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The acceptance of conditionally automated cars from the perspective of different road user groups

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The foreseeable advent of conditionally automated cars (CACs) at SAE Level 3 opens a range of opportunities along with numerous questions that must be addressed to safely adopt this new vehicle technology. While public acceptance and the acceptance of potential users have already been intensively researched, this study investigates the acceptance of CACs from the point of view of different road user groups, such as pedestrians, cyclists and riders of powered two-wheelers as so-called vulnerable road users (VRUs), as well as the drivers of conventional cars. The study measures a priori road user acceptance of CACs using an international population survey that was conducted within the framework of the EU Horizon 2020 funded project 'BRidging gaps for the adoption of

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Automated VEhicles' (BRAVE) in the participating EU-countries France, Germany, Slovenia, Spain and Sweden as well as in Australia and the USA. Including 5,827 respondents, the study findings disclose a rather positive acceptance of CACs from the perspective of different road user groups. However, concerns are also apparent. Results from multivariate analyses indicate that the acceptance of CACs differs between road user groups in that VRUs demonstrated lower acceptance than non-automated car drivers. The role of trust in the new vehicle technology also appears to be significant. Consequently, future developments of CACs should also focus on the communication between automated cars and bystanders (e.g. via external human-machine interfaces) to reduce uncertainties and promote trust.

Keywords: *conditionally automated cars, population survey, road user group-specific acceptance, SAE Level 3, trust, vehicle automation technology.*

1. Introduction

1.1 Technological development and the acceptance of automated vehicle technology

The technological development of automated vehicles is in full swing. Automated vehicles from SAE Level 3 to SAE Level 5, as defined by SAE International, are already in pilot stages or being tested. One distinctive feature of this development is that automation from SAE Level 3 onwards exceeds the limit that drivers must always drive during the journey: In certain driving situations, the machine is the executing and responsible system, and the human driver is the fallback system (see SAE International, 2018). Conditionally automated cars (CACs) corresponding with SAE Level 3 will be the first step towards automated driving, representing an upcoming paradigm shift in which the driver hands over the driving task to the car. Though in SAE Level 3 technology, the CAC being in automated mode requires the driver to be vigilant while attending to other tasks such as reading or using a smartphone etc. The driver must be able to take over the wheel and the pedals at any time. By definition, this restriction is only lifted in the later SAE levels 4 or 5. According to experts, the market-wide introduction of cars with SAE Level 3 technology may be expected within a few years, albeit at first in special traffic situations such as on motorways (Eriksson, 2021).

Despite the rapid progress in the last decade, the development of market-ready CACs still faces technological challenges, such as the vigilance on the part of the driver and the critical situation that follows take-over requests from the automated system (Banks et al., 2018; Gold, Happee & Bengler, 2018). Other problems refer to the interaction with other road users that remain to be defined (Straub & Schaefer, 2019). While the introduction of automated driving opens a range of societal opportunities, this technological challenge also creates a multitude of political and social problem areas (Fagnant & Kockelman, 2015; Johnsen et al., 2018; Milakis, van Arem & van Wee, 2017). A successful introduction of CACs, however, requires acceptance by potential users or buyers as well as by society and other road users. Concerns that are not taken seriously or insufficient clarification of regulatory issues could lead to a negative attitude towards CACs, potentially preventing their widespread introduction. Moreover, and along the same lines, researchers consider the widespread acceptance of CACs in society an important prerequisite, as the benefits of automated vehicle technology will only materialise if this technology is widely disseminated (Cunningham & Regan, 2020).

While public acceptance and potential users' approval of the technology have already been intensively researched, the acceptance of automated driving vehicles from the point of view of different road user groups, including vulnerable road users (VRUs) such as cyclists and pedestrians, has received scarce attention to date (Deb et al., 2017; Hulse, Xie & Galea, 2018; Saleh, Hossny & Nahavandi, 2017). Pedestrians, cyclists or riders of powered two-wheelers (PTW riders) have most often been included in the discussion when their communication or interaction with automated vehicles have been the object of research (Merat et al., 2018; Stanciu et al., 2018). However, the research and development of automated vehicle technology might consider the drivers of non-automated vehicles, cyclists and pedestrians as 'bystanders' (Scholtz, 2003) whose acceptance must also be comprehensively taken into account in the event of this impending change in road traffic. In this sense, the technological development of automated vehicles must follow the principle of a Pareto-optimal improvement (Diekmann, 2016). That is, it must be of general interest that the introduction of CACs must not be limited only at increasing the road safety and comfort of the 'drivers' of automated vehicles. At the same time, other road users like pedestrians, cyclists, PTW riders and drivers of non-automated cars must not be placed in a worse position and exposed to any new safety risks or other disadvantages created upon the introduction of automated vehicle technology.

1.2 Study aims

Against that background, the first aim of this study is to investigate the acceptance of CACs from the perspective of the different road user groups. For this purpose, this paper proposes a measurement tool for road user acceptance that captures the a priori acceptance of CACs from the perspective of other road users and explores the mentioned research gap. Subsequently, as a secondary goal, the research examines whether road user groups differ in their a priori acceptance of automatic vehicles with SAE Level 3 technology. In this regard, a special focus will be placed on the acceptance of CACs on the part of VRUs and whether VRUs differ from each other as well as from drivers of manually driven cars.

The study bases its findings on a population survey from the research project 'BRidging gaps for the adoption of Automated VEhicles' (BRAVE), funded by the European Union's Horizon 2020 research and innovation programme (No. 723021). This multidisciplinary research project, including partners from seven countries, evaluated the needs and concerns of all road users affected by the introduction of CACs and sought to encourage technological improvements accordingly.

In this paper, chapter 2 addresses the mentioned research aims by reviewing the status of the existing literature on the acceptance of automated vehicle technology and identifying crucial factors for examining road user groups' acceptance of CACs. Chapter 3 then describes the methods chosen to measure the acceptance of CACs from various road users' perspectives. The survey results thus obtained are analysed in chapter 4. Chapter 5 discusses the study findings, and chapter 6 completes this study with a conclusion.

2. Literature

2.1 Acceptance of automated vehicle technology[5]

A major challenge for measuring the acceptance of automated vehicle technology (i.e. more advanced than SAE Level 2) by users or different road user groups is the lack of automated cars featuring SAE Level 3 and above on the roads. Consequently, measuring the acceptance of CACs in surveys based on objective criteria, observable behaviour or subjective experiences is not currently possible. At present, studies are limited to approximating acceptance through

[5] Although the survey and the presented results explicitly focus on automation at SAE Level 3, the following chapter uses the term 'automated' for SAE Levels 3 to 5 without detailing the specific level.

experiments, simulations or surveys examining the willingness to buy, the attitudes towards automated cars or the intention to use them (Adell, Nilsson & Várhelyi, 2014).[6]

In related research, several theoretical psychological models have been applied to predict the individual behavioural intention to use or buy a CAC as proxies for an a priori acceptance. For example, the Theory of Planned Behaviour (TPB) (Ajzen, 1991) and the Technology Acceptance Model (TAM) (Davis, Bagozzi & Warshaw, 1989) or the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) have been used in research investigating the acceptance of automated vehicles (Kaye et al., 2020; Madigan et al., 2017; Nordhoff et al., 2020). In these theoretical models, acceptance was originally recorded as the observable behaviour concerning the use of the technical artefact. In case of the acceptance of automated cars, any research objectives are limited to measuring behavioural intention. Different factors in these theoretical models facilitate explaining attitudes and behavioural intentions towards automated vehicles, such as perceived usefulness or perceived ease of use of automated vehicles (Choi & Ji, 2015; Zhang et al., 2019; for a review, see also Jing et al., 2020).

