User Diverse Privacy Requirements for V2X-Technology
Quantitative Research on Context-Based Privacy Aspects

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Abstract: The paper will show, how different types of users are evaluating privacy and data security differently according to contextual differentiating traffic situations. The focus is hereby on an analysis of user types to see, if general attributes towards data capture can be identified. User requirements are investigated in age, gender, experience with driver assistance systems and technical affinity. Several significant effects like the influence of prior experience increasing the willingness to share data in an traffic optimizing scenario could be revealed. But results show also an undeniable reluctance towards sharing private data with other traffic participants or companies. Traffic management such as police or the infrastructure itself are however entrusted with various personal information and data.

1 INTRODUCTION

Integrating smart mobility in metropolitan areas and urban city parts is an important step for a sustainable supply of all residents, no matter age, health status or distance to a city centre. With intelligent transportation systems, not only the quality of life would enhance, but also the feeling of care which is taken to support and optimize the current situation of urbanisation.

A large part of lived mobility takes place on the street, more precisely in motorized personal transport (MIV). On the MIV accounts for just over 80% of passenger kilometers (PKM) measured in motorized passenger transport performance (BMVI, 2014). In 2012 were the 914.6 billion passenger kilometers. In the future, this type of transport should continue to rise: Despite the stagnating population development predicts the BMVI, among others due to increasing travel distances, an increase in performance of the MIV from 8.44% to 2030 compared to 2012.

Further, the number of traffic accident fatalities (in Germany) increased – reportedly 335 people died in road accidents in August 2015 (Destatis, 2015) which shows an increase of 18.4% compared to August 2014. A main goal is therefore to offer people a safe and intelligent technology, which helps to lower the number of traffic crashes by using it. By implementing new, smart technologies like the electronic stability control could be confirmed, that this technology can be used to decrease car crashes (Farmer, 2004, Breuer et al., 2007). In addition, the integration of intelligent communication systems into vehicles has the potential to further increase traffic safety by exchanging sensor data between road users and road infrastructure to broaden the information base for decision making of drivers and autonomous vehicles in safety critical situations (Picone et al., 2015, Endsley and Garland, 2000). Moreover, the so-called V2X-technology that make collaborative road environments possible could lead to a more efficient and more comfortable individual mobility.

While current research mainly focusses on technical issues, for example the development of specialised network technology (Ma et al., 2009, Trivisonno et al., 2015, Wedel et al., 2009), there is still little known about users' demands on V2X-technology. Most studies that take the user into account concentrate on usability issues, e.g., data visualization or transfer of control (simTD, 2013, Rakotonirainy et al., 2014), but neglect the users' requirements on the information exchange in traffic conditions in general. The acceptance or willingness to actively use V2X-technology or cooperate by sharing (personal) data within transport systems is incompletely explored so far.

Previous studies (Schmidt et al., 2015b) could identify general concerns and drawbacks such as a steadily growing distrust to share data. The more personal data gets; the less willing are users to share it with an intelligent traffic network.

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However, the influence of user diversity on the acceptance of V2X-technology in general and the information exchange in particular is still insufficiently explored. The effect of user factors like age or gender on technology acceptance in different mobility contexts has been shown in previous studies (Ziefle et al., 2014) and is expected to influence the requirements for V2X-technology as well. In addition, there might be context dependent acceptance patterns, which should be taken into account during technology development to increase users' acceptance.

2 METHOD

Based on a set of prior focus group studies, we identified possible user scenarios to test the appreciation of technical support in form V2X-supported driving. The further empirical approach reported here is the outcome of two surveys, which were constructed to look closely into different types of users in order to find acceptance patterns dependent on specific traffic situations. Therefore, aspects of privacy and data security were questioned.

2.1 The Survey

The online survey was divided into four main parts.

Demographics. The first section addressed demographic data as well as information about the previous experience (due to a job) with different vehicles. Following a question about the driver's licence(s), the frequency of vehicle usage was questioned. Then, the experience with smart vehicle technology (brake assistant, lane assistant, automatic parking, distance control and cruise control). Also, the technical self-efficiency was measured (Beier, 1999), the individual confidence in one's capability to use technical devices.

