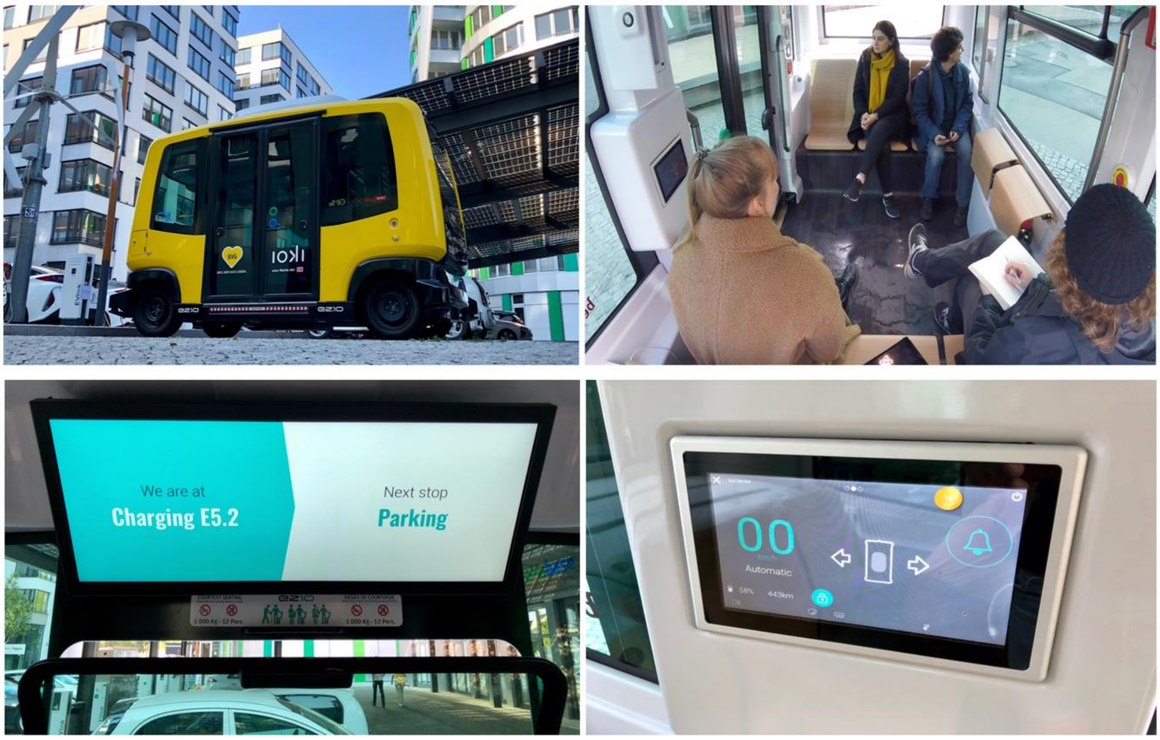

Figure 1 A (top left) Automated shuttle 'Emily' by Easymile on the EUREF campus in Berlin
B (top, right) Accompanied test ride with two respondents (front), the interviewer and steward hidden as minute writer
C (middle, left) Information display with route information
D (middle, right) Operator interface
E (below, right) Door opening button (top), button to pull out wheelchair ramp (middle), button to connect the shuttle to an external control room (below) (not active when test rides were performed)
F (below, left) Emergency stop button

8.4. Questionnaire content

8.4.1. Shuttle and service characteristics & Van der Laan's usefulness and satisfaction scale

The questionnaire asked the respondents to describe the driving behavior of the automated vehicle on a scale from very passive (1) to very aggressive (5) (Q1). Next, respondents were asked to rate specific aspects of the vehicle (i.e., air quality, size, cleanliness, comfort, speed, reliability, safety, brightness, number of seats, seating comfort, standing room, hand grips, interior and exterior design, accessibility, vehicle noise, practicality for everyday use) on a scale from very good (1) to very bad (6) (Q2), and whether there were other vehicle features that were important to them and that had not been mentioned in Q2 (Q3). The respondents were asked to rate the comfort of the trip on a scale from 1 (very comfortable) to 5 (very uncomfortable) (Q4), and to mention the specific aspects that were comfortable (Q5), and uncomfortable (Q6).

8.4.2. Attitudinal questions

Questions Q8–Q11 were self-constructed to explore respondents' perceptions of their perceived safety as passengers when using the shuttle (Q8) and the safety of other external vulnerable road users (i.e., pedestrians and cyclists) when travelling with the shuttle who are outside the shuttle at the time of their journey (Q9). Q8–Q9 were measured on a scale from 1 (not at all worried) to 6 (extremely worried). Q10–Q11 were designed to assess respondents' perceptions of safety as a pedestrian (Q10) or cyclist (Q11) when sharing space with the driverless shuttle on a scale from 1 (strongly disagree) to 6 (strongly agree).

Q12–Q13 were designed to explore how respondents would cross the road as a cyclist (Q12) or pedestrian (Q13) in the vicinity of the driverless shuttle, picking one of the following four options: I wait in a convenient place to cross until there is an acceptable gap between the shuttle and me; I wait in a convenient place to cross until there is no traffic coming; I cross the road before the shuttle; and I cross the road after the shuttle. Next, respondents were asked which type of information (i.e., auditory (words), auditory (tones/signals), visual (lights), visual (words), none) they would like to receive as pedestrian or cyclist when the shuttle is stopping, starting to move, turning, when the shuttle has detected them, and how fast the shuttle is riding (Q14) based on Merat et al. (2018).

Q15 was designed to explore using a body diagram whether respondents felt any pain during the ride or abrupt, unpleasant movements somewhere in their body during the ride that did not show up until the ride, and if so, to indicate these sensations on the body diagram.in a convenient place to cross until there is an acceptable gap between the shuttle and me; I wait in a convenient place to cross until there is no traffic coming; I cross the road before the shuttle; and I cross the road after the shuttle. Next, respondents were asked which type of information (i.e., auditory (words), auditory (tones/signals), visual (lights), visual (words), none) they would like to receive as pedestrian or cyclist when the shuttle is stopping, starting to move, turning, when the shuttle has detected them, and how fast the shuttle is riding (Q14).

8.4.3. Indicators of acceptance

Q16–Q17 were designed to explore whether respondents could imagine to use automated shuttles feeding public transport on the first and last end on their daily trips. Q18 explored respondents' assessment of the impact (i.e., radical, moderate, not at all) of automated shuttles in public transport on their mobility behaviour, adjusting the construct 'mobility needs satisfaction' of Labeye, Brusque and Regan (2015) to the context of this study. In Q19, respondents were asked how the service with automated shuttles would have to change to make the use of automated shuttles attractive on their daily trips. The operationalization of Q19 was used from the WOB Emobility cube questionnaire (WOB, 2016) and adjusted to the context of this study. The WOB Emobility cube questionnaire was conducted by the Innovation Centre for Mobility and Societal Change (InnoZ) to assess the acceptance of electric vehicles. Q16–Q19 were open-ended questions.

8.4.4. Demographics

Questions Q20–Q31 asked the respondents to provide their personal information on their gender (Q20), age (Q21), residential situation (Q22), employment status (Q23), highest level of education (Q24), access to a valid driver license (Q25), frequency of walking more than 500 meters per trip (Q26), cycling (Q27), moped or motorcycle (Q28), conventional car as driver or passenger (Q29), public transport on less than 100 km per trip (Q30), and public transport on more than 100 km per trip (Q31).

During the accompanied test rides, respondents were asked to provide answers to Q8–Q14 in general terms (without rating their responses on scales). We will not report the results from Q1–Q7 and Q15–Q19 as these questions are beyond the objectives of the present paper. Responses to all questions can be found in the digital annex.

8.5. Analysis of responses

Interview responses were analysed following principles of inductive category development. The data analysis was primarily performed by the first author of this study and two colleagues until consensus on the coded interview material was reached. Four main steps were executed.

First, the interviews were recorded and transcribed verbatim. The interview transcripts were scrutinized line-by-line by applying common steps of text analysis, such as underlining/highlighting in the text, writing notes, searching for keywords in the text, and jumping to different text passages (Mayring, 2000).

In the second stage, we read the transcripts again to develop the categories and subcategories out of the interview responses, refine and align them to the literature (e.g., Ackermann et al., 2018; Bhat, 2018; Mahadevan, Somanath, & Sharlin, 2018; Petrovych, Thellman, & Ziemke, 2018; Nordhoff, De Winter et al., 2019).

In the third step, we quantified the qualitative data from the accompanied test rides by counting the number of times a subcategory was mentioned by respondents (i.e., quotes). As respondents shared the ride with other travellers at the same time, the clear assignment of a quote to a single respondent could not always be warranted. Therefore, instead of assigning a quote to a single respondent, we assigned every quote to the test ride (TR) which the respondent participated in. We decided to report subcategories only when mentioned at least ten times across all test rides to maintain a certain degree of objectivity in the data analysis. Subcategories that received less than ten quotes were reported as miscellaneous. Multiple mentions of a subcategory by the same respondent were merged. A maximum of one quote per respondent was allowed for each subcategory to prevent a dominance of a subcategory by a respondent. When a quote addressed more than one subcategory, it was assigned to each of these subcategories.

In the fourth step of the analysis, we illustrated the nature of each category with quotes following the principle of "prototypical and outlier illustrations" (Graham-Rowe et al., 2012, p. 144). We decided to select a maximum of four illustrative quotes per subcategory to preserve some objectivity in processing the interview material.

For the data obtained from the questionnaires, descriptive statistics (i.e., means, standard deviations) were calculated per questionnaire item.

8.5.1. Respondents

Individuals who (1) participated in former car-sharing or electro-mobility projects of the Innovation Centre for Mobility and Societal Change (InnoZ), and (2) who enrolled in the meetup group named "Taking a ride with an Automated Vehicle in Berlin" (www.meetup.com) organized by the first author of this study were invited to take part in the accompanied test ride. In total, 119 respondents participated in 62 accompanied test rides that lasted on average 37:08 minutes. An overview of respondents' sociodemographic profile is given in Table 1.

Table 1.

Overview of respondents' sociodemographic profile. *n* represents the number of respondents.