Besides these theoretically oriented studies, the body of research regarding the public acceptance of automated vehicles is continuously growing, using respondents' attitudes, behavioural intentions or the willingness to pay or buy to measure this phenomenon (Becker & Axhausen, 2017; Cunningham et al., 2019b; Daziano, Sarrias & Leard, 2017; Gkartzonikas & Gkritza, 2019; Jing et al., 2020; Nordhoff et al., 2019). In general, empirical studies have reported mostly positive attitudes towards the new automated vehicle technologies – or rather, positive intentions to use an automated vehicle. For example, Schoettle and Sivak (2014a) found that 65.8% of their respondents from the USA, UK and Australia expressed at least a slight interest in owning or leasing an SAE Level 4 automated car. Other empirical studies, however, have indicated a certain reluctance towards the adoption of CACs. In the BRAVE population survey, 39.0% of the respondents agreed with the item 'I think I will not use conditionally automated cars when available' and only 33.2% of the respondents expressed their future intention to use a CAC by refusing this item; 27.8% of the respondents stayed neutral (Schrauth et al., 2020). Further empirical results have shown that potential users would pay less for SAE Level 3 automated vehicles than for vehicles featuring SAE Level 4 (Bansal, Kockelman & Singh, 2016; Kyriakidis, Happee & Winter, 2015). Furthermore, acceptance studies often took a country-specific perspective and documented results e.g. for Australia (Cunningham et al., 2019a) or Austria (Wintersberger, Azmat & Kummer, 2019). But there is also a substantial number of studies that conduct multi-country surveys which often report diverging results between the countries (Kaye et al., 2020; Kyriakidis, Happee & Winter, 2015; Nordhoff et al., 2020; Schoettle & Sivak, 2014b).

Research findings also demonstrated that sociodemographic characteristics affect people's attitudes or behavioural intentions toward automated vehicles; for example, males tend to show a higher acceptance of automated vehicles than females (Choi & Ji, 2015; Cunningham et al., 2019a; Hohenberger, Spörrle & Welpe, 2016; Hulse, Xie & Galea, 2018; Kyriakidis, Happee & Winter, 2015; Zhang et al., 2019). Although findings based on age vary or are not statistically significant in multivariate settings, results generally tend to indicate higher acceptance among younger respondents (Bansal, Kockelman & Singh, 2016; Nordhoff et al., 2019; Schoettle & Sivak, 2014a). Furthermore, people living in urban areas apparently display a higher acceptance of automated vehicle technology (Hudson, Orviska & Hunady, 2019; Piao et al., 2016). Findings reflecting individual socioeconomic background are scarce, though some have indicated positive influence of higher education on acceptance (Hudson, Orviska & Hunady, 2019) or of higher income on the willingness to pay for automated technology (Bansal, Kockelmann & Singh, 2016; Kyriakidis, Happee & Winter, 2015). In addition to individual sociodemographic characteristics, individual attitudes toward the use of new technologies also show a positive influence on the acceptance of automated vehicle technology (Deb et al., 2017; Zmud & Sener, 2017) or on the intention to use or

6 For a discussion on a priori acceptance and acceptability, see Adell, Várhelyi, and Nilsson (2014).

buy it (Bansal, Kockelmann & Singh, 2016). In several studies that capture both sociodemographic and attitude-based variables it appears that attitudinal measures outweighed characteristics such as gender or age. Attitude-based measures often demonstrated a stronger correlation with the used measure for the intention to use, the willingness to buy a vehicle with automated technology or acceptance of automated vehicles in multivariate settings (Cunningham et al., 2019b; Kaye et al., 2020; Payre, Cestac & Delhomme, 2014).

Parallel to the research on acceptance of automated vehicle technology, numerous studies have collected insights on concerns, needs and expectations raised by the foreseeable introduction of CACs (König & Neumayr, 2017; Schoettle & Sivak, 2014a). Gkartzonikas and Gkritza (2019) in their meta-study provided a concise overview of extant findings. Among the frequently mentioned benefits leading to increased acceptance of automated vehicles, the authors enumerated improvements in road safety, increased productivity, higher fuel efficiency, lower emissions and cost reductions for fuel, parking or insurance. Additionally, automated technology might provide enhanced mobility for persons with reduced mobility (Piao et al., 2016). On the other hand, research studies have uncovered serious concerns about automated technology, including various aspects of safety issues related to system failures, legal liability or data privacy as well as the cybersecurity of automated vehicles (Gkartzonikas & Gkritza, 2019).

2.2 Trust as a precondition for acceptance

Trust in vehicle technology, which was not explicitly taken into account in the original versions of psychological acceptance models, was later integrated, e.g. in a revised version of the TAM (Ghazizadeh et al., 2012). Nevertheless, researchers regard trust as a vital factor in the acceptance of automated vehicle technology (Hoff & Bashir, 2015; Lee & See, 2004). Lee and See (2004) captured trust as an attitude and a prerequisite for the development of behavioural intentions and actual behaviour, making it an essential issue for measurement in the context of automated vehicle technology. The formation of trust is described as an experience-based variable (Hoff & Bashir, 2015) which can hardly be depicted as such in current research on CACs. Thus, Hoff and Bashir (2015, p. 420) referred to initial trust as 'trust prior to interacting with a system', in contrast to the dynamic learned trust formed via interaction with a system.

Several relevant studies have proven trust being a significant factor in research on the experimental or simulated use of automation technology (Gold et al., 2015; Hergeth et al., 2016; Payre, Cestac & Delhomme, 2016). Other empirical studies have included this dimension in analysing the acceptance of automated cars and verified its importance (Choi & Ji, 2015; Kaur & Rampersad, 2018; Jing et al., 2020; Zhang et al., 2019). Results indicate that higher levels of trust in the automation technology correlate specifically with an increased intention to use automated vehicles or, more generally, with higher acceptance. Likewise, Zmud and Sener (2017) reported a lack of trust as the top reason for a low probability of using automated vehicles.