Roadside Scenarios. In the second section, two V2X traffic scenarios were introduced to help the participants envision the possibilities of V2X-technology actively. Here, we were able to fall back on previous qualitative studies (cf. Schmidt et al., 2015a) to differentiate between making driving more comfortable via information visualization and make driving more efficient by optimizing routes (e.g. smart traffic light, re-arranging of order).

V2X-technology. A set of seven items (6-point Likert scale, 5=full agreement) questioned the usage of V2X-technology in form of which data would be shared (see Table 1).

Table 1: Item example of approval of data collection.

What information about you or your vehicle may be collected / would be shared?
- Current motion data (e.g. position).
- Intention to move (e.g. planned route in navigation system).
- Information of past trips (e.g. average speed, preferred routes).
- Type of road user (e.g. bus, pedestrian).
- Vehicle specifications (e.g. safety equipment).
- Demographic data of driver (e.g. age, gender).
- Physiological data of driver (e.g. reaction rate, emotional state).
- Other personal data of driver (e.g. driving experience).

And a set of four items which questioned from whom and how long the data may be stored (see Table 2).

Table 2: Item example of data handling and storage.

Who may collect information about you (and your vehicle) and how long may the collected information be used / stored?	
- Local road users.	Capturing and processing
- Local road infrastructure (e.g. traffic light system).	
- Central servers of traffic management and public authorities.	Short-term storage
- Central servers of companies (e.g. car manufacturer or insurance companies).	Long-term/permanent storage

Ranking. The last part of the survey conveyed a ranking of six different factors due to their own perception of importance: control, cost, comfort, safety, privacy and time (saving).

2.2 Scenarios

Infotainment. The first scenario invited the participants to envision a situation in which they are the driver of a car in an unknown city. In need of information about a place to eat or where the next ATM is positioned.

This scenario includes the integration of all, most of personalized value-added services that increase the comfort, entertain or inform. The spectrum of possible applications is very versatile and ranges from automated payment systems, the integration of games and multimedia, information on local attractions to personalized advertising. Manufacturing and maintenance-oriented applications, such as automatic software updates or the transmission of data on vehicle condition to the favored workshop, are in the literature partly its own category (Dressler et al., 2014).

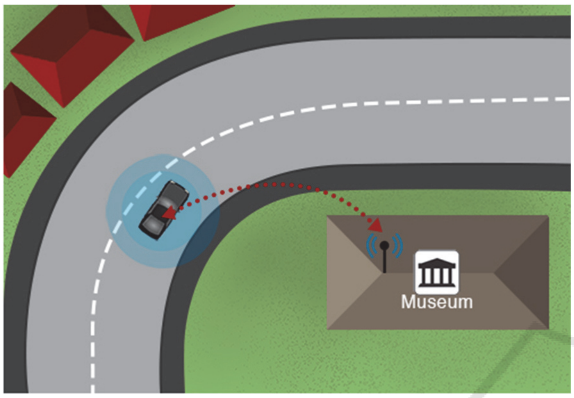

Figure 1: Infotainment. A car drives through an unknown city and gets information via V2X-technology.

Traffic Optimization. Participants had to envision the scenario in which they are again the driver of a car. In this situation, they are driving on a