Personal characteristic	Response category	*n*
Age	19–30	34
	31–40	35
	41–50	17
	51–60	9
	61–70	8
	71–75	1
Gender	Male	71
	Female	40
Living situation	Outside city in house in countryside	1
	In house on city outskirts	6
	Within city, but outside city centre in purely residential area	35
	In apartment in immediate city centre	63
Employment status	Pupil, student, apprentice	20
	Retired	4
	Seeking employment	6
	Half-time employment	17
	Full-time employment	59
Education status	Primary school/ elementary school with completed education	3
	Secondary/ technical/ business school without school leaving examination	5
	School leaving examination/ qualification	13
	Completed academic studies	83
	I am still student	4
Valid driver license	Yes	91
	No	16
Walking > 500 meters per trip	Daily or almost daily	76
	1–3 days per week	22
	1–3 days per month	4
	Less than monthly	4
	Never or almost never	1
Biking	Daily or almost daily	35
	1–3 days per week	35
	1–3 days per month	12
	Less than monthly	12
	Never or almost never	29
Moped or motorcycle	Daily or almost daily	0
	1–3 days per week	7
	1–3 days per month	5
	Less than monthly	11
	Never or almost never	85
Car as driver or passenger	Daily or almost daily	11
	1–3 days per week	25
	1–3 days per month	14
	Less than monthly	28
	Never or almost never	29
Public transport < 100 km per trip	Daily or almost daily	54
	1–3 days per week	31
	1–3 days per month	11
	Less than monthly	9
	Never or almost never	3
Public transport >100 km per trip	Daily or almost daily	2
	1–3 days per week	4
	1–3 days per month	28
	Less than monthly	51
	Never or almost never	23

8.6. Results

The categories and sub-categories extracted in the accompanied test rides, their meaning and literature sources are shown in Table 2. In total, we identified three main categories and eighteen sub-categories.

Table 2.
Overview of main categories and their subcategories, their meaning and sources

Category numbering	**Main category**	**Subcategory**		**Sources**
1.	Perceived safety	Vehicle-related	Speed: Low speed	Self-constructed
		Vehicle-related	Dynamic object and event identification: Ability of automated shuttle to identify and react to other road users	Self-constructed
		Vehicle-related	Longitudinal and lateral control: Smooth and passive steering, braking and acceleration	Self-constructed
		Vehicle-related	Emergency button: Pressing emergency button	Self-constructed
		Individual-related	Trust in technology: Having trust in technology	Xu et al. (2018)
		Individual-related	Automated shuttle sharing: Sharing automated shuttle with fellow travellers	Bhat (2018); Mahadevan, Somanath, & Sharlin (2018); Petrovych, Thellman, & Ziemke (2018)
		Environment-related	Controlled environment: Operation of automated shuttle in controlled, limited-scope environment	Self-constructed
		Environment-related	Behavior of other road users: Being more concerned about safety of vulnerable road users than about safety as passengers	Self-constructed
2.	Interaction with automated shuttles in crossing situations	Type of crossing behaviour: Crossing road (1) before or (2) after automated shuttle, (3) waiting until there is acceptable gap between automated shuttle and road user, or (4) until no traffic is coming		Merat et al. (2018)
		Lack of eye contact: Being more concerned in crossing situation with automated shuttle than with human driver due to lack of eye contact		Self-constructed
		Lack of trust: Being more concerned in crossing situation with automated shuttle than with human driver due to lack of trust in automated shuttle		Self-constructed
		Testing automated shuttles: Crossing road in close distance to automated shuttle to test its capabilities		Madigan et al. (2019); Merat et al. (2018); Hagenzieker et al. (2020)
		Motion trajectory: Using shuttle movements to form crossing decision		Fridman et al. (2019)
3.	Communication with automated shuttles	Information about travel: Reception of information about travel via in-vehicle display, voice, or app		Nordhoff, De Winter et al. (2019)
		Predictability of shuttle behavior: Reception of information about current and future actions of vehicle		Ackermann et al. (2018); Mahadevan,

			Somanath, & Sharlin (2018); Petrovych, Thellman, & Ziemke (2018)
		Information about shuttle behavior: Receiving visual (lights/words), auditory (tones/signals/words), or no information about the stopping and turning behavior of the vehicle, detection of other road users and vehicle speed	Merat et al. (2018)
		Auditory shuttle information: Mixed evaluation of receiving auditory vehicle information	Self-constructed

8.6.1. Perceived safety

The first category – perceived safety – represents an assembly of eight factors that respondents associated with the perceived safety of traveling as passengers in automated shuttles. These were divided into vehicle-related, individual-related, and environment-related factors. The following sections will now address each sub-category separately.

8.6.1.1. Speed

Concerning their personal safety inside the shuttle, several respondents attributed their positive safety perceptions to the low speed of the automated vehicle:

„Yes, it's slow, so it's safe." (TR16)

„It seems very slow. Sure, the slower it is, the safer you feel on the one hand. There are two souls living in my chest, because the low speed gives you the feeling of safety, but on the other hand, you would also like to arrive quickly somewhere." (TR25)

„No, because of the speed, the speed is very comforting." (TR30)

8.6.1.2. Dynamic object and event identification

Respondents also indicated that they felt safe due to the automated shuttle's ability to identify and react to road users and objects in the external environment.

„No, the system seems to respond to anything, if it is even responding to grass." (TR26)

„Not with this driving behavior; it is doing well. It knows where the stop signs are as well." (TR43)

„I'm more concerned about my arrival time, technically it works fine. It stops right away, it's safe, I have no fears that someone outside will be run over." (TR57)

8.6.1.3. Longitudinal and lateral control

Safety also seems to be a function of the smooth and passive lateral (i.e., steering) and longitudinal (i.e., acceleration and deceleration) control of the automated vehicle. Respondents noted:

„Not worried at all, it is reacting very fast. […] It's always braking or decelerating great, much better than a normal car driver would do." (TR01)

„I feel very safe actually. It drives very smooth, it does not make any weird movements around." (TR19)

„Not worried about my personal safety. The car is very quiet and smooth […]. This is really like driving in a train." (R22)

„The steering is very consistent and smooth, not as strong as with normal bus drivers where you are immediately swung backwards. You already have a safe feeling." (TR32)

8.6.1.4. Emergency button

Respondents pressed the emergency button on 28 of 62 test rides. When respondents were asked why they pressed the emergency button, they stated that they wanted to test the reactions of the automated shuttle. Several respondents expressed their views on pressing the emergency button as follows:

„So if you have an emergency stop button somewhere, that's a safety for the people." (TR28)

„Actually, it feels safe now. I do not feel like we're going to hit the wall right now. If the button here works, why not." (TR37)

„I like it that I press the button myself. I'm curious pressing it because I don't know what happens then. But it's good to have that. Also as an idea if something happens. Not just for getting out of the shuttle but also in cases of emergency. For anxious people." (TR47)

Several respondents referred to the absence of physical supervision inside the automated shuttle.

„Here is no traffic, so I'm not really afraid. But still, that's the first association, there is no driver here." (TR10)

„It actually feels really normal even though you do not see anyone steering or accelerating or doing anything." (TR18)

„Does not bother me at all to be in a driverless vehicle. There are also subways that are autonomous." (TR57)

„To be honest, it's still funny. But at the end of the day you still drive in a vehicle without a driver not operating on tracks." (TR59)

8.6.1.5. Trust in technology

Respondents indicated to feel safe due to their general trust in technology, including automated driving technology and the entities operating it.

> *„I trust the system. Once I trust, it is like in the airplane. If I am stressed because I don't see anything, it does not change anything. […] This type of transportation will always be safer than the normal trains because of the responsibility of the transport companies. Once they open the service, it's safe, […] and I know they have the responsibility and I am safe."* (TR14)

> *„I am not worried at all but I also trust technology a lot."* (TR33)

> *„I'm a technology optimist. Of course, I read about some of the accidents that happened with self-driving cars in the United States, and of course all the newspapers love to report about it. But if we would report about everyone being killed in traffic, the newspaper would not even have enough space because there would be so many. […] It's still safer than someone driving a car here […]."* (TR58)

8.6.1.6. Automated shuttle sharing

Several respondents indicated to feel uncomfortable when sharing the space inside the automated shuttle with fellow passengers:

> *„[…] If I do not play with my phone now, then I have to stare people to the ground and probably they will do the same with me too. It is just a lot more intimate here, because the shuttle is so small."* (TR06)

> *„I am not sure whether people will still feel comfortable when the shuttle is crowded with 12 people. […] If six people are standing and six people are sitting here, I would want to get out here as soon as possible."* (TR27)

> *„I think 12 people, that's too much […] because you can get scared and then if the door does not open. Then heart racing. In the beginning, you should fit less people, 9 would probably work."* (TR28)

8.6.1.7. Controlled environment

Several respondents indicated that their positive perceptions of safety are the result of the operation of the automated shuttle in a controlled environment.

> *„Not worried, the environment is very safe, it is not stressful at all."* (TR14)

> *„Not worried, but again it is a very limited environment and that's the issue I would say. Apart from that I don't feel unsafe, I did not put the emergency stop. The shuttle is doing very well and I like the*

performance, but it is very limited in scope, this is a limited scope environment." (TR43)

„I do not feel insecure at all. This is also a closed campus. It cannot happen that much." (TR51)

Consequently, respondents noted that their safety perceptions might change when the automated shuttle is driving at higher speeds in a mixed-traffic situation:

„Yes, I feel safe, but I think it is not so easy to transfer this experience to something like: „Ok, it is going 50 km/h, there is traffic around it." (TR18)

„At the moment I am not sure whether it is safe enough to drive on public roads, this is a very overfitted environment. For example, the situation that a car came in and it just stopped, that is not reliable. Would I trust this particular shuttle or the software in it? No. This was a very nice and smooth ride, but it was actually not enough for me to trust it on the road. It is a very limited test ground to say that the software is reliable." (TR43)

„At a speed above 80 km/h, I wouldn't trust it. Because the traffic or the situation is too complex and there can be so much exceptions that can happen." (TR47)

8.6.1.8. Behavior of other road users

As shown in Figure 2, respondents indicated that that they were less worried about their personal safety when travelling with the automated shuttle (Q8, M = 1.68, SD = 1.01) than about the safety of road users outside the shuttle (Q9, M = 2.57, SD = 1.28). Safety concerns related to a lack of knowledge on how the automated shuttle perceives and reacts to road users outside the shuttle.

