Conditional Privacy: Users' Perception of Data Privacy in Autonomous Driving

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Abstract: Connected autonomous driving can be a key for safety enhancement in road traffic and long-term reduction of driver-induced accidents with personal injury. Though, its acceptance is challenging, because of perceived restrictions on data security and privacy concerns. Hence, in this study, the focus was on users' perception of data privacy in autonomous and connected driving. For this purpose, a two-tiered research approach was conducted, based on semi-structured interviews (N=7) and an online questionnaire (N=100). Special attention was given to data storage and processing, data distribution, as well as personal usage purposes as predictors for the use intention. Results showed that the driver was most likely accepted as data decision maker, whereas the own car was preferred as data receiver. Besides, evaluation profiles indicated user diverse attitudes concerning the willingness to use autonomous driving regularly. These study outcomes contribute to a deeper understanding of user requirements in the context of mobility acceptance.

1 INTRODUCTION

Due to increasing traffic on the streets today, with the human as accident reason number one, road safety poses a global challenge. Regarding Germany, for example, 3,180 people were killed in road traffic accidents in 2017, which is about nine people a day (Destatis, 2018b). Although the total number of casualties dropped to its lowest level in more than 60 years (Destatis, 2018d), there is still a need for progress in road safety, in particular, to prevent driver-related causes of accidents, like insufficient distant, inappropriate speed, and improper road use (Destatis, 2018c).

To this, smart mobility systems and technologies, such as in autonomous driving, have the potential to reduce traffic accidents and improve road safety in the long-term (Bishop, 2000; Farmer, 2004; Liu et al., 2008). Automated vehicle systems, for instance, adaptive cruise control (Vahidi and Eskandarian, 2003) and autonomous brake assist (Breuer et al., 2007; Kusano and Gabler, 2012), support drivers in their responsibility under certain driving conditions to provide a high level of safety in specific traffic situations. Concerning the automation and intelligent connection of transportation systems and road traffic, Vehicle2X-technologies offer innovative communication possibilities for data sharing and interaction between vehicles and their environment (e.g., other vehicles, transport infrastructure, and pedestrians) (Picone et al., 2015). To increase overall road safety, special attention is given to the technical development, e.g., sensor models (Eichberger et al., 2017), data processing (Scherping et al., 2013), and traffic management as well as efficiency (Wedel et al., 2009) in this context.

With regard to the users' perspective on autonomous driving, previous research revealed that users are aware of the advantages of automated driving, but also, that perceived barriers, e.g., the fear of hacker attacks, limit its acceptance (König and Neumayr, 2017). Hence, research focus was on, for instance, predictors for trust (Haeuslschmid and Buelow, 2017), safety perceptions (Schmidt et al., 2016b), driverless car ethics (Bonnefon et al., 2016), and, in particular, user diverse privacy and data security requirements (Schmidt et al., 2016c). To this, different approaches were applied, such as qualitative and quantitative methods (Schmidt et al., 2016a) as well as experimental study designs (Waytz et al., 2014). Key findings indicate a general distrust when it comes to transfer data, provided that the willingness to share personal data with an intelligent transport system is particularly low. Against the background of fast-developing technologies, further research is needed to clarify why and to what extent users accept or reject data processing and storage as well as

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Table 1: Statements about data storage and data processing.

General evaluation: **Do you agree with the following statements?**
Personal data recorded by the car should be identified with my person.
Each driver should have an ID chip to log & in the vehicle and store personal data.
I want to know where my personal data is & stored and processed.
I want to know how long my data will be stored.
I want to be able to delete the history or & individual entries of the recorded data individually.
I want to know who stores and processes my & personal data.
I want to decide for myself which personal & data I want to release.
I want to know which of my data is stored & processed.

its distribution in autonomous driving.

The aim of this study was to explore users' perception of data privacy in autonomous and connected driving.