2.3 Acceptance of other road users

A major part of research to date has examined users' or public acceptance of automated vehicle technology. However, this perspective overlooks the various road users who will be directly affected and forced to interact with automated cars in road traffic. Even though many studies have asserted that automated vehicle technology will increase road safety, for example, by reducing human errors and following traffic rules, researchers also pointed out numerous barriers and concerns about the pending introduction of automated vehicles that refer to users and other road users (Gkartzonikas & Gkritza, 2019; Johnsen et al., 2018; König & Neumayr, 2017).

To date, only a few empirical studies have focused on the perspectives of other road users and examined their attitudes towards automated vehicles (Deb et al., 2017; Penmetsa et al., 2019; Pyrialakou et al., 2020). Deb et al. (2017) conducted a survey to identify pedestrians' receptivity of fully automated vehicles. Their findings indicated a positive correlation between the acceptance of vehicle technology and three identified factors: the safe operation of an automated vehicle, the interaction with an automated car in a crossing situation and the compatibility of an automated vehicle with the existing traffic system. Penmetsa et al. (2019) reported that pedestrians and cyclists who had experienced interactions with automated vehicles on Pittsburgh's public proving ground expressed more positive beliefs regarding their safety than others with no interaction experience. Pyrialakou et al. (2020), in a study involving interactions on a public testing ground in Phoenix-Mesa-Scottsdale, Arizona, found that respondents felt safer driving near an automated vehicle than walking or cycling close to it. In these studies, males showed more positive attitudes towards automated vehicles than females. Moreover, the studies' results partially confirmed the previously mentioned findings relating to age and location from other acceptance studies.

Behavioural studies evaluating the interaction of road users with automated vehicles have additionally pointed to possible adverse reactions of other road users toward automated vehicles on the road. Specifically, road users might exploit the risk-averse and rule-compliant driving style of automated vehicles by taking the right of way or driving aggressively, knowing that the automated vehicle will stop or give way in any case (Camara et al., 2018; Liu et al., 2020; Millard-Ball, 2018).

3. Methodology

3.1 Study design

Data from an international population survey were used to pursue the investigation of the study aims outlined in section 1.2. The survey, which was conducted within the context of the research project BRAVE (Schrauth et al., 2020), took place in the seven countries of the participating project partners (the EU countries France, Germany, Slovenia, Spain and Sweden plus Australia and the USA) and lasted from December 2019 to February 2020. The survey was conducted via computer-assisted web interviews. Participant recruitment for the online survey was carried out using the online access panel from KANTAR Lightspeed. The Ethics Commission of the School of Business, Economics and Society of the University of Erlangen-Nuremberg approved this research project. The survey was performed concurrently in all seven countries in the respective national language, and quotas for gender, age and regions within each of the countries were applied (for more details see Schrauth et al., 2020). In each of the participating countries, 1,000 road users aged 18 and above were interviewed. Of these 7,000 respondents, 392 cases were deleted after data quality checks, leaving 6,608 respondents in the data set of the BRAVE population survey for further analyses.

3.2 Questionnaire

In the BRAVE project, the questionnaire for the population survey was developed according to the results from a preceding literature review (Johnsen et al., 2018) and explorative focus group discussions conducted in four countries – Germany, Slovenia, Spain and Sweden (Kraetsch et al., 2019). The questionnaire's introduction informed the respondents about the concept of SAE Levels as well as the characteristics of vehicles with SAE Level 3 technology and specified that the survey questions throughout referred to CACs featuring SAE Level 3. The questionnaire covered multiple topics and contained questions regarding the acceptance of and trust in CACs as well as concerns and expectations towards the new automated vehicle technology. Furthermore, it included questions exploring respondent's affinity for technology, preferences for external human-machine interfaces (HMIs) and the ethical and legal implications of CACs. The gathered survey data also yielded information on preferences related to the main transportation mode, the mobility behaviour and social demographics of the respondents. The complete questionnaire containing 62 questions and statements to assess can be viewed in the documentation of the openly accessible data (Schrauth et al., 2021).

At the core of the questionnaire, respondents were provided with a description of a predefined traffic situation including a fictitious interaction with a CAC in automated mode. This description varied for the different types of the main transportation mode, including pedestrian traffic (see

Table 1). The respondents were given the traffic situation that corresponded to their previously indicated main transportation mode most frequently used in a working week.[7] This approach allowed exploiting respondents' experiences regarding their main transportation mode in the survey. Furthermore, possible differences between road user groups could be detected. All the presented fictitious traffic situations had in common that they contained a crossing situation in which the respondent – as a pedestrian, cyclist, PTW rider or car driver – would have the right of way over the CAC. Following the description of the road user-specific traffic situation, respondents were asked to document their subjective feelings about their personal road safety in this hypothetical situation, along with their acceptance of and trust in CACs from their point of view.

Table 1. Specified traffic situations for different road user groups

Main mode of transportation	Specified traffic situation
Pedestrian	You are walking in an urban area and want to cross the road at a pedestrian crossing without traffic lights. At the same time, a conditionally automated car (SAE Level 3) approaches the pedestrian crossing. The car is driving in automated mode.
Cyclist	You are riding a bicycle in an urban area and approach a junction without road signs or traffic lights. From the left, a conditionally automated car (SAE Level 3) approaches. The car is driving in automated mode. You have the right of way in this situation.
PTW rider	You are riding a powered two-wheeler in an urban area and approach a junction without road signs or traffic lights. From the left, a conditionally automated car (SAE Level 3) approaches. The car is driving in automated mode. You have the right of way in this situation.
Car driver	You are driving a non-automated car in an urban area and approach a junction without road signs or traffic lights. From the left, a conditionally automated car (SAE Level 3) approaches. The car is driving in automated mode. You have the right of way in this situation.

3.3 Measures

Road user acceptance

Setting up and analysing a measure for the a priori acceptance of CACs from the perspective of other road users was one central aim of this study. As outlined earlier, a fundamental problem in measuring the acceptance of CACs is the non-market ready stage of their technological development and the resulting lack of approval for road traffic. The current measurement of acceptance can only refer to road users' a priori acceptance since the respondents most likely have not had any experience with automated vehicles from SAE Level 3 onwards. Another issue impedes the measurement of non-user's acceptance: While most of the existing research has examined the potential users' acceptance of automated vehicle technology, comparable studies and theoretical concepts for developing and assessing the measurement tool for road user acceptance proposed in this study are hardly available.

The approach chosen in the BRAVE population survey was based on the findings of psychologically oriented user-centred research (Johnsen et al., 2018). Existing research on user acceptance employing simulations or experiments has already identified dimensions that provide explanatory power for predicting user acceptance, such as perceived ease of use, perceived usefulness or the compatibility of (conditionally) automated vehicles (Choi & Ji, 2015; Ghazizadeh et al., 2012; Jing et al., 2020; Zhang et al., 2019). These dimensions were used for an attitude-based

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7 The use of public transport was omitted because users of public transport would not be in direct interaction with the CAC. Instead, respondents were asked to consider the way to or from public transport in indicating their main transportation mode.

measurement of road users' acceptance of CACs (see Table 2). Accordingly, the three items listed in Table 2 were specially (re-)formulated or modified according to the prevailing intention of the population survey. In the questionnaire, these items followed the description of the traffic scenario outlined in section 3.2 and their formulation was individually adapted to reflect the respondents' indicated main mode of transportation so that the specific perspective of a pedestrian, cyclist, PTW rider or driver of a non-automated car was collected. Respondents could state their opinion on a 5-point Likert scale ranging from 1 'I strongly disagree' to 5 'I strongly agree'.