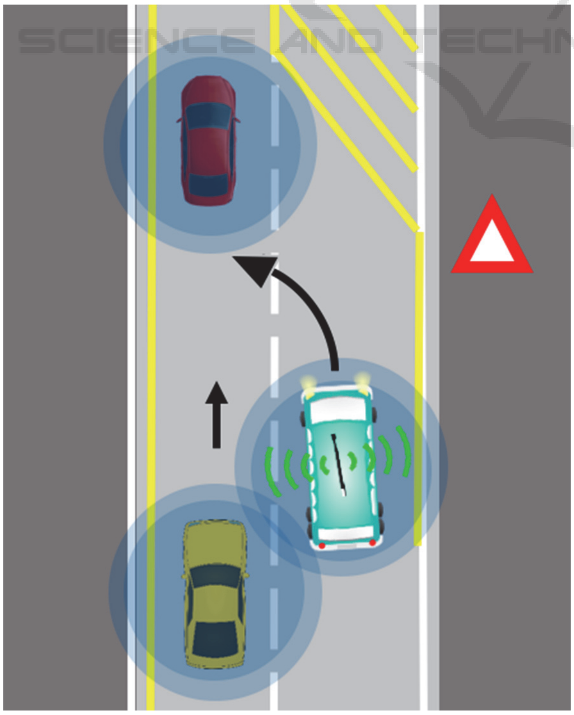

Figure 2: Traffic optimization. A car drives through an unknown city and gets information via V2X-technology.

highway with a building site. Here, they need to rearrange to another line with the zipper method.

Here, the smart vehicles or infrastructure use applications that improve the flow of traffic. This prevents traffic jams and environmental pollution can be reduced by a reduced fuel consumption. Through local networking of vehicles and infrastructure an optimal, environmentally friendly driving behavior can be recommended to the driver or warning signals and traffic lights are switched according to the current volume of traffic. The central processing of traffic data allows an intelligent traffic and redirect management.

2.3 Participants

In total 274 participants took part with an age range of 17 to 70 years (**M**ean=33.02; **S**tandard **D**eviation=12.51). The gender distribution is symmetrical with 137 men (50%) and 137 women (50%). All participants hold a driving licence (age 17 holds a driving licence class B17, which corresponds accompanied driving). The sample contains 45.4% with a university degree (n=124), followed by 34.1% with a technical college degree (n=93) and 12.1% did vocational training (n=33) plus 4.4% stated another level of education (n=12).

All participants reported a rather high technical self-confidence with 3.70 / 5 (SD=1.16). Here, men are slightly more technical affine (M=4.12; SD=0.98) than women (M=3.29; SD=1.18).

For further research, users had to classify if they used technical support systems (brake assistant, lane assistant, automatic parking, distance control and cruise control) in vehicles before. Here, the overall sample has rather little experience M=1.82 (scale form 0 = no experience to 5). Men have slightly more experience (M=2.25; SD=1.61) than women (M=1.39; SD=1.50).

3 RESULTS

In the following section the obtained results will be presented in detail. First, the findings for both scenarios based on the complete sample will be reported. Afterwards, the effects of age, gender, technical affinity and prior experience will be introduced extensively.

3.1 General Findings

In a first step, we report a general evaluation about which information of the user may be collected or in other words which information the user is willing to share with regard to the two scenarios introduced above.

Infotainment. Among the more uncritical data, which participants would mostly agree on sharing in the context of gaining information while driving, is type of road user (M=2,89, SD=2,10), current motion data (M=2.76, SD=2.04) and intention to move (M=2.50, SD=2.05). There is overall a lower propensity to share information about past trips (M=1.33, SD=1.75) and vehicle specifications (M=1.16, SD=1.69). Most critical are demographic data (M=0.86, SD=1.35), other personal data (M=0.48, SD=1.05) or the physiological state of the user (M=0.45, SD=1.01).

Traffic Optimization. In the second scenario are similar findings identified. Here, current motion data (M=3.49, SD=1.70) and type of road user (M=3.44, SD=1.87) would be shared immediately, but the intention to move is not perceived as uncritical data (M=2.25, SD=2.01). Further, information about past trips (M=1.50, SD=1.83) and vehicle specifications (M=1.47, SD=1.85) would not be shared without hesitation. The most critical data is again demographic data (M=0.59, SD=1.21), physiological data (M=0.58, SD=1.22) and other personal information (M=0.54, SD=1.15) like driving experience.

Storage and Duration. All participants had to identify the tolerated duration of data storage and the recipients, which should be allowed to store it. Figure 3 shows the findings.