For this purpose, a two-tiered research approach was chosen including preceding interviews (N=7) and a subsequent online questionnaire study (N=100). The identification of influential acceptance factors for autonomous driving is an essential step towards a user-centered technology development. Not only major acceptance-relevant factors like perceived benefits and barriers of the technology itself, but rather a deep dive into an understanding of users' privacy and data security appraisals is necessary at this stage of the mobility shift. In particular, we focused on user diverse evaluation patterns, for instance, concerning questions about the data receiver (*Who can access the data?*), decision maker (*Who can decide on the data distribution?*) and personal usage purposes as contribution to deeper insights into mobility acceptance.

2 METHOD

With a two-tiered research approach, we addressed the questions of data security and privacy perception in autonomous driving via a preceding interview study. Including these first findings about users' perception of data distribution and handling, a questionnaire was developed to validate the results. As can be seen in Figure 1, the usage intention was assessed to form evaluation groups. All evaluation differences on privacy in autonomous driving will be laid out, focusing on data storage and processing, data distribution and purpose of use.

Data Acquisition and Analysis. The following empirical work was designed as an online questionnaire. The participants were acquired in the university environment or in thematic forums. The quality of the responses was checked with regard to processing time and contradictory response behavior. The resulting data were analyzed by descriptive analysis and, with respect to the effects of user diversity. The level of significance was set to $\alpha = .05$.

2.1 The Survey

The survey was divided into three main parts.

Demographics. The demographic data was addressed in the first section. Further, information about monthly income, possession of driving licence, and vehicle owner status was questioned. Also, the willingness to use technology (Neyer et al., 2016) and the need for control was measured.

Mobility and Digital Profile. In the second section the participants had to evaluate their mobility and digital profile. Here, the previous experience with driver assistance systems (brake assistant, lane assistant, automatic parking, distance control and cruise control) as well as usage-patterns and attitudes toward smartphone applications were questioned. Concerning the prior experience with driver assistance systems, we focused on advanced speed regulation systems (adaptive cruise control (ACC)) with automation level 2 (SAE, 2016), as this is the system with the highest automation level that is currently available.

Data Security and Privacy Evaluation. The last section addressed an overall evaluation of data security and the users' perception of privacy in an autonomous driving context. Here, several sets of items (6-point Likert scale, 5=full agreement) questioned data storage and processing (see Table 1), the distribution of data and different reasons to share data.

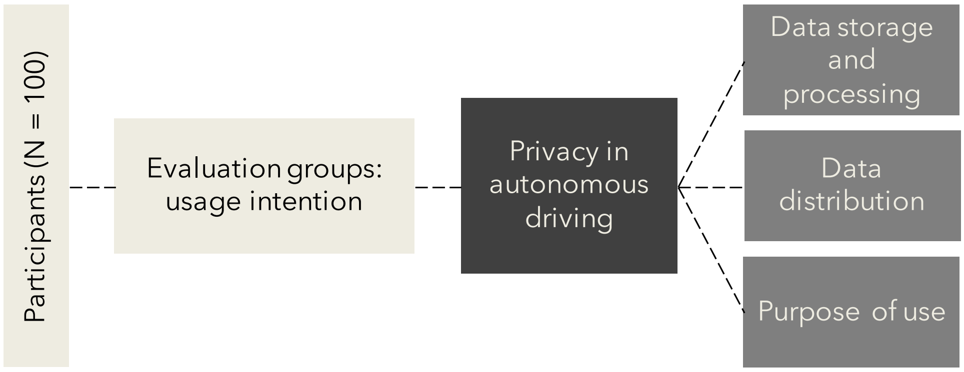

Figure 1: Methodological concept of research model.

2.2 Sample

A total of 134 people participated in the questionnaire study, of which 34 were excluded from statistical analyses because of incomplete data sets. Hence, the sample consisted of N=100 participants, divided into 36 women and 64 men. The participants' age ranged from 19 to 68 years, with an average of 34.5 years (SD=12.5). With 59% holding a university degree (n=59), the sample was of above average education (Destatis, 2018a). Besides, 22% had an university entrance qualification (n=22), followed by 11% with a vocational baccalaureate diploma (n=11), 7% with a secondary school diploma (n=7), and 1% with a primary or secondary school leaving certificate (n=1). The majority's (62%) monthly net household income was below 3000 Euro (n=62).