Table 2. Items for the measurement of road user acceptance of CACs and descriptive statistics

Item	Dimension	n	$\bar{x}$	SD	Cronbach's α
As a [pedestrian/cyclist/rider of a PTW/driver], I think conditionally automated cars will be easy to communicate with.	Perceived ease of use *Elaboration based on: Ghazizadeh et al. (2012)*	5,827	3.20	1.05	0.78
As a [pedestrian/cyclist/rider of a PTW/driver], I think that conditionally automated cars will cause problems for me and other road users.[8]	Compatibility *Elaboration based on: Ghazizadeh, Lee, and Boyle (2012)*	5,827	3.15	1.05	
As a [pedestrian/cyclist/rider of a PTW/driver], I think that conditionally automated cars will make roads safer.	Perceived usefulness *Elaboration based on: Ghazizadeh et al. (2012)*	5,827	3.30	1.03	

* Response categories for items on road user acceptance: 1 = 'I strongly disagree', 2 = 'I disagree', 3 = 'I neither agree nor disagree', 4 = 'I agree', 5 = 'I strongly agree'.

* SD = standard deviation

To assess the consistency of the scale, the reliability measure of Cronbach's alpha is used. Cronbach's alpha for the three items was 0.78, which is above the generally agreed lower limit of 0.70 and thus allows further use in one index (Hair et al., 2014). Hence, these three items were used to calculate an additive index representing the a priori road user acceptance of CACs. The index was calculated by adding the values of each of the three items and dividing the sum by the number of items resulting in an index that ranges from 1 to 5 corresponding to the single items. The built index reflects the measurement of an a priori acceptance of CACs from the perspective of road users and forms the central target variable of bi- and multivariate analyses in this study.[9]

General trust in CACs

The measurement of general trust in CACs was carried out with an already existing scale consisting of three items and having proven reliability (Choi & Ji, 2015; Zhang et al., 2019). As with the measure of acceptance, these items cannot depict trust formed by real experiences but can represent the initial trust that road users may place in CACs (Hoff & Bashir, 2015). The formulation of the items has been adapted to the context of CACs. For further use in statistical analyses, the three items were combined into an additive index in the same way as for the road user acceptance before. The reliability analysis for the three items yielded a Cronbach's alpha of 0.89 (see Table 3).

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8 Because of the negative formulation of this item in contrast to the other two items on road user acceptance, the values of this variable were recoded for the calculation of the additive index of the road user acceptance. With the reversed coding, the values of all items now point in the same direction where higher values correspond with more positive attitudes towards CACs.

9 If not otherwise emphasised in the following text, the road user acceptance in this study always refers to an a priori measurement.

Personal innovativeness

Several studies have shown the importance of enthusiasm to use or try out technology, e.g. Deb et al. (2017) identified personal innovativeness as a predictor for the acceptance of automated vehicle technology. Innovativeness describes a personal interest in testing and using new technical devices. In this study, an already existing measurement instrument was used to assess personal innovativeness (Agarwal & Prasad, 1998) that has also been used in Deb et al. (2017). For the questionnaire, three items were selected from the original instrument and slightly modified to fit the research subject. To conduct further statistical analyses, an index was formed out of the three items. Again, the additive index was formed in the same way as the index of the road user acceptance before. Cronbach's alpha for these three items was 0.75 (see Table 3).

Table 3. Items and descriptive statistics for measurement of general trust in CACs and personal innovativeness

Item	n	$\bar{x}$	SD	Cronbach's α
General trust in CACs				
Conditionally automated cars will be dependable.	5,827	3.34	1.02	0.89
Conditionally automated cars will act reliably.	5,827	3.31	1.02	
Overall, I will trust conditionally automated cars.	5,827	3.20	1.12	
Personal innovativeness				
Among my peers, I am usually the first to try out new technologies.	5,827	2.83	1.18	0.75
In general, I am hesitant to try out new technologies.[10]	5,827	2.74	1.16	
I like to experiment with new technologies.	5,827	3.54	1.09	

* Response categories for items on general trust in CACs and personal innovativeness: 1 = 'I strongly disagree', 2 = 'I disagree', 3 = 'I neither agree nor disagree', 4 = 'I agree', 5 = 'I strongly agree'.

Sociodemographics and mobility behaviour

Next to the attitude-based measures, several information on sociodemographics and the mobility behaviour of the road users surveyed are available in the dataset. The survey data entails information on gender and age as well as measures for the educational level, the socioeconomic status and the place of living. The measurement of these latter three variables follows standardized questions from the International Social Survey Programme (ISSP), which ensures international comparability (GESIS Leibniz Institute for the Social Science, 2019). The educational level was measured by the highest educational degree following a slightly modified standardised procedure specified by the ISSP for each country (ISSP Research Group, 2019). The socioeconomic status was depicted with an existing self-placement scale for social positioning within the society. This instrument measured the self-assessment of respondents using a 10-point scale from 1 'Lowest, Bottom' to 10 'Highest, Top'. The respondents' place of living was operationalized using five categories of which the two categories 'village' and 'farm' were combined due to the low number of respondents on farms.

Measures reflecting the mobility behaviour of the road users surveyed were the average frequency of trips on a day from Monday to Friday, the most frequently used mode of transportation for everyday private mobility and the previous experience with advanced driver assistance systems (ADAS) which was measured on a 4-point Likert scale ranging from 1 'Never' to 4 'Often'.

[10] Like in footnote 8, the negative formulation of this item was considered in data analysis by recoding the values of the variable.

3.4 Data analysis
Data analysis was performed in two steps. In the first step, the results of the measurement tool determining road user acceptance were examined with the use of univariate and bivariate analysis methods. The bivariate analysis used a set of independent variables, including gender, age, respondents' country of residence and main transportation mode demonstrating underlying correlations of the variables with the road user acceptance. In the second step, a multivariate analysis was applied, considering the calculated additive index of road user acceptance as the dependent variable. By using a multivariate analysis method, the individual effects of the different determinants can be depicted in isolation while controlling for the chosen set of independent variables. According to the metric level of the dependent variable, a two-step linear regression was carried out. From the 6,608 respondents remaining in the original sample of the BRAVE population survey, some were removed due to missing values mostly caused by item non-response, leaving 5,827 records for the univariate and bivariate as well as for the multivariate analyses.[11] The predictors of age and respondents' socioeconomic status as well as personal innovativeness and general trust in CACs are included as metric variables in the regression analysis. The categorical independent variables of main mode of transportation, place of living, highest educational level, number of trips per day, and experience with ADAS are added to the model in dichotomized form. So is gender, which is also included dichotomously in the calculation. The analytical strategy took into account the location of the respondents in the individual countries to adequately address the multi-level research design of the survey, which had been conducted in seven countries. Thus, the multivariate analysis used one common model for all countries with country-specific clustered standard errors (Bryan & Jenkins, 2016). Data analysis was performed using Stata IC 13.