As can be seen the most tolerated time span is capture and process the data in the very moment of the traffic situation (in all cases above 59.0% agreement of all participants). The agreement scores lower tremendously when asking about a short-term storage (max. storage of one week), with scores from 16.1% to 26.6 %. Generally disliked is the long term / permanent storage of the data, here, the scores are in all cases the lowest of the storage duration possibilities.

Ranking. We asked participants to prioritize six criterions according to perceived importance. The results show that safety is the most important factor (M=1.87, SD=1.10), followed by privacy (M=2.93, SD=1.71) and control (M=3.10, SD=1.65). Saving time (M=4.28, SD=1.41), cost (M=4.30, SD=1.22) and comfort (M=4.49, SD=1.35) are evaluated with less importance.

3.2 Age

In the following section age will be considered in detail as the first of the examined user factors.

First, age had effects on the willingness to share information in both scenarios: There was a significant correlation between age and the agreement on revealing *demographic data* in infotainment use cases (p=.002, r=-.145). The older the participants were, the more consent to limit the exchange of demographic information could be observed. With regard to traffic optimization scenarios, age influenced the willingness to disclosure both the *intention to move* (p=.006, r=.126) and the *vehicle specifications* (p=.000, r=-167). Older participants tended to state slightly higher agreement levels concerning the sharing of intended movements than younger participants and vice versa in regard to technical information of the vehicle.

Second, age influenced the consent to long-term data storage by infrastructure. This effect was significant for traffic optimization scenarios with F(2.243)=4.183, p=.016. The older the participants were, the more willingness to accept longer storage periods could be determined.

Table 3: Overall results of storage (who may keep the data) and duration time (how long may it be stored) in %.

	Infotainment				Optimization			
	Capturing and processing	Short-term storage	Long-term storage	n	Capturing and processin g	Short-term storage	Long-term storage	n
Road user	78.9	16.1	4.9	223	76.9	18.7	4.4	251
Infrastructure	70.0	22.9	7.0	227	59.7	26.2	14.1	248
Traffic management	62.5	25.0	12.5	208	59.0	26.6	14.4	229
Companies	77.9	16.1	6.0	199	77.1	17.1	5.9	205