Most of the participants (96%) hold a driving licence (n=96) and owned a motor vehicle (69%, n=69). In general, the experience with driver assistance systems was rather low (M=2.42, SD=0.70). In detail, navigation systems were commonly used (M=4.53, SD=0.80), next to cruise control (CC) (M=3.67, SD=1.20), whereas parking assistant (M=2.85, SD=1.11), adaptive cruise control (ACC) (M=2.49, SD=0.98), and lane keeping assistant (M=2.40, SD=0.85) were only little used and known, just as assistants for traffic signs (M=2.20, SD=1.01), emergency brake (M=2.18, SD=0.82), and lane change (M=2.16, SD=0.93). Besides, the willingness to use technology was rather positive (M=3.54, SD=0.73), whereas the need for control was more average (M=2.74, SD=0.59).

User Group Allocation. In order to classify the groups, the willingness to use autonomous vehicles regularly in the future was surveyed as part of an item set. According to the participants' intention to use a connected autonomous vehicles, two groups were formed, comprising potential users (n=37), who were more likely to agree autonomous driving in future (M=4.62, SD=0.49) and non-users (n=63), who rather rejected autonomous driving (M=2.16, SD=0.95). Descriptive profiles of specific user group characteristics are presented in Table 2.

3 RESULTS

In the following section the obtained results will be presented in detail. First, an overview of the evaluation based on the complete sample, the results on data storage and processing, data distribution and purpose of use will be introduced extensively. Following each evaluation, the group-specific differences will be laid out.

3.1 Data Storage and Processing

Overall, the results show that obtaining information about data storage and processing is favored. The highest approval rates could be found in statements on receiving information about the data type, which is stored (M=4.33/5 points max., SD= 0.87), the possibility to decide for oneself, which personal data is released (M=4.32, SD=0.88) and receiving information about who stores and processes the data (M=4.31, SD=0.91). In addition, it was agreed on the possibility to delete the history or individual entries of the recorded data (M=4.25, SD=1.07), receiving information about how long (M=4.04, SD=0.99) and where data will be stored and processed (M=3.68, SD=1.23). The strongest disagreement was found regarding a possible ID chip, which is used to log on to the vehicle containing personal data (M=2.07,SD=1.55) and the identification of a person via the personal data recorded by the vehicle (M=1.72, SD=1.36).

User Groups. Addressing the data storage and processing, group differences showed up. To be precise, the non-user group (M= 3.87, SD=1.13) evalu-

Table 2: Characteristics of user groups.

User Groups	User (n=37)	Non-user (n=63)
Age	M=29.51, SD=10.17	M=37.49, SD=12.92
Male	83.8% (n=31)	52.4% (n=33)
Female	16.2% (n=6)	47.6% (n=30)
Net household income <3000 Euro	70.2% (n=26)	57.1% (n=36)
Driving licence holders	64.9% (n=24)	71.4% (n=45)
Willingness to use technology in general	M=3.95, SD=0.53	M=3.30, SD=0.73
Perceived need for control	M=2.63, SD=0.44	M=2.80, SD=0.66
Prior experience with driver assistance systems	M=2.65, SD=0.80	M=2.28, SD=0.60

ated the possibility to know where the data is stored significantly higher (F(1,98)=4,34), $p<.05$) than the user group (M=3.35, SD=1.34). Also, the information about who stores the data showed a similar outcome: the non-user group (M=4.46,SD=0.67) urged that information significantly stronger (F(1,98)=4,86), $p<.05$) than the user group (M=4.05, SD=1.18).

3.2 Data Distribution: Data Receiver and Decision Maker

With regard to data distribution, two thematic categories were measured: First, the question of who is entitled to have the recorded data was addressed (see Figure 2) and second, who should decide who may use the data by the connected autonomous vehicle.