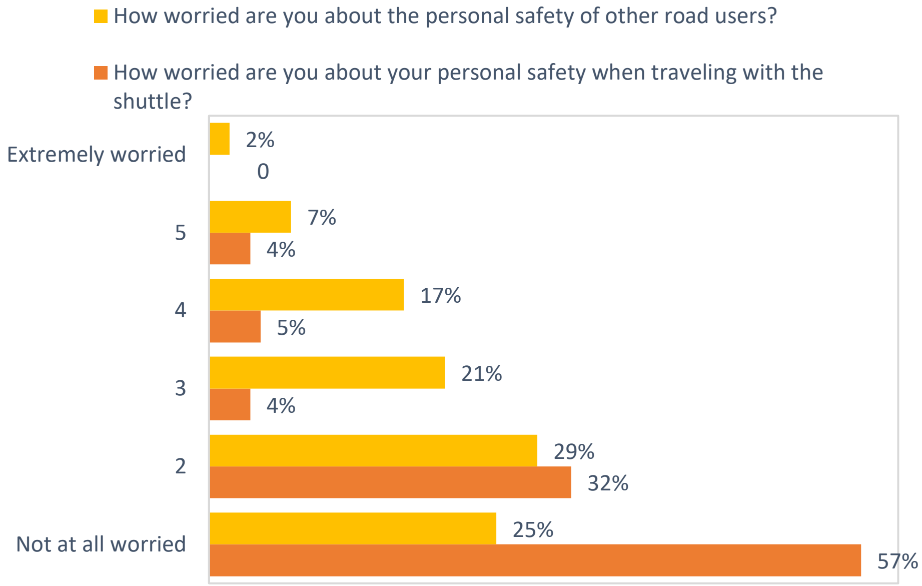

Figure 2. Bar diagram showing the distribution of the responses for the items Q8 *(„How worried are you about your personal safety when traveling with the shuttle?"*, green bar) and Q9 (*„How worried are you about the personal safety of other road users?"*, orange bar)

„I think […] I am a little concerned for the people outside like the couple that was passing in front. The shuttle slowed down eventually, but they were looking at us and making eye contact, and then I got nervous for them, yes, and of course they got nervous because you don't know whether we are going to stop, we don't have control over it. I was nervous for them because they were nervous." (TR30)

„Actually, more worried about mine. I'm more afraid that the car will not recognize them." (TR53)

„Just because I do not exactly know how it is working, I would be more concerned about the pedestrians and cyclists outside the shuttle. Where I come from, New Mexico, I think we have the highest amount of crashes in the entire United States. A lot of people die all the time in car accidents. Friends have died, relatives have died, I do not trust other people driving. Like my only concern here is not trusting other people driving around me. It is absolutely insane." (TR61)

8.6.2. Interaction with automated shuttles in crossing situations

8.6.2.1. Type of crossing behaviour

As shown by Figure 3, respondents indicated to wait in a convenient place to cross until there is an acceptable gap between the shuttle and them as cyclist (Q11, *M* = 2.07, SD = 1.24), and pedestrian (*M* = 2.08, SD = 1.25).

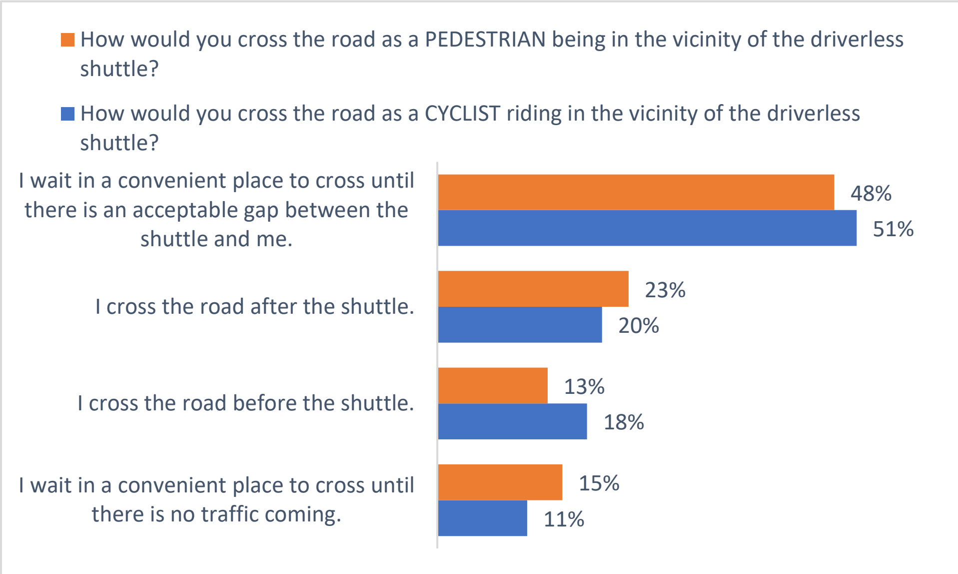

Figure 3. Bar diagram showing the distribution of the responses of items Q11 *("How would you cross the road as a CYCLIST riding in the vicinity of the driverless shuttle?")* and Q12 (*"How would you cross the road as a PEDESTRIAN riding in the vicinity of the driverless shuttle?")*

8.6.2.2. Lack of eye contact

Several respondents indicated that they would be more cautious in crossing the road in front of an automated shuttle due to the lack of eye contact with the human driver.

> *„[…] What's missing here, I have no idea, does this machine see me? Yes or no? There is no driver who looks in my direction and says: 'Ok, I recognize that you are there.' […] Therefore, I would handle this shuttle more carefully […] and not just walk in front of it […], but I would let it pass."* (TR05)

> *„I think I would be more careful than with a normal person. […] The driver […] behind the steering wheel probably recognizes me and I can see him, we have eye contact. […] Here, when I cross the […] road, the shuttle would probably slow down, but I have no interaction with the shuttle […]. Will it really stop or will it not?'"* (TR08)

> *„You are probably going to be more uncertain because it is a machine, at least in the very beginning, […] because the thing can't see me, what it's going to do next?"* (TR19)

8.6.2.3. Lack of trust

Several respondents reported to be more cautious in the crossing situation with an automated shuttle due to a lack of trust in the behaviour of the automated shuttle.

> *„I would not – as I do now with a regular car – cross the road just in front of the shuttle, hoping that the shuttle would stop […] because I'm not sure how fast it will react until it perceives something. As new as the technology is, I would be a little more cautious than with conventional vehicles."* (TR07)

> *„I would simply wait in the initial phase until it really stops before I cross the street. It is also a question of trust."* (TR11)

> *„I will wait for it to pass, just now. When I see an autonomous car, I still have some worry about it. I don't know who will take over the responsibility when I got in there? […] I can't say that I am 100% trusting this technology right now."* (TR27)

8.6.2.4. Testing automated shuttles

Several respondents anticipated that the automated shuttle will be tested by other road users due to its defensive driving behavior.

> *„People are jerks. So if these things are commonplace, you have a bunch of kids standing in the way and not going out of the way. A bus driver could yell at the kids but if it is automated ..."* (TR12)

> *„Well, we just drove past some people there and they went in front of the vehicle. They said: 'There this automated vehicle is coming. It is stopping anyway.' I would do that too. Simply, to test what the automated vehicle can do and what it can't do. Maybe at some point I would stop doing it because I know the device and that it brakes."* (TR51)

> *„I saw an automated vehicle in a pedestrian zone as well. People always did this.[6] There were always four stewards around the vehicle, telling people to step out of the way."* (TR51)

8.6.2.5. Motion trajectory

Several respondents indicated that they would use the movements of the automated vehicle to form their crossing decisions.

> *„Just the same like with the tram. I estimate how fast it is going, how far it is, can I pass safely? Either pass or wait for it. For me it is mostly about predictability […] mostly in terms of speed and direction."* (TR34)

[6] Stepping in front of the automated shuttle.

„I would treat it the same as [anybody/anything] else. From a distance, I calculate the speed like 'Ok, I can now speed up a bit, and cross the road.'" (TR54)

8.6.3. Communication with automated shuttles

8.6.3.1. Information about travel

Respondents mentioned the attractiveness of receiving travel information via in-vehicle display, voice, or app:

„It would be very nice if we have an application for the shuttle […] because sometimes when we are […] in a train […] I need to know what the next station is. Sometimes it's crowded or some trains don't have displays, so it would be very nice to have the application. That's something I would like to have." (TR09)

„It would be nice to hear a voice saying what the next stop is, but more important is when I […] enter the car, I need information on the destination, when it will arrive, about how I get in, how much I have to pay." (TR33)

8.6.3.2. Predictability of shuttle behavior

In addition to receiving information about travel, respondents emphasized the need to be able to intuitively understand the current and future actions of the automated vehicle.

„I think the two typical problems of any AI[7] is that the software has to be transparent. Why does the software act like this? In the first round, the shuttle stopped over there, but there was nothing. It would be good to know why the AI decided like this. And this is absolutely missing. There is no information about what this shuttle does or will do." (TR09)

„Maybe it would help if you could see what the car is currently seeing and how it interprets it so that, at least in the beginning, you get a feeling for how the car perceives things, which would give me a sense of safety." (TR17)

„If we could see how the car perceives the outside like on a screen. If we see how this car is identifying the objects, then it might be easier or less concerning. But now I have no idea of what the car is seeing. This makes me concerned." (TR31)

„What is it doing now?[8] Wouldn't it make more sense to say 'Obstacle detected' so that we know what it is as passengers? Because now it's like: 'What happened? Is there a kid on the street?'" (TR42)

[7] Abbreviation for artificial intelligence.
[8] Respondent pointed to the bell of the automated shuttle that is ringing.

8.6.3.3. Information about shuttle behaviour

As shown in Figure 4, respondents reported to prefer visuals (lights) and auditory tone and signals (26%, 34%) when the shuttle is stopping (48%) and turning (44%).