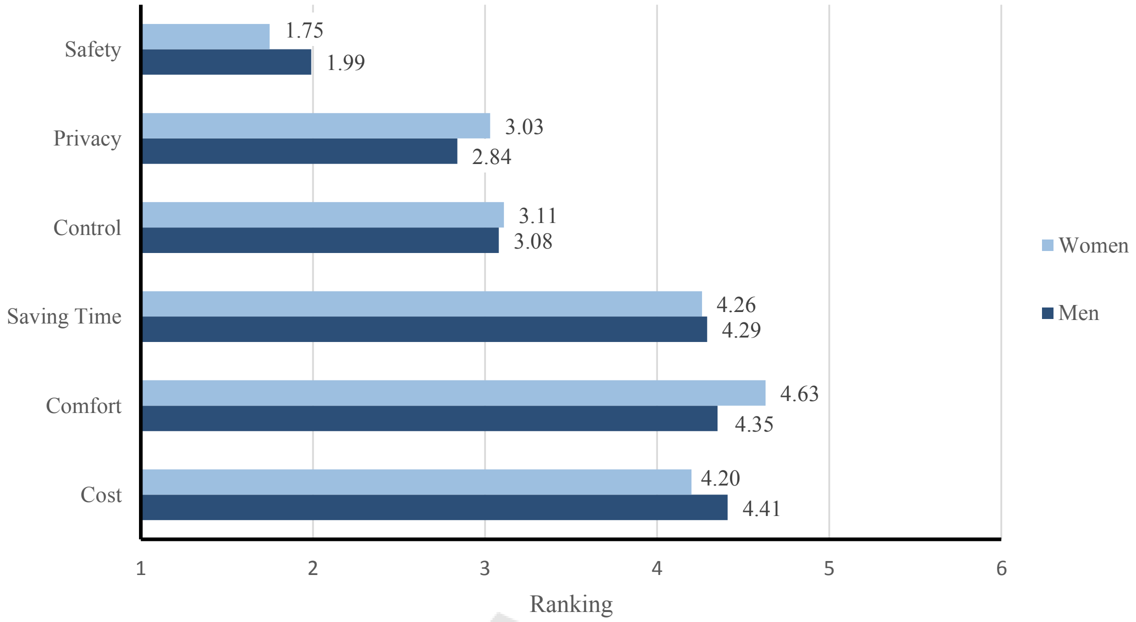

Figure 3: Average ranks of V2X-evaluation criteria based on gender (1 = most important criteria, 6 = least important criteria).

Finally, several effects of age on the ranking of V2X evaluation criteria could be determined: Age correlated with the items *control* (p=.001, r=.123), *comfort* (p=.001, r=-.150) and *saving time* (p=.000, r=-.183). Therefore, comfort and the economy of time were more important for older participants, while younger people tended to attach higher importance to control aspects.

3.3 Gender

With regard to gender, only a few significant effects were found. The willingness to disclosure which type of road user someone is was higher in women (M=3.23, SD=1.97) than in men (M=2.56, SD=2.19). This effect was significant but small with t(274)=-2.640, p=.009, d=.319 and limited to the infotainment scenario. Moreover, there was no influence of gender on both the willingness to share any other type of data and the question who is allowed to store the information.

In view of the evaluation criteria a quite uniform picture emerged. Both men and women rated safety, privacy and control as the most important criteria for evaluating V2X-technology. However, the ranking of safety was more important for women (Mdn=1) than for men (Mdn=2) with U=7664.5, Z=-2.831, p=.005, r=-.174. A complete overview of gender-based rankings can be found in Figure 3.

3.4 Technical Affinity

Infotainment. With regard to technical affinity, two significant effects were found. The willingness to share technical data decreases with a lower level of technical affinity (r=.-105, p<.028). Also other personal data about the driver decreases with a lower technical affinity (r=.158, p<. 001).

Traffic Optimization. A close evaluation of the results of the second scenario showed critical significant differences in willingness to share data. A lower level of technical affinity indicates on the one hand a smaller propensity to share the current motion data (r=.105, p<.024) and type of road user (r=.093, p<.047). On the other hand, this group is more willing to share physiological data about the driver (r=-.118, p<.016) and other personal data (e.g. driving experience) (r=-.128, p<.010).

Storage and Ranking. There were no significant differences in the storage and duration of data with regard to technical affinity. There were also no significant differences in the ranking of the important criteria.

3.5 Prior Experience

Infotainment. In this scenario, the group without any prior experience denies to share any kind of data except the information about what type of road user they are (M=2,73, SD=2,11). The group with prior experience however would share the type of road user (M=3,09, SD=2,10), current motion data (M=3,04, SD=2,05) and the intention to move (M=2,84, SD=2,11). The other types of data are denied by both groups, which individually answered below an arithmetic mean of 1,60 (below 2,50 = rejection).

Further, the unexperienced group showed significantly lower scores in the following data types: current motion data (t(265)=-2.208; p<.028), intention to move (M=2,19, SD=1,99) (t(265)=-2.579; p<.010) and information of past trips (M=1,09, SD=1,54) (t(264)=-2.062; p<.040).

Traffic Optimization. The group without prior experience and the group with prior experience would both share what type of road user they are (M=3,15, SD=1,97; M=3,86, SD=1,63) and the current motion data (M=3,26, SD=1,79; M=3,83, SD=1,48). The experienced group would also share their intention to move (M=2,52, SD=2,12). As we can see in figure 4 the experienced group has higher agreement scores overall. The only exception is the vehicle specification (M=1,45, SD=1,88), which data both groups do not want to share, but the unexperienced slightly more (M=1,48, SD=1,84).