3.2.1 Data Receiver

The strongest consent of all the possible receivers were found for the own car (M=3.52, SD=1.43) followed by the police and emergency services (M=3.43, SD=1.38), and by an addition of the infrastructure (M=3.02, SD=1.50). In contrast, the vehicle manufacturer (M=1.17, SD=1.17) and the insurance company (M=1.50, SD=1.37) matched the least average agreement rates.

User Groups. Concerning the user groups, almost all statements according the data distribution were perceived significantly different (see Figure 2). On average, potential users show a stronger agreement to most of the given possible data receivers.

3.2.2 Decision Maker

Addressing the responsibility to decide who uses the data, the driver reached the highest average approval with 4.33 out of 5 points (SD=1.03) followed by the vehicle owner (M=3.46, SD=1.59). The vehicle manufacturer however has received the strongest rejection as a decision-maker with an average agreement of 0.79 (SD=0.97).

User Groups. Again, the groups revealed to significantly impact the evaluations. While users had a small tendency towards neutral agreement about the manufacturer as decision maker (M=1.05, SD=1.05), non-users tend to disagree strongly (M=0.63, SD=0.89) (F(1,98)=4,53, $p<.05$). Further, a similar difference can be found in the agreement of the legislator as decision maker. Here, the willingness to use the technology had a significant effect (F(1,98)=6,83, p=.01). On average, the users agreed more on the legislator as decision-maker (M=2.70, SD=1.76) than non-users (M=1.84, SD=1.48).

3.3 Purpose of Use

The sample has agreed on average to all possible reasons to share data (see Figure 3). Here, safety for oneself and other traffic participants was of highest interest: to report own accidents to police and rescue services (M=4.07, SD=1.02) and for accident clarification (M=3.88, SD=1.03). Thematically, comfort issues followed the safety-related reasons to use data: the data may be used for personal benefits (e.g. traffic information or reservation of parking spots) and for the improvement of street and traffic flow. Hence, to enable the police to immobilize the vehicle in case of emergency received the least approval with an average of 3.06 (SD=1.61).

User Groups. Here, the intention to use the connected and autonomous technology showed an impact on the evaluations of the purposes of use. All results were significantly different, except the reasons inspection of vehicles and to immobilize the vehicle. In all cases the group with potential users had higher agreement rates.