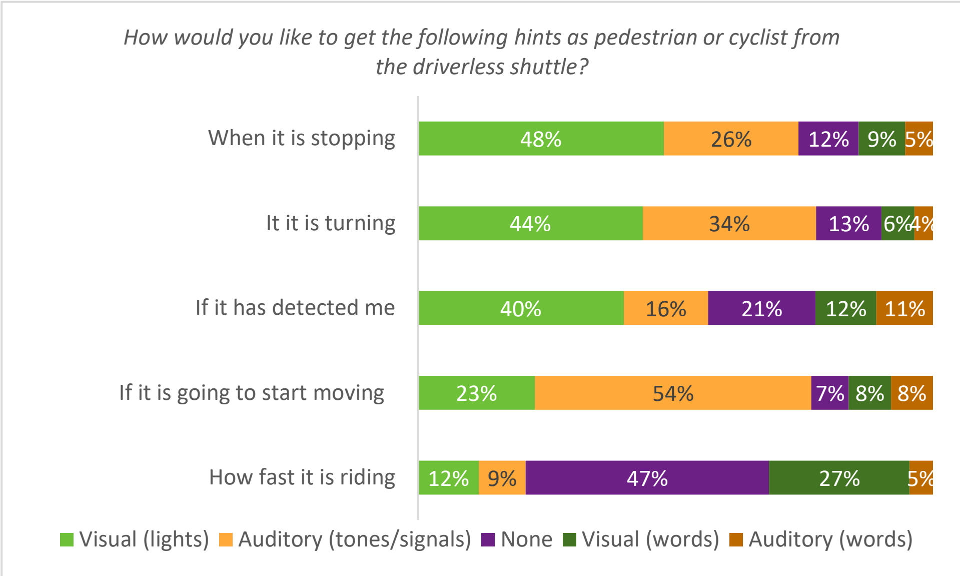

Figure 4. Bar diagram showing the distribution of the responses for Q13 *(„How would you like to get the following hints as pedestrian or cyclist from the driverless shuttle?")*

„Yep, maybe like an LED screen that displays a stop sign." (TR51)

„Maybe with a light. If I am crossing and I didn't see the car, my first reaction would be to look at it in panic. […] Either ring the bell or show a red light that can tell you 'Ok, it is stopping' so I don't have to panic or run or do something." (TR51)

Respondents would also like to receive visuals (lights), followed by auditory tones and signals to be informed when the shuttle has detected them (40%, 16%). The reception of visuals (lights) could replace the eye contact with human drivers:

„It would be nice to see that the shuttle sees me and stops. Maybe some lights; something that has the same function like eye contact." (TR16)

„For me, some visual sign would be needed. […] It is like getting an eye contact with the driver." (TR18)

„It would be nice to know that I am visible, maybe with a Bluetooth that within a certain area of the shuttle you know you've been detected. […] Maybe it is the shuttle signalling to me or one of my personal devices. Let's say there is a poplight saying: 'Yes, you are visible.'" (TR42)

Auditory tones and signals (54%) and visual information (lights) (23%) were preferred by the respondents when the automated shuttle starts moving.

„Maybe a bit more information than the turning signal. For example, some lights in the front when it starts moving." (TR10)

Respondents did not want to receive any (47%), or visual information (words) (27%) to be informed on how fast the automated shuttle is riding.

„I really do not want to communicate that much. We live […] in a time of overstimulation. Less is more […]. If the door is closing and there is a light then, that's maybe good to prevent that I will be stuck in the door. […] There should not be unnecessary information; this would be annoying." (TR20)

8.6.3.4. Auditory shuttle information

Respondents had diverse opinions about the ring of the automated shuttle to inform outside road users when it starts driving or moving around the corner. The ring of the automated shuttle was considered annoying, disturbing and useless.

„Just earlier the bell rang around 10 times. This is a bit annoying, but once is okay." (TR34)

„It must be driving people nuts with the rings[9]. If this would run every ten minutes, I would either wear earplugs or go out and break the speaker. […] With this speed, you don't need any rings. It's basically like you have a better chance of being hit by a garbage can. The bell is fine but it seems not to have a cool-off period. So it's ringing and then if it gets stuck, like with the grass, it rings to say: 'All right, I am turning.' And then it's like: 'This is bothering me, this is bothering me, this is bothering me.' It's ringing again and again and again. And to me ringing when you are at a speed of 1 km/h, is a bit ridiculous, unless you are trying to say: 'Move, move, move.'" (TR35)

Others considered the auditory information as useful.

„The horn is fine, you know that it is aware of you, that there is a cyclist or a person coming, so it detects it, it knows it should not run over that person." (TR43)

„It seems to work with the rings from the bell. This dog, who did not know any better, and the cyclist who deliberately cut us were now the only ones who ever stopped the vehicle. Insofar it feels safe and less stressful compared to a ride on the M29[10] where not only the driver is stressed but also the passengers." (TR51)

8.7. Discussion

The aim of the accompanied test ride study was to obtain insights into the perceived safety of passengers of automated shuttles, and pedestrians and cyclists interacting with automated

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[9] The respondent is referring to the ring of the automated shuttle

[10] Bus route in Berlin.

shuttles as external road users. The data that was gathered in this study can be summarized into three main categories: (1) Perceived safety, (2) interaction with automated shuttles in crossing situations, and (3) communication with automated shuttles.

8.7.1. Perceived safety

8.7.1.1. Vehicle-related

Respondents reported to feel safe due to the operation of the automated shuttle at low speeds, the ability of the automated shuttle to identify and react to other road users and traffic objects in the external environment, and the smooth and passive longitudinal and lateral vehicle control. Several respondents pointed out that they would not feel comfortable driving at higher (car-like) speeds. This can be due to the capabilities and behavior of the automated shuttle, which are naturally adapted to the operation at lower speeds, or to a lack of trust in the behavior of the automated shuttle (see Section 4.1.2.). Our findings correspond with prior research on the determinants of perceived safety and trust, which associated vehicle characteristics (e.g., motion and speed) with perceptions of safety and trust (Aarts & Van Schagen, 2006; Charalambous, Fletcher, & Webb, 2015; Mahmud et al., 2019; Smiley & Rudin-Brown, 2020; Van Winsum & Heino, 1996). We recommend future research to examine the relationship between vehicle motion characteristics and perceptions of safety. Key challenges will include enabling intuitive interactions with other road users, in particular at higher speeds. This will presumably lead to “smooth” driving styles also contributing to improvements in motion comfort. Here it shall be noted that the current test rides resulted in a positive evaluation of motion comfort (rated 2.6 on a scale from 1 = very good, to 6 = very bad – see the digital annex).

The emergency button was used on 28 from 62 test rides. Respondents reported to press the button to see how the automated shuttle behaved. This suggests that passengers “test” the shuttle. It is somewhat surprising that a relatively large number of respondents felt the need to put it to the test, considering the ubiquitousness of emergency stop buttons in current transport systems, where misuse is discouraged socially and financially. The urge to test could be an indicator of distrust or curiosity, but can also indicate that respondents perceived some level of responsibility for the vehicle due to the absence of physical human supervision. The absence of supervision inside the automated shuttle may have enhanced their feelings of perceived responsibility, and suggests that they indeed believed that the automated shuttle was driverless. The curiosity may also be rooted in the novelty factor of the vehicle, and may have been encouraged further by the experimental setting (i.e., the interviewer of this study invited the respondents to press the button when desired). Future research should investigate whether pressing the emergency button could be considered an objective indicator of perceived safety or trust in response to studies calling for the use of more objective (vehicle) data to measure acceptance (Nordhoff et al., 2018), and how the use of the emergency button changes with the operation of automated shuttles in more realistic and complex driving conditions.

8.7.1.2. Individual-related

Our study has shown that respondents attributed their perceptions of safety to their general trust in technology. The relationship between trust and perceived safety has been documented in the literature. Zöllick et al. (2019) modelled trust in automated vehicles as a function of the perceived safety of automated vehicles. In contrast, Kerschbaum, Lorenz and Hergeth (2015) posited that trust is a condition for the belief that automated cars are safe.

Respondents considered sharing the ride with other fellow travellers an uncomfortable aspect of automated shuttle use. This concurs with our multi-level model on automated vehicle acceptance, called MAVA (Nordhoff, Kyriakidis et al., 2019), which has shown that sharing the ride with individuals outside one's own immediate social circle is an important factor in automated vehicle acceptance. Our automated shuttle provided two opposing rows with three seats of limited width, which could magnify privacy issues. This may be addressed with larger-sized vehicles simulating the 'cocoon effect' of the private car. The shuttle interior can be redesigned, for example, preventing the opposite seating of passengers, dividing the space into smaller cubicles, providing larger-width seats and armrests. High speed internet could allow passengers to hide behind their digital devices rather than having to interact with their fellow passengers.

8.7.1.3. Environment-related

Respondents reported to be more worried about the safety of road users outside the automated shuttle than about their personal safety as passengers and attributed their perceptions to a lack of knowledge on how the automated shuttle perceives and reacts to road users outside the shuttle. Respondents are probably aware of the risky behaviour of vulnerable road users and their high involvement in fatal accidents (Dey & Terken, 2017; Hulse, Xie & Galea, 2018). Our study has also shown that respondents attributed their perceptions of safety to the operation of the shuttle in a controlled environment. More research is necessary that exposes automated shuttles to more dynamic and complex traffic situations to get a more accurate estimate of respondents' perceptions of safety.

8.7.2. Interaction with automated shuttles in crossing situations

Our results show that respondents reported to be more cautious in crossing the road in front of the automated shuttle than in front of conventional human drivers, indicating to wait in a convenient place until there is an acceptable gap to cross the road. They attributed their more cautious crossing behavior to the lack of eye contact with the human driver and trust in the automated shuttle. These findings correspond with Rothenbücher et al. (2016) who reported that respondents mentioned an uncertainty about the automated vehicle's behavior in a crossing decision, and with Pillai (2017) who revealed that respondents had difficulties to cross the road in front of an automated vehicle in a virtual-reality environment due to the lack of confirmation from the driver. Rad et al. (2020) found that respondents who trust in automated vehicle technology were more likely to cross the road before the automated vehicle.

Our study has further shown that respondents indicated to rely on the movements of the automated shuttle (e.g., speed, distance) to form their crossing decision. The literature widely supports the use of eye contact between pedestrians and human drivers as communication cue (Chang et al., 2016; Guéguen et al., 2015; Ren, Jiang, & Wang, 2016; Ŝucha, 2014). Recent studies (AlAdawy et al., 2019; Rad et al., 2020), however, propose that instead of making eye contact with an approaching vehicle when making their crossing decisions, pedestrians might be more likely to rely on vehicle kinematics (e.g., vehicle speed, distance to approaching vehicle, turn signals, brake lights) (Fridman et al., 2017, 2019; Ackermann et al., 2019). We encourage future research to examine the hypothesis that pedestrians look in the direction of the car approaching, and force the car to slow down without necessarily establishing eye contact with the driver. Future research should also establish the causality of this relationship, and investigate the perspective of the human driver. Do human drivers recognize the eye contact of pedestrians, and if so, how do they interpret and respond to it? Do human drivers slow down because they recognize a pedestrian and anticipate that the pedestrian wants to cross the road without establishing eye contact, or do they make eye contact with the pedestrian and then slow down?

Respondents also expected that automated shuttles will be tested by other road users due to their conservative driving behavior, which is consistent with Millard-Ball (2018) who posited that autonomous vehicles are programmed to obey the rules of the road, giving pedestrians the right of way to cross the road. Similarly, Madigan et al. (2019) who analysed video data on the interactions between automated shuttles and external road users found incidences of road users testing an automated shuttle. In the study of Rad et al. (2020), 81.7% of respondents expected the automated vehicle to stop for them at zebra crossings, and even 25% of respondents everywhere. Manufacturers, vehicle operators, and the media should educate the public that the testing of automated vehicles could jeopardize the safety and efficiency benefits of vehicle automation. Another strategy is to program automated vehicles to behave more human-like (i.e., less conservative and more aggressive without mitigating safety benefits) to prevent that road users change their crossing behavior when interacting with automated vehicles. Infrastructure could also be put in place that separates other road users and automated vehicles. Finally, the sensors of automated vehicles could also identify road users disrespecting the traffic rules and inform the corresponding authorities (e.g., police) sanctioning this type of activity.