Here again, the assent of participants without prior experience was significantly lower in four different types of data, namely type of road user (t(264)=-3.177; p<.002), current motion data (t(265)=-2.832; p<.005), intention to move (M=2,03, SD=1,91) (t(264)=-1.982; p<.049) and information of past trips (M=1,21, SD=1,62) (t(265)=-2.767; p<.006).

Storage and Ranking. The critical issue of storing data did not show any significant differences between the experience groups. There were no significant differences in the ranking of the important criteria with regard to prior experience.

4 DISCUSSION AND CONCLUSION

The current study was directed to the diversity of future V2X-technology users and their manifold privacy issues regarding context-based traffic scenarios. V2X-technology is focused by an increasing research community, often regarding technical issues (Ardelt, 2012, Lefevre, 2013). Nevertheless, the most important factor for the success of V2X-technology concepts is the user himself and the public perception and acceptance in order to gain enough trust regarding the conscientious handling of personal data and private information needed.

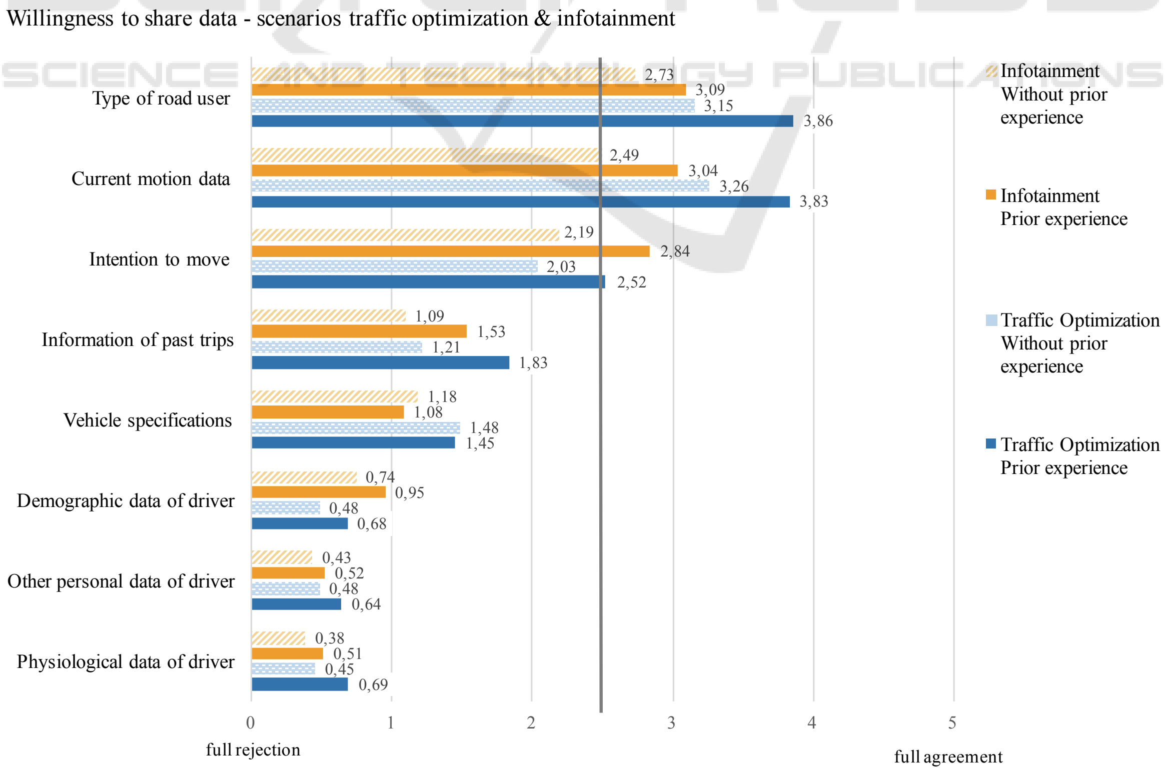

Figure 4: Arithmetic means of data sharing agreement differentiated by roadside scenario and prior experience.