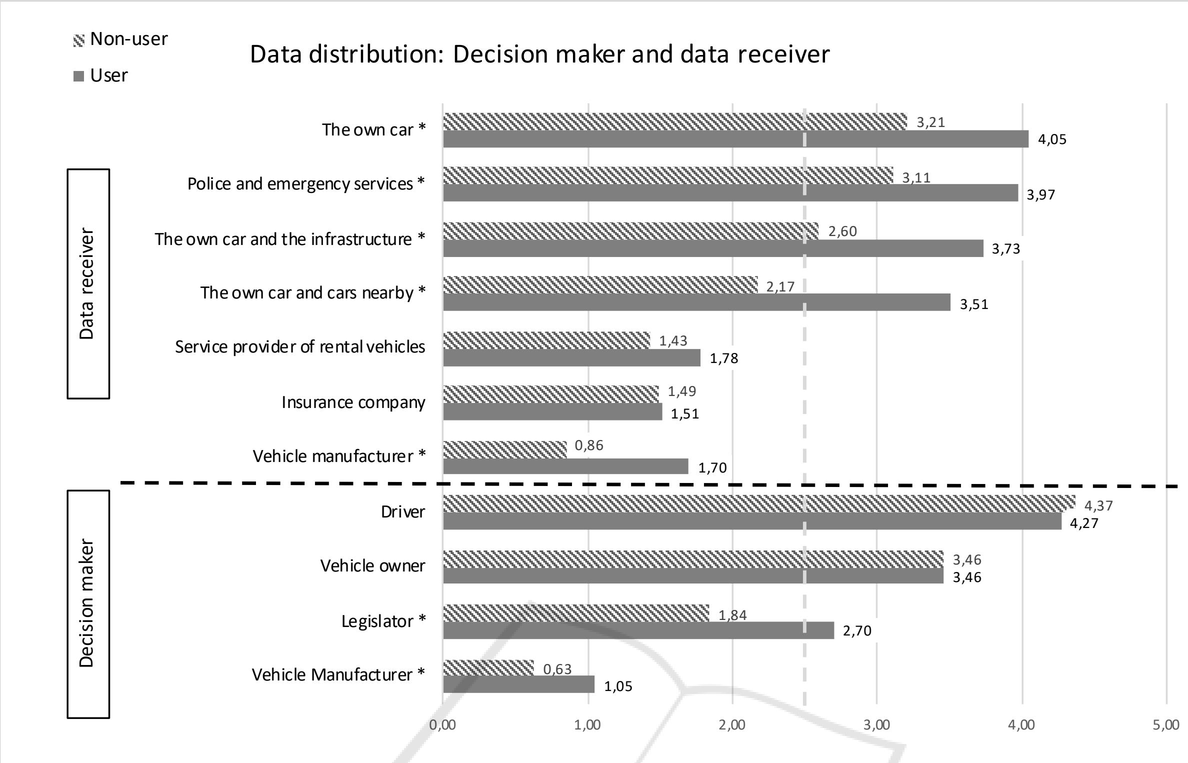

Figure 2: Overall results of data distribution: who decides who may receive the data (decision maker) and who may access the data (data receiver). 0=full disagreement, 5=full agreement. * indicates significant group differences.

4 DISCUSSION

The present study aimed at an understanding of users' perceptions towards data privacy in autonomous and connected driving. Methodologically, we focused in a first investigation on understanding general insights of possible technology user about autonomous driving, in particular their fears and doubts according data security (interview study). In a second step, we assessed the desire for information on data processing, storage, and distribution in a western European sample (survey study). Additionally, we analyzed evaluations of user groups with respect to their willingness to use the technology in future. The discussion will mirror the result structure and will furthermore question the empirical procedure as well as needed future research topics.

Concerning data **storage and processing**, the most valued information was which type of data is shared (e.g. own position, speed) – for both user groups. This result goes in line with the research findings of Schmidt et al. (2016a). Further, it was shown that there are different types of data, which are shared more willingly than others (the more personal data the data is, the less willing users are to share them). A closer look into the user groups showed, that non-users would like to know the data type with a significantly higher consent.

The wish to maintain these information shows also a possible distrust to the system, not necessarily a dislike or distrust for the technological idea. Hence, only less than half of the sample agreed to use the technology in future. Given the fact that the technology was only described and could not be tested, the number of potential users was rather high.

A closer look onto the groups shows, that the user group in this study is mainly male and rather young, given the fact that the "early adopters" of mobility technology (e.g. electromobility) are about 51 years of age (Trommer et al., 2015). Whereas the non-user group is almost symmetrical in gender distribution. In fact, this is particularly noteworthy since the entire sample had a high male proportion and therefore women may be more likely to be theoretical non-users (at least in this study). The group of users has a higher willingness to use technology in general and they have also more experience with driver assistance systems. Interestingly, their average value for perceived need for control was lower compared to the non-user group.