8.7.3. Communication with automated shuttles

8.7.3.1. Information about travel

Our study has shown a preference of individuals to receive information about travel. This finding corresponds with our interview study (Nordhoff et al., 2019), which has shown that respondents considered the provision of travel information on routes and interchanges a convenient aspect of automated vehicle usage. Smartphone apps and displays inside the vehicle or in close proximity to the vehicle's stop could provide individuals with the corresponding information.

8.7.3.2. Predictability of shuttle behavior

Respondents emphasized the importance of having an intuitive understanding of the current and future actions of the automated shuttle both as passengers and pedestrians and cyclists. This is in line with Ackermann et al. (2019) who found that respondents preferred the communication with an automated vehicle to be intuitively comprehensible and similar to pedestrians' current communication system. The desire to receive information about the behavioral intent of the automated shuttle as passengers might indicate that respondents have an initial need to verify that they can trust the system. The usefulness of communicating the intent and current state of the automated vehicle to pedestrians has been corroborated (Habibovic et al., 2018; Rad, Correia & Hagenzieker, 2020; Reig et al., 2018). Khastgir et al. (2018) showed that informing respondents on system capabilities increased their trust. We suggest to install displays inside automated shuttles to provide passengers with information on road users' movements outside the environment as well as on the current and future actions of the automated shuttle. The additional use of smartphone apps is also advisable given the high saturation and daily usage rates of smartphones. Chater et al. (2019), however, remind us that the communication between automated vehicles and road users has to work in safety-critical environments, in real time and with low-bandwidth communication, implying that smartphone apps can't be the sole medium of communication. Finally, in line with the reflections of Fridman et al. (2017, p. 3–5), the need to employ "external communication signals in automated vehicles intended for public roadways beyond those already used in non-automated vehicles" should be critically discussed to address the still "open research question as to whether new external displays are necessary for communication of intent". We suggest that it might be more effective if automated shuttles behave like conventional vehicles when interacting with road users so that the proportion of new communication to be learned by road users is limited.

8.7.3.3. Information about shuttle behavior

Respondents favoured auditory information in situations when the automated shuttle was starting to move. This corresponds with Merat et al. (2018) where respondents interacted with an automated shuttle in La Rochelle and Trikala. Several respondents also considered the reception of auditory information annoying and useless, which suggests that sound is not appreciated for non-urgent and frequent messages. Visual information was preferred when the automated shuttle was stopping or turning, which is a finding that reflects the preferences of respondents who encountered an automated shuttle in Lausanne (Merat et al., 2018). Our respondents also reported to favor visual information when the automated shuttle detected them, which is in correspondence with the respondents testing an automated shuttle in Lausanne, but not consistent with respondents testing an automated shuttle in La Rochelle and Trikala (Merat et al., 2018). These findings suggest that the reception of visual and auditory information and a combination thereof to communicate with automated shuttles is appreciated differently by individuals across countries. We recommend that future studies examine the cultural differences of interacting with automated shuttles as external road users, and how their interaction behavior determines their requirements to communicate with automated shuttles.

Our study further revealed that only a small proportion of respondents valued the reception of words as visual information cues to be informed when the automated shuttle was stopping, turning, starting to move, or whether it had detected them. Mahadevan, Somanath, and Sharlin (2018) found that an interface, which included a visual cue sent through an Android phone signalling the respondent to be seen, was considered the most effective interface for communicating with an automated vehicle. Bazilinskyy, Dodou, and De Winter (2019) revealed that electronic human-machine-interfaces with simple textual instructions and icons to communicate intent to road users obtained the highest clarity ratings by respondents. Following the recommendation of Bazilinskyy et al. (2019), we recommend future research to test electronic Human Machine Interfaces in real traffic with high visual demands to investigate the conditions under which individuals prefer textual information. Future research should also consider the situational aspects in which Human Machine Interfaces are presented to respondents since it can be expected that results depend on the context (e.g., whether interfaces are presented on computer screen without context, on a picture or simulation of the vehicle, or in the real world).

8.7.3.4. Study strengths & limitations

A first strength of our study is that respondents had an extensive physical experience with the automated shuttle that lasted on average around 37 minutes per ride. In previous studies, respondents experienced automated shuttles for a limited amount of time (e.g., 15 minutes per ride) (Nordhoff et al., 2018; Zoellick et al., 2019a, b), or were asked to imagine the use of automated shuttles (Nordhoff et al., 2018). We recommend future research to survey respondents before and after their rides with automated shuttles to control for the influence of experience.

Second, despite improvements in the performance of on-road automated vehicles (Favarò, Eurich, & Nader, 2018), human safety drivers or operators are often still needed to monitor the operation of automated vehicles to take over control when requested (Van Brummelen et al., 2018; Wang & Li, 2019). Consequently, in studies investigating automated vehicle acceptance, respondents were accompanied by human drivers or operators on board the vehicle. This may have inflated their safety perceptions. In our study, respondents were accompanied by a 'hidden steward' on board the shuttle to increase their sense of autonomy and simulate the experience of taking a ride in a driverless shuttle.

Third, our study contributes to the discussion on the suitability of the research methods to evaluate the interactions between automated vehicles and other road users (Dey et al., 2018). Our research study applied a mixed-method approach to examine the interactions between automated shuttles and pedestrians and cyclists from the perspective of passengers who were interviewed on an individual- and group-basis during and surveyed after their ride in the automated shuttle. Sharing the ride with fellow travellers has the advantage that respondents learn from, build upon and contrast their ideas (Pudāne et al., 2019). The triangulation of qualitative, in-depth data with questionnaire data elucidated motives behind the ratings of the questionnaire items, and revealed new themes and patterns that were not covered by the questionnaire items. Furthermore, the shuttle is outfitted with windows on all sides (Zoellick et al., 2019a). We argue that this research setting along with the extensive test experience allowed our respondents to accurately envision the interactions with automated shuttles as external road users and to evaluate their perceived safety. We recommend future research to replicate such methods to evaluate suitability given the lack of standardized methods to assess interactions with automated vehicles (Habibovic et al., 2018).

A first limitation is that respondents were asked to evaluate a hypothetical scenario: Respondents did not physically interact with the automated shuttle as pedestrians or cyclists but were passengers, which may bias results. It is possible that respondents had overly negative attitudes towards interacting with automated shuttles as pedestrians and cyclists, which may have been fostered by the media reporting accidents with automated vehicles and vulnerable road users, or because they are aware of the risky behaviour of vulnerable road users when interacting with conventional traffic (Hulse et al., 2018; King, Soole, & Ghafourian, 2009). It is also plausible that the ring that respondents heard during the test ride inside the shuttle did affect their preference to communicate with the shuttle as pedestrians and cyclists. For example, respondents may have a higher preference for the reception of visual rather than auditory information when interacting with automated shuttles as pedestrians and cyclists because they were negatively affected by the ring as passengers inside the shuttle.

Second, it can be argued that more important than the exposure time for the development of an accurate mental model and acceptance as well as perceptions of safety is the exposure to traffic scenarios that permit the testing of the system performance and reliability. Consequently, we encourage future research to assess acceptance of automated shuttles in more complex and risky traffic scenarios that bear the risk of failure.

Third, the present study did not account for how sharing the ride with fellow travellers influenced the response behaviour of our respondents. While it was of the impression of the interviewer of this study that group behaviour effects were not present, the presence of other travellers should be taken into account when interpreting the results.

Finally, the automated shuttle in the present study was not truly driverless but was operated by a 'hidden' steward on board. Future research should try to omit obvious physical supervision and deploy automated shuttles that are supervised from an external control room or without any type of supervision if possible.

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8.9. Supplementary material

S1. Digital annex: Overview of questionnaire results (available on request)

8.10. References

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Chapter 9: Discussion and conclusions

The aim of this PhD thesis was to examine the acceptance of automated vehicles in public transport. This chapter summarizes and discusses the knowledge that was gained in the context of this PhD, outlines the limitations and provides recommendations for future research.

9.1. What are the general attitudes towards automated vehicles in public transport?

Overall, the attitudes of respondents towards automated public transport were positive. In Chapter 2, the second-highest mean rating was obtained for the item pertaining to the intention to use a 100% electric driverless vehicle in public transport (M = 5.09, on scale from strongly disagree (1) to strongly agree (6)). This corresponds with Chapter 3, which revealed that respondents liked the idea that a 100% electric driverless shuttle will transport them from the train station to their final destination (M = 5.04, on scale from strongly disagree (1) to strongly agree (6)). In Chapter 4, respondents were positive towards the idea of using automated vehicles in public transport, yet expressed their disappointments regarding the actual technical capabilities of automated vehicles, which did not meet their expectations. Respondents' idealized expectations about the technological capabilities of automated vehicles may have been fostered by the media. Chapter 4 thus reveals the discrepancy between idealized and actual acceptance.

Chapter 2 revealed a desire for human control as shown by the highest mean rating obtained for the item pertaining to the willingness to have a button inside the driverless vehicle (M = 5.18, on scale from strongly disagree (1) to strongly agree (6)), which corresponds with respondents' high rating for preferring a button to stop the vehicle (M = 5.23, on scale from strongly disagree (1) to strongly agree (6)) in Chapter 3. Chapter 3 found that respondents favored the supervision of the automated vehicle from an external control room, followed by having a steward onboard to no human supervision. Chapter 4 revealed a preference among respondents for the supervision of the automated vehicle via an external control room or steward onboard to no supervision. In Chapter 7, respondents indicated that they consider a steward inside the vehicle to be moderately important, favoring the supervision of the automated vehicle from an external control room. The lowest mean rating was obtained for feeling safe without any type of supervision (M = 2.902, on scale from strongly disagree (1) to strongly agree (6)).

9.2. What are the factors impacting the acceptance of automated vehicles in public transport, and what is their relative importance?