In order to get a first impression on what information would be shared with this novel technology, we used a well-educated, but diverse sample. With a wide age range and a symmetrical gender distribution, it was possible to take a closer look on both user specifications. Further, the participants were questioned about general and traffic addressing information about themselves in order to characterize the sample into diverse user types such as prior experienced with driver assistance systems or technical affinity - which we believe are key factors for the acceptance of new intelligent technologies.

An introduction to two different traffic scenarios set the focus towards a distinguishing level of efficiency for daily traffic situations. In the infotainment scenario, no further benefit except more information about a city or a region could be gained. Here we could identify that women are more willing to share what type of road user they are. This can maybe be connected to the fact, that saving time and cost was more important to women in comparison to men. Overall, the most important factor for all participants regardless the group specifications was safety – which validates past research results of Schmidt et al. (2015a).

Further, the results of the infotainment scenario show that also prior experience has effects on the propensity to share data. To sum up, without prior experience with driver assistance systems, almost no data would be shared in general. Here we can conclude, that more experienced drivers do understand or trust in the possibility of an increasing information support. Or it is possible that non-experienced drivers simply mistrust the technology. Comparing the amount of shared data of non experienced drivers to the data a simple navigation system uses – which is at least the direction in which the driver is moving, speed and route – this finding is rather surprising. For a situation without further benefit as information support, they are not willing to share information with the infrastructure. This leads to the question, if traffic participants are generally aware of current privacy situations (e.g. privacy settings of a navigation system or application) and if they are aware of how detailed the information is, which is already shared with that kind of technology.

The second scenario showed the ability of V2X-technology to increase the driving efficiency by optimizing the behavior of all traffic participants. Here could be identified that younger people tend to be more curious about the disclosure of technical information about their vehicle, whilst older people have less concerns about their intention to move (direction or destination). Regarding an overall look at the data, the intention to move would not be shared by the overall sample. This finding is extremely confusing, because the optimization of traffic cannot work without knowledge of the theoretical next position of all traffic participants. Not sharing that information would immediately interfere with the given scenario. Further, even common technologies like navigation systems need and receive the drivers' intention to move via destination input and these are frequently used support systems (Yamashita, 2004).

In comparison can be seen that physiological data, demographic data and other person data would not be shared by either one of the prior experience groups. This is interesting, because people are not willing to give too many information about themselves as drivers to the infrastructure – not even for more efficiency in the overall traffic behaviour. Here we can see that privacy is very important, which can be seen in the ranking of the V2X-evaluation criteria.

Nevertheless, we can see, that experience seems to be a crucible factor of willingness to share data – even more if there is a benefit in traffic behaviour and not only more information. Bringing V2X step by step to the user or even integrating users in the development of the technology is therefore an inevitable step for further research.

Another fruitful research topic could relate to the different cultural attitudes with respect to safety and data privacy – as different countries show different legal and societal etiquette to handle this trade-off.

A very different outcome could be identified for the question how long which data may be stored and which authority may be allowed to store it. Neither gender, nor prior experience or technical affinity have any influence here. Only older people were willing to accept longer periods of storage in the traffic optimization scenario, which is the only effect detected so far. This result leads to the conclusion that duration (short-term storage is preferred in all scenarios and groups) and storage are kinds of universal factors. Here, no user diverse influence could be found. In the cases of long-term storage, there is an undeniable reluctance towards sharing private data with companies or other traffic participants on the one hand. One the other hand, traffic management, such as police or the infrastructure itself are however increasingly entrusted with private information. Also surprising is the result, that companies are entrusted with information in the shortest duration possibility (capturing and processing). The results show no explanation for this outcome. Therefore, a closer research may be able to identify possible reasons.

Also, the understanding of privacy and data sharing in general should be questioned as well as possible trade-offs and drawbacks. This would lead to a deeper understanding about the already shared data in persons daily lives out of the user's perspective. Further future research should also compare more fatal roadside scenarios in order to see, if traffic participants are willing to share personal data to protect themselves and others.

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