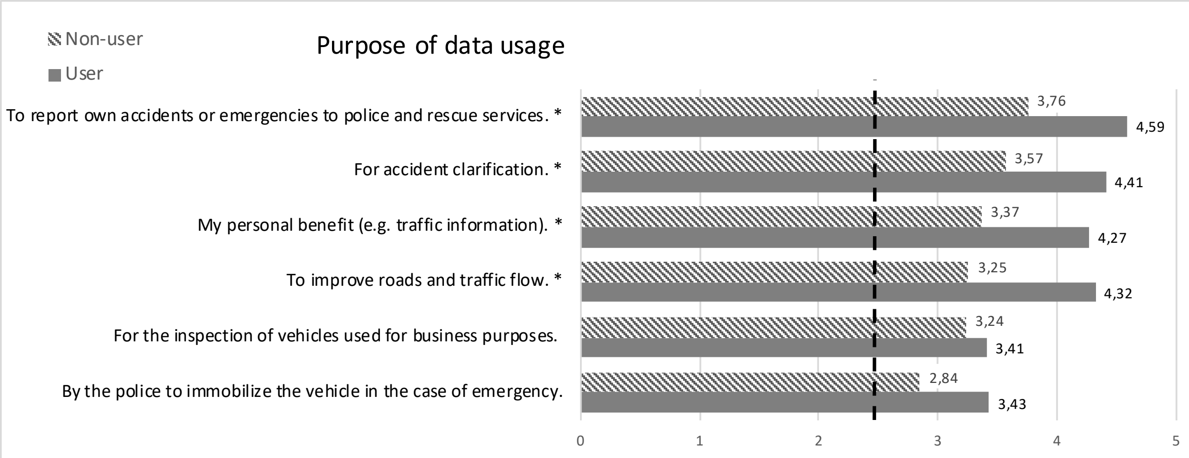

Figure 3: Overview of the agreement to the use of the recorded data. 0=full disagreement, 5=full agreement. * indicates significant group differences.

The group of users is almost neutral to need for control, which might mirror the lower evaluation rates on information about data storage and processing.

Now concerning the **data distribution**, the group of users has significantly higher rates on all possible data receivers, almost showing a disinterest in who receives the data at all. And further, they also have rather high average agreement rates on who decides about the data distribution.
Interestingly, no group is overall agreeing to the vehicle manufacturer as data receiver or distributor. This is an astonishing result, given the fact that the manufacturer is right now the main receiver of all vehicle-related data. Here, a potential distrust to authorities can be identified, given the recent negative events and press about the liability on car manufacturers, e.g. VW Diesel scandal (Jung and "Alison" Park, 2017; Sharpe, 2017). However, one has to consider the western European sample. A comparison study in other European regions would definitely reveal possible cultural differences regarding the trust given to authorities in a mobility context. Trust also seems to be a main influencing factor in data privacy of autonomous vehicles. Hence, the survey did not question trust as user factor, the result that the own car has the highest approval values as data receiver and the driver him- or herself as decision maker for the data distribution shows a clear and needed focus on that topic in future work.

An average agreement on all **purposes of use** was identified. Safety is, however, still the most prominent purpose. This result validates several studies on benefits of autonomous driving (Brell et al., 2018). The group of users agreed significantly higher on all given purposes. Here, possibly a better understanding of the technology's benefits may be uncovered. This could be connected to the groups overall higher use of technology altogether. Also, personal benefits like traffic information or the improvement of road and traffic flow had very high acceptance rates – here, the general understanding of potential possibilities to enhance and develop traffic can be identified. However, further purposes of use need to be discussed. The general wish to improve the current situation does not automatically improve the acceptance or usage of a technology or infrastructure change.

5 CONCLUSION AND LIMITATIONS

Autonomous driving and connected vehicles in Germany are perceived as useful and although without practical experience, the western European sample showed interest in the topic and communicated a willingness to use the technology in future. Although data protection is a very critical issue and needs to be further explored in order to ensure up-front acceptance of the technology and a possibility to participate in its development, a group of users could be identified who agree to use the technology without practical experience. Therefore, data privacy is a highly important topic as well as the distrust or trust of data receivers, which showed that these topics are not handled well up until today. Clearly, the benefits must be communicated more transparent in order to pick up the more skeptical people. We found a high approval on police and emergency services as data receiver, but still not the highest agreement on using it actively. To enable the police to immobilize the vehicle in case of an emergency was an agreed upon reason, but still overall not the highest approval rates. The findings call for action to help transform the conditional perceived privacy into a fully perceived one.

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