The large cross-national questionnaire study in Chapter 2 found that the questionnaire items could be best explained through a general acceptance component that was retrieved by a principal component analysis. The principal component analysis reduces large amounts of data into a smaller number of components, thereby allowing for the detection of underlying patterns in the dataset. The loadings of the items on their underlying components (i.e., correlation coeffients) are indicative of the strength of the relationship between items and the component. High loadings can be interpreted as having a strong relationship with the acceptance construct. The highest loadings ($\cong$0.7) on the general acceptance component were found for items pertaining to the usefulness of automated vehicles, which suggests that the perceived usefulness is the strongest determinant of automated vehicle acceptance. Loadings between 0.5 and 0.6 were found for items concerning the ease of use, pleasure, and trust in driverless vehicles, as well as knowledge of mobility-related developments. Thrill seeking, wanting to be in control manually, supporting a car-free environment, and being comfortable with technology were identified as further components.

A similar approach was adopted in our questionnaire study in Chapter 3 which performed a principal component analysis on data from individuals who physically experienced an automated vehicle in a semi-public mixed traffic environment in Berlin. The principal component analysis resulted in the retention of three components. These are shuttle and service characteristics, the effectiveness of the automated shuttle compared to existing transport, and the intention to use automated vehicles in public transport. This suggests that the acceptance of automated vehicles is determined by the physical characteristics of the automated vehicle itself and the service offer, and the effectiveness of the vehicle in comparison to respondents' existing transport. The strong positive relationship between shuttle and service characteristics and intention to use is consistent with studies showing that quality of service is linked to intentions to use public transport systems (Lai & Chen, 2011).

The interview study in Chapter 4 provided an in-depth understanding of the motives for using automated vehicles in public transport of 30 individuals. This interview study as a qualitative research method was performed as it has the advantage of developing a deep understanding of the research phenomenon under consideration, generating new theoretical insights inductively (Punch, 1998; Walsham, 2006). It complements existing work on automated vehicle acceptance that has been skewed towards quantitative research methods, allowing respondents to spontaneously address issues rather than being prompted to consider aspects in questionnaires they may not have considered otherwise (Pettigrew et al., 2019). The interview data was classified into six categories, which can be understood as factors impacting automated vehicle acceptance: (1) expectations about the capabilities of the automated shuttle (10% of quotes), (2) evaluation of the shuttle performance (10%), (3) service quality (34%), (4) risk and benefit perception (15%), (5) travel purpose (25%), and (6) trust (6%). This study revealed that respondents had idealized expectations about the technological capabilities of the automated shuttle, which may have been fostered by the media.

The questionnaire study in Chapter 5 has shown that hedonic motivation (i.e., degree to which using automated vehicles is perceived enjoyable) was the strongest predictor of behavioral intentions to use automated vehicles, followed by performance expectancy, and social influence. The structural equation modeling analysis in Chapter 7 revealed that compatibility was the strongest predictor of the intention to use automated vehicles, followed by automated vehicle sharing. Such differences may well emerge from the different vehicles, operating conditions and populations tested, as will be discussed further in the limitations section. Another explanation for the differerences originates from the types of variables examined. In Chapter 5, the UTAUT2 was applied, while in Chapter 7 the UTAUT was combined with the DIT constructs trialability and compatibility, trust, and automated vehicle sharing. Hence, different variables interacted as predictors of automated vehicle acceptance, producing different effects on the outcome variable.

The review-based study in Chapter 6 resulted in the development of a multi-level model on automated vehicle acceptance, called MAVA, which introduces the notion of a procedural view of automated vehicle acceptance. Thereby, it establishes the temporal importance of the acceptance factors. MAVA revealed the prevalence of the acceptance factors on the basis of the 124 studies, including the studies presented in Chapters 2 to 5, that formed its basis. 6% of the studies investigated the exposure of individuals to automated vehicles (i.e., knowledge & experience), 22% of the studies investigated domain-specific factors (i.e., performance and effort expectancy, safety, reliability, and security, service and vehicle characteristics, 4% symbolic-affective factors (i.e., hedonic motivation, social influence), and 12% moral-normative factors (i.e., perceived benefits and risks). Factors related to a person's socio-demographic profile, travel behaviour, and personality were investigated by 28%, 15% and 14% of the studies, respectively. The number of times the factor was investigated across the studies could be seen as an indicator of its importance as an acceptance factor. A similar reasoning was adopted in the interview study in Chapter 4 where the number of times a topic was mentioned by our study respondents was interpreted as follows: *„We assumed that the more respondents spoke on a particular subcategory, the greater the importance of this subcategory as a determinant of the acceptance of automated shuttles."* On the other hand, it can be argued that the relationship between the frequency with which a given acceptance factor is investigated and its strength as predictor of automated vehicle acceptance is not linear. For example, while our study in Chapter 6 revealed that socio-demographics were investigated relatively frequently, Chapters 2 and 3 have shown that correlations between socio-demographics and general acceptance scores were small (< 0.20). The number of factors to be investigated in questionnaires is inherently limited. Their combined effect on the behavioral intention to use automated vehicles still has to be established. We propose that future research deploys multivariate analysis techniques to examine the combined effect of the factors influencing the intention to use automated vehicles identified across studies in a single study (see Gold, Happee, & Bengler, 2018).

9.3. To what extent are the factors predicting acceptance interrelated?

The Principal Component Analysis applied in Chapter 2 revealed relations between the components thrill seeking, wanting to be in control manually, supporting a car-free environment, and being comfortable with technology. The PCA in Chapter 3 revealed positive bivariate correlations between the three components shuttle and service characteristics, the effectiveness of the automated vehicle in comparison to respondents' existing transport, and the intention to use automated vehicles.

The Principal Component Analysis assumes that we do not have a hypothesis about the number of components and their underlying items. As we obtained knowledge about the components and their relations via the Principal Component Analysis in Chapters 2 and 3, a confirmatory factor analysis was performed in Chapters 5 and 7 to thoroughly confirm the relations between the latent constructs and their underlying observed variables (i.e., questionnaire items). In Chapters 5 and 7, structural equation modeling was performed to examine the structural path relations between the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Diffusion of Innovation Technology (DIT) constructs. The interrelationships between the UTAUT predictor constructs performance and effort expectancy, hedonic motivation, social influence and facilitating conditions were investigated. Chapter 5 has shown positive effects of effort expectancy and social influence on performance expectancy, suggesting that in order to increase the perceived usefulness of automated vehicles, the ease of automated vehicle use has to be enhanced and automated vehicles promoted in the social networks of individuals. The positive effects of facilitating conditions and hedonic motivation on effort expectancy imply that in order to increase the ease of use of automated vehicles, facilitating conditions supporting the use of automated vehicles have to exist, and taking a ride in an automated vehicle has to be pleasurable. The positive effects of facilitating conditions and social influence on hedonic motivation imply that in order to increase the pleasure of being driven (i.e., hedonic motivation), there should be facilitating conditions supporting the use of automated vehicles, as well as people in the individual's social network promoting the use of automated vehicles. The positive effects of social influence on facilitating conditions imply that promoting automated vehicles in the individual's social network can promote the individual's belief to be in possession of the necessary resources to use automated vehicles.

In the questionnaire study in Chapter 7 the interrelationships between the UTAUT constructs performance and effort expectancy, social influence, and facilitating conditions and the Diffusion of Innovation Theory (DIT) constructs compatibility and trialability as well as trust and automated vehicle sharing were examined. It was shown that the effect of performance expectancy and social influence disappears when compatibility was entered to the model. This points to some level of redundancy among performance expectancy, social influence and compatibility. As compatibility and automated vehicle sharing were the predictors of automated vehicle acceptance, substituting performance expectancy, future research could assess the similarity between compatibility and performance expectancy, and examine the conditions under which the effect of performance expectancy on behavioral intention diminishes when it is considered together with compatibility.

Compatibility was the strongest predictor of performance expectancy. This implies that individuals who believe that automated vehicles are compatible with their existing mobility needs and routines are more likely to consider automated vehicles useful. Social influence was the second-strongest predictor of performance expectancy. This implies that individuals who believe that important others in their social network appreciate their use of automated vehicles are more likely to consider automated vehicles useful. Facilitating conditions was the strongest predictor of effort expectancy. This finding shows that individuals who believe to be in possession of the necessary physical resources are more likely to consider automated vehicles easy to use. The provision of infrastructure supporting the use of automated vehicles could promote automated vehicle acceptance. Trust was the strongest predictor and trialability second-strongest predictor of compatibility, respectively. This finding shows that individuals who trust automated vehicles and appreciate the importance of trials prior to adoption are more likely to consider automated vehicles compatible with their existing mobility needs and routines. Social influence was a predictor of trust, implying that an individuals' reliance on the social network promotes trust in automated vehicles. Social influence also predicted the willingness to share the automated vehicle with strangers and trialability, implying that individuals who rely on their social network are more likely to share automated vehicles with strangers, and are more likely to appreciate trialing automated vehicles before adoption. Trust was the strongest and automated vehicle sharing the second-strongest predictor of facilitating conditions. This suggests that individuals with higher levels of trust in automated vehicles and the willingness to share automated vehicles with strangers are more likely to believe they are in possession of the necessary resources to use automated vehicles.

9.4. Redundancy among study variables

In Chapter 3 significant positive correlations were found between the three components intention to use, shuttle and service characteristics, and shuttle effectiveness in comparison to respondents' existing travel. In Chapter 5 a relatively strong correlation was found between effort expectancy and facilitating conditions, while Chapter 7 identified a relatively strong correlation between performance expectancy and compatibility. These findings point to the existence of redundancy among the constructs that originate from the interrelations between the constructs. This implies that whether a variable has significant effects on the outcome variable depends on the multivariate context (i.e., number and types of variables) in which the predictor variable is considered. Note that the thesis defines *multivariate* as all statistical techniques that simultaneously analyze more than two variables (Hair et al., 2014). One of the objectives of structural equation modeling is to improve the predictive power of the predictors. When variables lose their predictive power when they are considered together with other variables (i.e., they become insignificant), this means that these variables are not needed to produce the optimal prediction of the outcome variable. This, however, does not mean that they are less important or have less impact but that their effect on the outcome variable is already represented by the other predictor variables with which they are related (Hair et al., 2014). As the constructs are conceptually very similar, this finding is not surprising and to some extent even expected as a similar wording of questionnaire items induces respondents to give similar ratings as the discrimination between the constructs is difficult. A practical implication could be to merge the constructs that are conceptually very similar and omit the items that are redundant. The advantage would be that a more economic measure could be deployed while preventing the loss of valuable information. Whether and under what circumstances these variables can then be neglected has to be carefully determined by the researchers. The researcher has to critically ask the question as to which reality should be presented? The bivariate reality in which the predictor variable has a significant relationship with the outcome variable, or the multivariable reality in which the predictor variable loses its relation with the outcome variable (Hair et al., 2014)? Real-world processes are inherently complex and often multi- rather than two-dimensional. For this reason, researchers should strive to model research phenomena in a way that permits the examination of more complicated relations to provide a more complete and better representation of reality (Gefen, Straub, & Boudreau, 2000). This discussion involves the trade-off between model parsimony versus comprehensiveness. Citing the study of Whetten (1989) on model comprehensiveness versus parsimony, Venkatesh and Bala (2008) posit that comprehensive ensures that the model includes all relevant factors, while the goal of parsimony is to delete factors that contribute little to understanding the research phenomenon.