4. Results

4.1 Demographics and technology-related attributes
In the data set prepared for the data analyses (n = 5,827), 50.0 % female road users remained. On average, the survey participants had an age of $\bar{x}$ = 44.69 years (*standard deviation SD* = 16.44). Regarding the respondents' educational level, the category of educational degrees on tertiary level formed the largest group with 45.2%, participants with upper or post-secondary degrees comprise 39.5%. The lowest proportion was made up by road users with lower or no educational degrees (15.3%). Regarding the self-reported estimation of socioeconomic status, the respondents ranked themselves, on average, somewhat above the middle ($\bar{x}$ = 6.23; *SD* = 1.66).

26.1% of road users in the dataset lived in cities and 23.0% in suburbs. The largest proportion of 31.1% resided in towns and 19.2% of the road users stated that they live in villages or on farms. Regarding the mode of transport used most often for everyday private mobility, car drivers formed the largest (66.9%) and pedestrians the second largest proportion (24.7%); cyclists (6.0%) and motorcyclists (2.4%) were in the minority. The median number of trips per day was $\tilde{x}$ = 3.

Of the road users surveyed, 15.5% had already often used ADAS up to the time of the survey. Furthermore, in the survey 25.2% stated they have sometimes used ADAS and 22.2% stated that they have rarely done so. The share of respondents not having used ADAS was the largest with 37.1%. Regarding the respondents' enthusiasm of dealing with new technologies, the index for personal innovativeness yielded an average of $\bar{x}$ = 3.21 (*SD* = 0.93) and the average general trust in CACs was $\bar{x}$ = 3.28 (*SD* = 0.95).

4.2 Univariate analysis of items regarding road user acceptance
The additive index calculated from the three items introduced in Table 2 yielded an average value of $\bar{x}$ = 3.12 (*SD* = 0.87) on a scale ranging from 1 'I strongly disagree' to 5 'I strongly agree'. The

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11 The results reported below may differ from results presented in Schrauth et al. (2020), as this paper's findings refer to the cases included in the multivariate analysis only.

response frequencies to the three items underlying the formation of road user acceptance are presented in Table 4. 44.7% of the road users in the sample expected easy communication with CACs, remarkably less survey participants (strongly) disagreed with this statement (27.1%). The statement that CACs will make roads safer was (strongly) agreed to by 47.1%. This assessment is contradicted by 23.2% of the road users surveyed. In contrast to the rather positive attitudes before, 39.7% of road users expected problems for themselves and other road users; 30.1% of the respondents, on the opposite, did not expect any problems. The univariate findings suggest a basic acceptance of CACs in which positive agreement exceeds disapproval regarding the communication with the CAC and the expected improvements in road safety. However, the findings simultaneously signal doubts about how the new technology will fit into the current road traffic system.

Table 4. Items and descriptive statistics for measurement of the road user acceptance of CACs

Item	n	I strongly agree	I agree	I neither agree nor disagree	I dis-agree	I strongly disagree
		%				
As a [pedestrian/cyclist/rider of a PTW/driver], I think conditionally automated cars will be easy to communicate with.	5,827	8.4	36.3	28.3	21.3	5.8
As a [pedestrian/cyclist/rider of a PTW/driver], I think that conditionally automated cars will make roads safer.	5,827	10.2	36.9	29.8	18.6	4.6
As a [pedestrian/cyclist/rider of a PTW/driver], I think that conditionally automated cars will cause problems for me and other road users.	5,827	9.5	30.2	30.3	25.6	4.5

4.3 Bivariate analysis of the road user acceptance

For subsequent bivariate analyses, the additive index of the road user acceptance of CACs was used as the dependent variable. A correlation analysis of road users' acceptance and gender using Pearson's product-moment correlation coefficient resulted in a moderate negative correlation ($r = -0.13$, $p < 0.001$). This result suggests that the female road users demonstrated less road user acceptance of CACs than males. A negative correlation also resulted from the bivariate correlation analysis between road user groups' acceptance and age ($r = -0.20$, $p < 0.001$), signalling that acceptance of CACs decreased with advancing age. Categorising age into subgroups as presented in Table 5, furthermore, a non-linear relationship became apparent saying that in particular the oldest age group demonstrates a lower acceptance of CACs.

Road user acceptance differed greatly depending on the respondents' countries of residence (*Kruskal-Wallis H test with* $\chi^2(6) = 220.041$, $p < 0.001$; *Cramer's* $V = 0.10$, $p < 0.001$). Respondents from Spain and Slovenia showed, on average, the highest acceptance of CACs (see Table 5). Meanwhile, respondents from Sweden, Australia and France ranked midfield, and road users from the USA and Germany comparably reported the lowest acceptance of CACs on the street.

The subgroup analysis by the means of transport most frequently used in a working week also demonstrated statistically significant differences (*Kruskal-Wallis H test with* $\chi^2(3) = 21.214$, $p < 0.001$; *Cramer's* $V = 0.06$, $p < 0.01$). Among the road user groups, PTW riders showed the highest acceptance of CACs on the road, followed by car drivers and cyclists (see Table 5). In all countries, pedestrians indicated the lowest acceptance of CACs on the road. That is, motorized road user groups showed higher acceptance of CACs than cyclists and pedestrians.

Table 5. Index of road user acceptance by gender, age, respondents' country of residence and main mode of transportation

Variable	n	x̄	SD
Index of road user acceptance	5,827	3.12	0.87
By gender			
Female	2,913	3.01	0.84
Male	2,914	3.23	0.88
By age (in years)			
Up to 24	521	3.21	0.78
25 to 34	1,473	3.27	0.80
35 to 44	1,330	3.23	0.84
45 to 54	812	3.19	0.87
55 and more	1,691	2.84	0.90
By country			
France	832	3.03	0.79
Germany	866	2.97	0.89
Slovenia	818	3.36	0.78
Spain	853	3.38	0.80
Sweden	817	3.10	0.85
Australia	832	3.06	0.86
USA	809	2.92	0.98
By main mode of transportation			
Pedestrian	1,441	3.03	0.86
Cyclist	350	3.11	0.83
PTW rider	138	3.22	0.66
Car driver	3,898	3.15	0.88

Bivariate analyses with the attitude-based predispositions of general trust in CACs ($\bar{x} = 3.28$, $SD = 0.95$) and personal innovativeness ($\bar{x} = 3.21$, $SD = 0.93$) revealed a strong relationship with the index of road user acceptance. The calculated correlation between road user group acceptance and general trust was $r = 0.71$ ($p < 0.001$). As proposed by the theoretical models, this strong positive correlation highlights the essential role of trust for the acceptance of CACs. The correlation coefficient for the relationship between road user acceptance and personal innovativeness was $r = 0.46$ ($p < 0.001$). Thus, personal interest to experiment with new technologies showed a moderately strong positive correlation with the acceptance of CACs.