9.5. What is the process leading to automated vehicle acceptance?

MAVA introduces the notion of a procedural view of automated vehicle acceptance. The procedural view on acceptance implies that the process leading to acceptance (or rejection) is divided into four stages, ranging from the exposure of the individual to automated vehicles in stage 1, the formation of favourable or unfavourable attitudes towards automated vehicles in stage 2, making the decision to adopt or reject automated vehicles in stage 3, to the implementation of automated vehicles into practice in stage 4. The procedural view on automated vehicle acceptance is rooted in Maslow's (1954) hierarchy of human needs and assumes that individuals will first try to realize the fulfilment of basic and fundamental domain-specific aspects of automated vehicles (e.g., safety & comfort) before they aim for the realisation of higher-level symbolic-affective (e.g., pleasure) and moral-normative aspects (e.g., environmental friendliness) of automated vehicles. MAVA is the first process-oriented model to predict automated vehicle acceptance to the best of the author's knowledge. It represents a comprehensive model on automated vehicle acceptance and does not strive to be parsimonious (Nordhoff, Kyriakidis et al., 2019). A model can further be understood as a conceptual or mathematical model (Walker et al., 2003). MAVA represents a conceptual formulation of the acceptance process and the factors that constitute the process. It can be the basis for the formulation of a mathematical model in which the relations among the various factors as predictors of the outcome variable are expressed as functions. Researchers and practitioners could use MAVA as basline model and conduct qualitative interviews or focus groups in order to identify those factors that are found to be relevant predictors of automated vehicle acceptance in their context. In a second step, the role of these factors could then be validated using a questionnaire study.

9.6. To what extent does automated vehicle acceptance differ across groups and countries?

In addition to examining the relations between the acceptance factors, the differences in automated vehicle acceptance across groups and countries were also investigated. As indicated in the questionnaire study in Chapter 2, the effects of socio-demographics on the intention to use automated vehicles were small. In Chapter 3, it was found that older respondents expressed a higher intention to use automated vehicles. At the same time, older respondents found the shuttle less effective than their existing travel. There were no substantial gender differences between the three principal component analysis scores. MAVA, which provides a synthesis of acceptance research on automated vehicles in Chapter 6, has revealed that age and gender tend to have small effects on acceptance constructs or disappear when considered in a multivariate context. In Chapter 7, the effects of age and gender on the behavioral intention to use automated vehicles in public were insignificant. The negative correlation between employment on the EUREF campus and shuttle effectiveness indicates that people working on the EUREF campus consider the automated shuttle to be less effective compared to their existing form of travel. Chapter 2 reveals that individuals from higher-income countries were less accepting of automated vehicles in public transport than individuals from lower-GDP countries. In Chapter 5, it was found that car users are less inclined to use automated vehicles in public transport. Technology savviness was a positive predictor of facilitating conditions, and social influence, and a negative predictor of performance expectancy. This suggests that tech-savvy individuals are more likely to consider themselves capable to use automated vehicles, and believe that important people in their social network appreciate their use of automated vehicles. At the same time, they are less likely to consider automated vehicles in public transport useful. Chapter 5 further revealed that the relationship between social influence and facilitating conditions was moderated by technology savviness, implying that for tech-savvy individuals the appreciation of automated vehicles in their social network has a weaker influence on their self-perceived capabilities to use automated vehicles.

9.7. What are the safety perceptions, envisioned interactions and communication with automated vehicles of passengers of automated vehicles?

In the accompanied test ride study in Chapter 8, respondents attributed their positive perceptions of safety to the low speed, dynamic object and event identification, longitudinal and lateral control, passive driving behaviour, and the operation of the automated vehicle in a controlled environment. Respondents were allowed to press the emergency button inside the vehicle, putting it on 28 out of 61 rides to test. They indicated that they worried more about the safety of road users outside the vehicle than about their personal safety as passengers inside the automated vehicle. Safety concerns related to a lack of knowledge on how the automated vehicle perceives and reacts to road users in the external environment.

The study further revealed that respondents expected to be more cautious in crossing the road before an automated vehicle due to the lack of eye contact with the human driver and lack of trust in the behavior of the automated vehicle. They also indicated that they would rely on the movements of the automated vehicle as communication cue in the crossing situation. Respondents also expressed the need to understand how the automated vehicle interprets and reacts to the outside environment, and preferred to receive information about travel and the current and future maneuvers via internal Human Machine Interfaces (iHMIs). The ringing of the automated vehicle that is set off when the vehicle starts to move or moves around a corner received a mixed evaluation by respondents who considered it both useful and annoying.

9.8. Limitations and directions for further research

The results that were obtained in the thesis have to be interpreted with regards to a number of limitations, which, in turn, provide valuable avenues for future research. The limitations can be seen in relation to the accomplishments of the thesis. The thesis is one of the first research projects on automated vehicle acceptance that is based on an extensive set of real vehicle experience. At the same time, in the studies presented, respondents experienced the automated vehicle for a limited amount of time, up to 15 minutes per ride in Chapters 3–5 and 7, and around 37 minutes per ride in Chapter 8. Scientific scholars should investigate the development of automated vehicle acceptance over time. Practitioners should develop strategies to investigate how automated vehicles could form an integral part of the daily mobility trips of respondents, which may be the basis for the development of stable and robust attitudes. In Chapter 7, it was also found that the attitudes of respondents did not change after the ride with the automated vehicle. Hence, it could be argued that exposure to automated vehicles is not a necessary but sufficient condition for respondents to form stable attitudes towards automated vehicles as they can draw to analogic technologies that are already a part of their lives such as trains, busses or airplanes. Note that common public transport modes could also be regarded as driverless, or without human supervision, as the presence of the human driver is often not obvious. In that sense, it could be assessed whether virtual reality technologies that expose individuals to automated vehicles could compensate for real vehicle experience, but it should be realized that virtual reality will not recreate functional transport, and is thereby less suitable to analyse perceived transport utility.

Second, the studies presented in Chapters 3–5 and 7–8 were performed in trial-based rather than naturalistic settings. In all cases a safety steward was present, and the drives were not part of functional transport. Speeds were limited, and routes were constrained. Despite significant progress – e.g., reported crash involvement rates of the Google cars are lower than those of manually-driven passenger vehicles (Teoh & Kidd, 2017) – the performance of automated vehicles does not yet parallel the performance of human drivers (Aeberhard et al., 2015). Automated vehicles that correspond to SAE Level 5 automation have not been commercialized yet. The automated vehicles that are used in the context of research and development projects operate at SAE Level 4 automation in restricted operational design domains (ODDs) in less complex environments at low speeds, and under supervision either onboard or in an external control room (Fridman, 2019; Teoh & Kidd, 2017; Van Brummelen et al., 2018). One possible explanation for this is that many of the automated vehicles rely on a priori mapping methods that consist of pre-driving specific roads to collect detailed sensor data such as 3D images and GPS information. These data are then compared to the sensor data that automated vehicles generate while driving the roads in automated mode. While this method is effective in environments that do not change frequently, it limits the ability of automated vehicles to adapt and react to new situations such as construction zones, potholes and stoplights (Van Brummelen et al., 2018). A second explanation is that the perception software of automated vehicles is less suitable for the identification of incorrect or unexpected corner-case behaviors whose identification currently rests on the manual collection of labeled data that can be easily missed (Tian et al., 2018). The limited operation of the automated vehicles experienced by respondents in this thesis certainly affects their opinions towards automated vehicles. Respondents may overestimate their positivity towards automated vehicles as they have not experienced the "driverless" condition that the operation of fully automated vehicles necessarily entails. We recommend future research to perform studies in more realistic conditions that resemble the complexity and dynamism of conventional transport. Pilots that implement automated vehicles can also adopt the "hidden steward concept" that Chapter 8 applied to simulate a more realistic "driverless automated vehicle experience". Respondents should also be sharing the vehicle with fellow travelers to simulate a real public transport scenario. At the same time, it can also be argued that the attitudes of respondents towards driverless transport were positive *despite* the limited performance of the automated vehicles they experienced. A possible explanation is their level of technological enthusiasm that is not representative of the general population. As technology enthusiasts, they may be more *forgiving* of technological underperformance. Also cognitive dissonance effects and social desirability effects can't be ruled out (Nordhoff et al., 2018).

Third, the respondents that were surveyed throughout the thesis are not fully representative of the general population. Our respondents are more likely to be younger, male, more highly-educated and have a higher technology savviness than members of the general population. This implies that the attitudes that were obtained in the thesis are not fully representative of the general population and only apply to a smaller and more selective part of the population that can be understood as technological first movers. This is unfortunate considering that the Sceptics and Undecided (i.e., Early and Late Majority) represent 16% and 68% of the general population, respectively, in comparison to 16% of the Enthusiasts (i.e., Early Adopters/Innovators) (Rogers, 1995), thus promising a huge market potential. A limited understanding about the non-adopter phenomenon has been acknowledged in the technology acceptance management domain before. In fact, a lack of knowledge about the systemic differences between user groups that differ in their acceptance propensity of new technologies has contributed to the failure of technologies (Brown & Venkatesh, 2003). The knowledge obtained on the attitudes of the Sceptics and Undecided can contribute to the identification of the barriers of automated vehicle acceptance and inform the development of user-group specific strategies and appeals, facilitating a wide-scale adoption of automated vehicles (Laroche, Bergeron, & Barbaro-Forleo, 2001; Pettigrew et al., 2019; Sick Nielsen & Haustein, 2018). We recommend future research to use more representative, age and gender-balanced samples that include individuals with a more neutral and skeptical position towards automated vehicles in public transport.

Fourth, in the studies presented in Chapters 2–8, self-reported measures were used to operationalize the factors impacting automated vehicle acceptance and the acceptance construct itself. Research has pointed to the differences between self-reported and actual behaviors (Junco, 2013). Self-reported measures are inherently subjective and thus sensitive to individual differences, which leads to measurement error and biases in the estimation of the factors predicting the outcome variable (Bound, 1991). Brookhuis and De Waard (2002) advocate the use of a combination of both objective and subjective data. We recommend future research to use more objective vehicle (e.g., speed, braking behavior) and actual usage data (e.g., intensity and scope of AV usage), and link these to the self-reports. The collection of physiological data (e.g., heart rate variability, skin conductance, eye movements) (De Winter et al., 2014) as measures of the physical and mental state of the individual to assess its influence on automated vehicle acceptance is advocated. Future research could also examine whether the number of times respondents press the emergency button could serve as a valid objective indicator of perceived safety, trust or comfort (see Chapter 8).