4.4 Multivariate analysis of the road user acceptance

This section reports the results of a multivariate two-step linear regression analysis carried out with the index of road user acceptance of CACs as the dependent variable. In the first step of the multivariate analysis, the relationships between the dependent variable and variables covering sociodemographic characteristics such as gender and age[12], the main transportation mode, the frequency of daily trips and experience with ADAS were estimated (see Table 6). Likewise, the impact of the location of residence, the socioeconomic status and the highest educational level of the respondents on the specific acceptance of CACs was examined in the analysis since the extant research results have emphasised their relevance. The second step additionally included the variables of attitude-based predispositions 'personal innovativeness' and 'general trust in CACs' in Model 2.

[12] In the regression, age was included as a metric variable. The addition of age squared addressed the curvilinear relationship indicated in the preceding bivariate analyses (see Table 5).

Table 6. Linear regression models with road user acceptance of CACs as the dependent variable; use of robust standard errors, clustered by country (i.e. standard errors (SE), confidence intervals (CI))

Variable	Model 1 Unstandardised Coefficient	Model 1 Robust SE CI	Model 2 Unstandardised Coefficient	Model 2 Robust SE CI
Female (ref.: male)	-0.21***	0.03 -0.29, -0.13	-0.05*	0.02 -0.09, -0.00
Age	0.01	0.01 -0.01, 0.03	0.01	0.00 -0.00, 0.02
Age²	-0.00	0.00 -0.00, 0.00	-0.00	0.00 -0.00, 0.00
Main mode of transportation (ref.: car driver)				
Pedestrian	-0.09*	0.03 -0.17, -0.01	-0.10**	0.02 -0.15, -0.05
Cyclist	-0.14*	0.05 -0.25, -0.02	-0.14*	0.04 -0.24, -0.05
PTW rider	-0.07	0.08 -0.26, 0.13	-0.21*	0.07 -0.37, -0.05
Location of residence (ref.: farm/village)				
Town	0.07	0.05 -0.05, 0.20	0.02	0.04 -0.07, 0.12
Suburb	0.05	0.04 -0.06, 0.15	-0.03	0.03 -0.11, 0.04
City	0.16	0.07 -0.01, 0.34	-0.01	0.03 -0.08, 0.07
Highest level of education (ref.: low educational level)				
Middle educational level	-0.02	0.04 -0.13, 0.08	-0.01	0.02 -0.07, 0.05
High educational level	-0.02	0.03 -0.09, 0.06	-0.03	0.02 -0.08, 0.02
Social positioning	0.04**	0.01 0.02, 0.07	-0.01	0.01 -0.02, 0.01
Average number of trips per day (ref.: none or one trip per day)				
Two trips per day	0.09	0.07 -0.07, 0.26	0.03	0.05 -0.09, 0.14
Three to four trips per day	0.14	0.06 -0.01, 0.28	0.03	0.04 -0.08, 0.13
Five to eight trips per day	0.13*	0.05 0.010, 0.26	0.05	0.04 -0.05, 0.15
Nine and more trips per day	0.13	0.07 -0.05, 0.31	0.04	0.06 -0.10, 0.18
Experience with ADAS (ref.: never)				
Rarely	0.22***	0.02 0.17, 0.28	0.01	0.03 -0.06, 0.08
Sometimes	0.33***	0.32 0.26, 0.41	0.03	0.02 0.00, 0.07
Often	0.41**	0.06 0.26, 0.56	0.03	0.03 -0.04, 0.09
Personal innovativeness			0.17***	0.01 0.15, 0.20
General trust in CACs			0.57***	0.02 0.52, 0.63

Table 6. (continued)

Variable	Model 1 Unstandardised Coefficient	Robust SE CI	Model 2 Unstandardised Coefficient	Robust SE CI
Constant	2.61***	0.16 2.21, 3.00	0.53*	0.17 0.12, 0.94
Number of observations	5,827		5,827	
Adjusted R-square	0.12		0.54	

* Significance level: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6 presents the results of the linear regression analysis, including 5,827 respondents. Model 1 achieved an explanatory power of *Adjusted* $R^2 = 0.12$ indicating an only weak explanatory power. Statistically significant predictors in this model were the road users' gender and belonging to the vulnerable road user groups of pedestrians and cyclists – each in contrast to the drivers of conventional cars. Despite the significance in bivariate analysis, age and age squared did not yield a significant prediction in the regression model. Further variables of statistical relevance were the self-reported social positioning, a certain frequency of trips per day (five to eight) and previous experience with ADAS. These three variables all exerted a positive influence on road user acceptance in the first regression model. In other words, a higher self-placement on the ten-point-scale of the social positioning towards upper social strata, a higher number of trips per day, and more experience with ADAS significantly correlated with higher acceptance of CACs. In contrast, being female lowered road user acceptance as well as being mainly a pedestrian or a cyclist in reference to driving a conventional car. Other sociodemographic factors such as age or educational level did not yield a statistically significant relationship in the regression model.

The introduction of the attitude-based predispositions 'personal innovativeness' and 'general trust in CACs' in Model 2 remarkably increased the predictive power of the statistical regression model (*Adjusted* $R^2 = 0.54$). Simultaneously, some of the observed results in Model 1 disappeared, or the calculated strength of the correlation decreased in the second model. Of the variables identified in Model 1, gender and the main mode of transportation remained statistically significant predictors for the acceptance of CACs. Though, the strength of the correlation between gender and the dependent variable was considerably reduced in Model 2, females continued to exhibit significantly less acceptance of CACs than males. In contrast, the relationship between the main mode of transportation and the acceptance of CACs became more prominent and stronger in Model 2. Compared to drivers of manually driven cars, pedestrians, cyclists and PTW riders demonstrated significantly lower road user acceptance levels. This indicates that the modes of transportation attributed to VRUs stood out markedly in their lower acceptance of CACs. Whereas drivers of conventional cars, on the opposite, showed the greatest acceptance of CACs in the fictitious traffic scenarios in the questionnaire presented.

In Model 2, the indices of personal innovativeness and general trust in CACs proved statistically significant and appeared to be positive and rather strong determinants of road user acceptance in CACs. Comparatively, general trust in CACs showed an even stronger positive correlation than personal innovativeness. According to these results, the coefficients of the two attitudinal variables in the second model and the additional explanatory power show that personal innovativeness and, in particular, general trust in CACs were essentially related to road user acceptance of CACs as measured in the predefined traffic scenarios.

5. Discussion

5.1 Synthesis of findings

This study assessed the a priori acceptance of CACs from the perspective of different road user groups. Upon the market-wide introduction of CACs, road users such as pedestrians, cyclists and PTW riders as well as drivers of non-automated cars will be forced to interact with CACs, raising questions about their safety, especially among VRUs. Accordingly, the first aim of this study was to measure the acceptance of CACs from the perspective of the different road user groups. Furthermore, as a secondary goal, the presented study explored whether the road user groups differed in their acceptance of CACs on SAE Level 3. These research aims were investigated with a specifically developed measurement tool, building on previous research on user-centred acceptance of automated vehicle technology. Given prior findings, the items of this tool refer to the dimensions of the perceived ease of use, the compatibility with prevailing road traffic and the perceived usefulness and are adapted to the perspective of the road users. The questionnaire of the BRAVE population survey initially presented a description of a specific traffic situation involving an interaction with an approaching CAC. This description differed according to the individually used main mode of transportation, followed by the three items measuring the road user's acceptance of CACs.

The univariate results of the items for road user acceptance indicated a basic acceptance of CACs in which communication with the CACs and their benefits for road safety were rated quite positively. In this regard, the findings basically correspond with previous studies on public or user acceptance of automated vehicle technology (Cunningham & Regan, 2020; Jing et al., 2020). Compared to the positive assessment towards communication with CACs and their road safety, however, findings revealed doubts from the road users about the compatibility with the existing conditions in road traffic. Therefore, concerns raised regarding the reliability, cybersecurity or liability of CACs as well as detecting the intentions of other road users in the BRAVE population survey (Schrauth et al., 2020) should be thoroughly addressed in the further development and implementation of automated vehicle technology to further improve acceptance among all road user groups. An introduction of SAE Level 3 vehicles with insufficient acceptance among road users might lead to rejection or undesired behaviour of other road users towards automated vehicles, e.g. bullying or exploiting the risk-averse driving style of automated cars (Camara et al., 2018; Liu et al., 2020).

Results on sociodemographic variables from the bi- and multivariate analyses performed with the additive index of the road user acceptance of CACs recall similar patterns in familiar research on user or public acceptance (Hulse, Xie & Galea, 2018; Kyriakidis, Happee & Winter 2015; Nordhoff et al., 2020). Regarding gender, female road users showed a lower specific acceptance of CACs than males. This relationship has been statistically confirmed in bi- and multivariate analyses. Though in Modell 2 of the regression analysis, the gender effect weakened considerably after controlling for general trust and personal innovativeness. A weakening or non-existent gender effect after controlling for attitude-based variables in multivariate analyses was already evident in user-centered acceptance studies of Kaye et al. (2020) or also Payre, Cestac & Delhomme (2014). Similarly, the predictors of age and age squared did not become statistically significant in the regression models as they did in bivariate analyses before. Comparable findings on weak or diminishing effects of age on the acceptance of automated vehicle technology in multivariate settings were also reported in Nordhoff et al. (2019), Kaye et al. (2020) and again in Payre, Cestac & Delhomme (2014). These results reflect previous findings and underline the assumption proposed by Hohenberger, Spörrle & Welpe (2016) that attitudes may mediate the correlation between gender or age and the acceptance of automated vehicle technology.

Besides gender and age, other sociodemographic or mobility-related predictors, such as the frequency of trips per day, the experience with ADAS, the respondent's place of living, the highest level of education or subjective social positioning, were not relevant or rather lost their statistical significance in step two of the regression analysis. Instead, general trust and personal innovativeness were the central determinants for explaining road user acceptance of CACs. Both attitude-based determinants had the strongest correlation with the road user acceptance of CACs, while gender, age and other sociodemographic as well as mobility-related variables only showed a small, often non-significant relation with the explanandum in the multivariate setting.

These findings point out the central role of trust and innovativeness for the road user acceptance of CACs, which largely outweighs sociodemographic or mobility-related characteristics. As in other research, a reasonable conclusion is that trust in and enthusiasm for technology determine the acceptance of CACs among road users (Deb et al., 2017; Zhang et al., 2019). From the present results, it appears that trust could be one of the crucial factors to increase the acceptance of CACs among other road users. Further studies should thus also place trust in CACs at the centre of research interest and investigate its determinants more closely. First experiences in interaction with automated vehicles demonstrate positive effects on building trust, as has already became apparent in the research of e.g. Penmetsa et al. (2019) and underpinning the experienced-based character of trust (Hoff & Bashir, 2015). Though, it is challenging building trust in a vacuum where no CACs are yet driving in real traffic. What an appropriate trust-building measures in the current stage could look alike requires further efforts from research, industry and politics.

Next to the development of a measurement tool for road user acceptance, the second central aim of this study was to investigate the differences in the acceptance of CACs among distinct groups of road users. In this respect, the findings demonstrate that the road user groups significantly varied in their specific acceptance of CACs. In the multivariate analysis, all groups of VRUs – pedestrians, cyclists and PTW riders – revealed a lower acceptance of CACs in contrast to the non-automated car drivers. Interestingly, results for PTW riders in the second model reveal a stronger negative correlation than in the first model. This effect can be explained by examining the bivariate correlations between the main mode of transportation and general trust as well as personal innovativeness of the different road user groups: PTW riders have above-average general trust in CACs and above-average personal innovativeness compared to the other road user groups. Controlling for these relations in the second model, the net effect remains for the PTW riders, who then demonstrated a strongly reduced acceptance compared to car drivers.

According to these results, the road user groups showed diverging levels of acceptance of CACs, with VRUs expressing greater concerns about their subjective safety than car drivers. Two reasons seem plausible for this assessment: first, it is conceivable that VRUs assume they are less likely to be detected by CACs than cars and anticipate coordination problems with CACs. In addition, VRUs are less protected in the event of a crash with a CAC and perceive themselves to have a higher risk of injury when colliding with a CAC. Additionally, it fits the picture that cyclists and PTW riders who will share the road with CACs are even less accepting CACs than pedestrians. The interaction of CACs with pedestrians, cyclists and PTW riders must receive strong attention during technological development to ensure that the safety of the VRUs is not jeopardised by unsuitable detection systems that cannot precisely predict the VRUs' intentions.

Moreover, it is remarkable that the addition of trust and innovativeness in the second model reduced the effect sizes of most determinants regarding variables covering sociodemographics and mobility behaviour – but not those of the road user groups. The effect sizes and differences between the road user groups remained persistent – or even became more explicit – and signal that besides general trust-building measures, especially the individual road user groups must be targeted with policies fostering acceptance of CACs.