Fifth, the correlational nature of the relationships between the variables under study was investigated. Within each study, all participants experienced the same automated vehicle system, which enabled the explanation of variance within a population. These findings, however, do not establish the causal nature of the relationships. Establishing causation requires showing association, temporal precedence, and isolation. First, variables have to be correlated in the sense that it can be clearly established that when the cause (i.e., independent variable) happens, the effect (i.e., dependent variable) happens too. Second, the cause has to occur before the effect, thus establishing a clear temporal sequence of the cause preceding the effect. Third, the effect can’t occur without the presence of the cause, thus ruling out that the effect is due to some other factors and not to the specific cause that is needed to produce the effect (Gefen et al., 2000; Hair et al., 2014). We encourage future research to perform pre-and post-measurement tests before, during and after the exposure to automated vehicles. Experimental studies, varying the driverless public transport system and its service level could also be performed to better disentangle the causes from the effects, and investigate the temporal precedence of the processes that underlie automated vehicle acceptance.

Sixth, the present thesis investigated the *intention to use* rather than the *actual use* of automated vehicles given that automated vehicles only exist in a prototype form and are not available for daily use as an option in public transport. The gap between intention to use and actual use of automated vehicles is well-known (Davis, 1993; Godin, Conner & Sheeran, 2005; Van Hooft et al., 2005). Thus, it is not known to what extent the attitudes towards automated vehicles that were captured in the present thesis before commercialization reflect the attitudes towards automated vehicles after their implementation (Davis, 1993; Godin, Conner, & Sheeran, 2005). Future research should assess the extent to which the intention to use automated vehicles can be used as robust proxy to predict the actual use of automated vehicles, and which measures could be introduced to minimize the gap between behavioral intention and actual behavior.

Seventh, the present thesis deployed limited types of multivariate analyses (i.e., principal component analysis, structural equation modeling). Stated preference and stated choice experiments that ask respondents to indicate their preferences among a set of combinations of attributes of services or products or to choose one of the combinations of attributes, respectively (Hensher, 1993), were not performed. Preference/choice experiments enable the examination of the calculations of risks/costs and benefits and thus the trade-offs individuals make across different attributes of a service or product (Hess, Hensher, & Daly, 2012). Preference/choice experiments have also been applied to investigate individuals' preferences towards automated vehicles (Daziano, Sarrias, & Leard, 2017; Haboucha, Ishaq, & Shiftan, 2017; Krueger, Rashidi, & Rose, 2016; Winter et al., 2016; Winter et al., 2019). We recommend future research to integrate structural equation and discrete choice modeling to combine the strengths of both worlds into one model: Modeling the relations between latent psychological constructs, and the trade-offs that individuals make across a number of varying attributes (Ashok, Dillon, & Yuan, 2002; Potoglou, Palacios, & Feijóo, 2015; Temme, Paulssen, & Dannewald, 2008).

9.9. Application of findings

Automated vehicles in public transport can substantially contribute to the attractiveness and efficiency of public transport. As these vehicles feed public transport on the first and last end of a public transport trip and can be ordered on-demand, they can provide a flexible door-to-door transport service around the clock, and are more affordable due to decreases in labor costs (Shen, Zhang, & Zhao, 2018). As a hybrid form of individual-public transport, automated vehicles in public transport can enhance the inter-modality and individualization of public transport due to smaller-sized vehicles (Fraedrich, Beiker, & Lenz, 2015; Shen et al., 2018). Given the large investment in the development of automated vehicles at stake, forecasting the acceptance of automated vehicles in public transport is desirable (Davis, 1993; Gould, Boies, & Lewis, 1991; Rosson, Maass, & Kellogg, 1987). The knowledge obtained by the present thesis could be used by designers and operators to enhance automated vehicle acceptance. It could be used early in the design process, for example when a first prototype is built, to reduce the risk of rejection and increase the chance of automated vehicle acceptance by screening, prioritizing and refining ideas. One way of how could this could be is to let representative users interact with the vehicle, capture both quantitative and qualitative responses to the prototype, and refine the prototype accordingly (Davis, 1993).

9.10. Final conclusions

The present thesis investigated the acceptance of automated vehicles in public transport using both quantitative and qualitative research methods. The thesis has revealed that the respondents were positive towards the idea of using automated vehicles in public transport. However, they considered current automated vehicles less effective in comparison to their existing transport, and were disappointed by their low speed and limited functionality. Their overly positive and idealized expectations, which do not match the actual technical capabilities of the automated vehicle, have been nurtured by the media. This points to a discrepancy between idealized and actual acceptance (Chapters 3–4).

Socio-demographic factors such as age and gender were weak predictors of automated vehicle acceptance. Individuals from lower GDP-countries are more accepting of automated vehicles in public transport than individuals from higher-GDP countries (Chapter 2). The most important predictors of automated vehicle acceptance are domain-specific factors (i.e., performance and effort expectancy, facilitating conditions, safety, service and vehicle characteristics, compatibility), followed by symbolic-affective (i.e., social influence, hedonic motivation), and moral-normative factors (i.e., perceived risks and benefits). These factors are the basis of MAVA, the multi-level model on automated vehicle acceptance, which originated from the present thesis on the basis of 124 empirical studies on automated vehicle acceptance. MAVA further describes the process leading to automated vehicle acceptance that starts with the exposure to automated vehicles, which is then followed by the domain-specific, symbolic-affective, and moral-normative system evaluation. MAVA further posits that factors at the micro-level (i.e., socio-demographics, travel behavior, personality) influence the factors at the meso-level, i.e., factors that constitute the acceptance process (Chapter 6).

The acceptance factors are interrelated, creating redundancy among the acceptance factors. This is demonstrated by the development of a 'general acceptance component' consisting of the sub-factors pertaining to the usefulness of driverless vehicles, intention to use, ease of use, pleasure, trust in driverless vehicles, knowledge and mobility-related developments (Chapter 2). The interrelationships between the acceptance factors in Chapters 5 and 7 enables the identification of the determinants indirectly influencing automated vehicle acceptance. This knowledge can inform the development of strategies and policies to promote automated vehicle acceptance. The thesis also examined the perceptions of safety, envisioned interactions and communication of passengers of automated vehicles. Respondents attributed their positive perceptions of safety to the behavior of the automated vehicle and the limited-scope environment in which the vehicle operated, their familiarity with automated vehicles, and whether they were passengers inside or users of road users outside automated vehicles. Respondents expected that their behavior will change with automated vehicles, preferring information about how the automated vehicle perceives and reacts to the environment.

9.11. References

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CURRICULUM VITAE

Sina Nordhoff was born in Ostercappeln in Germany on September 05th, 1986. After spending her early life in a small village, named Hunteburg, Sina moved to Münster after finishing high school to study European Studies at the University of Twente in the Netherlands. After obtaining her Bsc. degree in European Studies, she did a double-master degree in Innovation Management & Entrepreneurship and Business Administration at the University of Twente and the Technical University of Berlin. During her studies, Sina worked at the Research Group ‚Society & Technology‘ of the Daimler AG in Berlin where she has become familiar with innovative mobility concepts such as carsharing and automated driving.

After obtaining her Msc., Sina started her PhD on the user acceptance of automated vehicles in public transport at the Innovation Centre of Mobility & Societal Change in Berlin and the Delft University of Technology in the Netherlands. During her PhD, she also worked with scholars from Leeds under the supervision of Prof. Dr. Natasha Merat on the interaction and communication between automated vehicles and the external traffic environment. Since January 2019, she is working on the L3Pilot project, analysing data from the L3Pilot User Acceptance Survey. Since August 2019, she is leading the L3Pilot User Acceptance Survey at the EICT GmbH.

Chapter	**Publication Details**	**Status**
Chapter 2	Nordhoff, S., De Winter, J., Kyriakidis, M., Van Arem, B., & Happee, R. (2018). Acceptance of driverless vehicles: Results from a large cross-national questionnaire study. *Journal of Advanced Transportation*, Article ID 5382192, 22 pages.	*Published*
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Chapter 4	Nordhoff, S., De Winter, J., Payre, W., Van Arem, B., & Happee, R. (2019). What Impressions Do Users Have after a Ride in an Automated Shuttle? An Interview Study. *Transportation Research Part F: Traffic Psychology and Behavior, 63, 252–269.*	*Published*
Chapter 5	Nordhoff, S., Madigan, R., Van Arem, B., Merat, N., & Happee, R. (under review). Structural equation modeling discloses interrelationships between predictors of automated vehicle acceptance.	*Under review*
Chapter 6	Nordhoff, S., Kyriakidis, M., Van Arem, B., & Happee, R. (2019). A Multi-Level Model on Automated Vehicle Acceptance (MAVA): A Review-Based Study. *Theoretical Issues in Ergonomics Science, 20, 682–710.*	*Published*
Chapter 7	Nordhoff, S., Malmsten Lundgren, V., Van Arem, B., & Happee, R. (prepared for submission). A structural equation modelling approach for acceptance of driverless automated vehicles based on constructs from the Unified Theory of Acceptance of Use of Technology and the Diffusion of Innovation Theory.	*Under review*
Chapter 8	Nordhoff, S., Stapel, J., Van Arem, B., & Happee, R. (under review). Passenger opinions of interactions with an automated vehicle: An accompanied test ride study.	*Under review*

Additional Publications	**Status**
Nordhoff, S., Louw, T., Innamaa, S., Lehtonen, E., Beuster, A., Torrao, G., Björvatn, A., Kessel, T., Happee, R., Malin, F., & Merat, N. (prepared for submission). Using the UTAUT2 model to explain public acceptance of conditionally automated (L3) cars: A representative questionnaire study among 8,144 car drivers from seven European countries.	*Under review*
Madigan, R., Nordhoff, S., Fox, C., Ezzati Amini, R., Louw, T., Wilbrink, M., Schieben, A., & Merat, N. (2019). Understanding interactions between Automated Road Transport Systems and other road users: A video analysis. *Transportation Research Part F: Traffic Psychology and Behavior, 66, 196–*213.	*Published*
Nordhoff, S., Van Arem, B., & Happee, R. (2016). A conceptual model to explain, predict, and improve user acceptance of driverless 4P vehicles. *Transportation Research Record: Journal of the Transportation Research Board, 2602*, 60–67.	*Published*

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