Above that, findings from the bivariate analysis pointed out substantial differences in road user acceptance of CACs among countries. Against the background of previous cross-national studies on public or user acceptance, the results fit the picture of varying degrees of acceptance between different countries (Cunningham & Regan, 2020) or different determinants within country-specific analyses (Kaye et al., 2020). However, it is difficult to clearly attribute the differences between these seven western and industrialized countries neither to varying information regarding CACs in the countries, diverging national technological progress, cultural aspects nor to the diversity in the transport system. Similarly, Kaye et al. (2020) in their comparative study also found country-specific results but could not clearly attribute them to specific reasons. Exemplary, Nordhoff et al. (2020) in their international study likewise acknowledged country differences and declared this to be still a research target. In this regard, more cross-country comparative studies would have to be carried out to obtain a possible consistent picture of country differences. At the same time, further multi-country studies would have to aim at exploring the effects of e.g. cultural aspects or national conditions. A more detailed cross-country analysis of the acceptance of CACs seems essential as the introduction of CACs will not be limited to one country only. International regulations for manufacturing or also cross-border traffic require cross-national consensus.

5.2 Practical implications

A core result of the study involved the clear differences in the acceptance of CACs between the distinct groups of road users. This road user group-specific acceptance was lower among VRUs than among drivers of conventional cars. The reason for the VRUs' more reserved acceptance might stem from higher scepticism towards self-driving cars, possibly resulting from higher uncertainty about interacting with these vehicles. Next to the implicit communication like the approach speed of CACs, the installation of external HMIs on automated vehicles might be one way to reduce such uncertainty. Examples of preferred solutions that were also surveyed in the BRAVE population study include an indication when the CAC is in automated mode or flashing light signals at the car when the CAC approaches a pedestrian crossing and gives way (Schrauth et al., 2020). The use of external HMIs on automated vehicles is already being researched and tested (Rouchitsas & Alm, 2019; Schieben et al., 2019). Results, however, show that attention must be paid to a moderate use of external HMIs to ensure comprehensible communication with road users via external HMIs (Kaleefathullah et al., 2020). Uniform and barrier-free concepts must also be considered, as well as the opportunity for road users to learn how to interpret the external HMI system.

Above that, communication via external HMIs as currently designed is unidirectional and originates solely from the CAC. In certain traffic situations, the pedestrian, cyclist or PTW riders may wish to communicate with the CAC and may wave the CAC past, for example. Such bidirectional communication does not seem to be foreseen in the current use of external HMI and is certainly an issue that needs to be addressed in the future.

The installation of external HMIs on CACs might also generate a trust-building effect. As the results presented here and in other research studies show, trust will be a substantial component in encouraging the acceptance of CACs – from the specific perspective of the different road user groups as well as from the viewpoint of potential users. Regarding the presented results, especially pedestrians, cyclists and PTW riders should be sensitised to interact with CACs. Likewise, women's scepticism about automated vehicle technology might also be addressed in communication campaigns that are expected to increase acceptance of automated vehicles (Pettigrew et al., 2019).

At the same time, technological developments and regulatory standards for the approval of automated vehicles must give the studied groups and all other population groups every reason to place trust in the technology and road safety of CACs. In the current absence of CACs in real traffic, it seems important for policymakers and the industry to create a trust-building framework through appropriate communication and by transparently setting the regulations for e.g. ethical and legal issues that are in line with societal values.

5.3 Strengths and limitations

The investigation of road user acceptance of CACs was conducted within a large-scale population survey including seven countries. Thus, the study took advantage of a commercial online access panel that has some considerable limitations (Couper, 2017). Besides the unfavourable response behaviour addressed by checks for the length of interviews and the identification of indifferent response behaviour (Schrauth et al., 2020), the representativeness of the data is another issue. Nevertheless, comparisons of selected sociodemographic data between the survey data and official population data from the United Nations (2019) demonstrate that the recruited survey participants approximately reflect the population in the seven countries in terms of gender and age (Schrauth et al., 2020). However, survey data from online access panels principally lack generalisability to the whole population of a country and must be considered representative only for Internet users in that country.

In the present study, an in-depth analysis of country differences was neglected in favour of measuring factors influencing the road user acceptance of CACs; these differences were instead considered a cluster variable in the regression. Hence, while this paper does not address the differences between the individual countries that appeared in the bivariate analyses, they are displayed in more detail in Schrauth et al. (2020). As already outlined, explanations for these diverse results regarding countries have not yet been explored in detail and should be addressed in further studies. In this regard, approaches dealing, for example, with legal regulations for a worldwide introduction of automated vehicle technology must consider national differences, which relate not only to road users' acceptance but also to initial trust in conditional automated technology, as well as technical and ethical considerations (Schrauth et al., 2020).

Moreover, the measurement tool for road user acceptance of CACs has been applied for the first time and in the context of one specified traffic situation. In doing so, the study primarily referred to extant findings from user-centred research on automated vehicles and draws on three central dimensions for the formulation of its three items. Comparable research results of acceptance of CACs from a non-user perspective are rare, making it difficult to assess the validity – however, they appear, against the backdrop of existing findings, theoretically and empirically plausible. Of course, this situation is also – as in all other studies – a matter of missing possibilities to measure acceptance of or trust in the new automated vehicle technology against real conditions. Therefore, using the measurement tool in other contexts as well would be desirable, e.g., in (quasi-) experimental research designs to verify the differences between the road user groups found in this study.

Another methodological remark concerns the operationalisation of the general trust in CACs and its textual proximity to the measurement tool of the road user acceptance of CACs. In the data analysis, it must be critically questioned, whether the strong correlation between trust and road user acceptance may also refer to the operationalisation of both variables. Future studies may, thus, try a different indicator measuring initial trust in CACs to better separate the two theoretical constructs of trust and acceptance.

6. Conclusion

The present study focused on the a priori acceptance of CACs from the perspective of different road user groups who will have to interact with automated vehicles after their introduction – without actively having 'decided' to do so. Following the principles of a Pareto-optimal improvement on the introduction of CACs, the different road users may not be put in a worse position. For example, they must not experience a higher risk to their subjectively perceived or objective road safety, nor must they inevitably encounter restrictions to their freedom of movement in road traffic – especially as high expectations on automated vehicle technology 'are at present largely speculative and yet to be proven' (Cunningham & Regan, 2020, p. 96).

For this reason, the legitimate interests of the different road user groups, particularly the VRUs, must be sufficiently considered in the development of automated vehicle technology prior to a market-wide introduction. Findings from this study reveal a basic acceptance on the part of the road users towards interactions with CACs on the road, though concerns about such interactions were apparent as well. Moreover, the presented findings provide initial evidence that, at least in the traffic situations defined in the questionnaire, the acceptance of CACs differs between the road user groups and thereby has identified a road user group-specific acceptance of CACs. Furthermore, it is remarkable that from their point of view, the VRUs currently feel unequally affected by the introduction of CACs and reveal a lower acceptance of CACs than drivers of non-automated cars.

These results provide a reason for further investigation of the acceptance of automated vehicle technology from the perspective of different road user groups. A greater consideration could ensure better identification of issues raised by road user group-specific requirements for interaction and communication with CACs. Nevertheless, it must be acknowledged that in this context, not only the requirements of the different road user groups already discussed must be considered, but further thought should be given to the needs of children, elderly or people with disabilities.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

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