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Public Perception of V2X-Technology – Evaluation of General Advantages, Disadvantages and Reasons for Data Sharing with Connected Vehicles

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Abstract— **This work aims at an evaluation of vehicle-to-infrastructure (V2X)-technology through the users' perspective. The technical opportunities of connected vehicles are affected by the acceptance of the technology and possible draw-backs on the privacy and data-security side. With a three-tiered research approach, this work identified beforehand argument lines in focus group discussions, which enabled a quantitative approach to evaluate positively and negatively perceived features of V2X-technology. Also gender related differences can be displayed. Further, the results of the second quantitative study indicate that although users who already have experience with driver assistance systems are more willing to share (personal) data to use V2X-technology, the overall sample is very reserved with respect to sharing driver-related data. Future research on user diversity and cultural differences is outlined.**

I. Technical Opportunities of Connectivity

The connectivity of vehicles, but also of pedestrians and cyclists, proliferates due to recent advances in mobile communication technologies. The huge market penetration of smartphones and consumer electronics devices enables the exchange of data between all traffic participants. Additionally, legislative activities enforce the connectivity of vehicles. In Europe the eCall system is mandatory [1] and the US aims to enforce vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communication as standard equipment [2]. Therefore, the robust and reliable exchange of data between traffic participants is technically feasible and will be available in close future. Connectivity provides great potential to not only improve energy efficiency [3] but also enhance traffic safety and reduce fatalities. The collaborative availability of information on vehicles, pedestrians and cyclists allows systems to e.g. warn drivers and hence avoid critical situations [4]. The performance of these systems strongly depends on the positioning accuracy, the communication technology used and the consent of users to share information with other traffic participants. The impact of technical influencing factors is assessed in several research studies and determined well [5]. Contrarily, the general consent of users to provide information, which is a fundamental requirement to grasp the benefits of connectivity, needs to be analyzed in more detail. This paper focuses on the users' perspective towards connectivity in order to determine the prerequisites for the introduction of connected systems.

II. Acceptance in and Trust of Novel Technological Developments

As early as in the late 80s of the last century technology acceptance and public perception of technical development has become a prominent research issue [6]. Nowadays an awareness that novel technology is not always capable being seamlessly integrated into customers' and public perception is raised. For pragmatic reasons, one could assume that any novel technology naturally evokes concerns and criticism in the launching phase, but these concerns decrease over time whenever customers get attuned to the technology. Another wide-spread assumption is directed to the fact that a powerful marketing might solve most of public concerns after technology products are already rolled out into the market. From a social science point of view however, both assumptions seem to be not far-reaching enough. Especially large-scale technologies are critically viewed or at least ambivalently by the public [7]. In contrast to technical artifacts (e.g. mobile devices), people have difficulties to comprehend or control large scale technologies, which leads to feelings of insecurity, aloofness and ultimately in rejection of the technology [8]. It has been shown that the users' perceived risk of a novel technology and the rejection probability are negatively correlated with the familiarity, the knowledge and information depth [9]. It was also found that personal factors as age or gender do considerably impact risk perceptions towards large scale technologies [10]. Beyond individual factors, which impact the acceptance for large-scale technologies, humans try to avoid unknown risks associated with technologies in general [11] and large scale technologies in particular [9]. Thus, public perception and users' acceptance should be implemented as early as possible within the technology development in order to adapt technology decisions in line with the fears and wishes of the customers. The research field of connected vehicles and infrastructure requires more personal data of both active (e.g. driver) and passive traffic participants (e.g. pedestrian,

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passenger) [12], [13], [14]. Therefore, a profound understanding of the users' acceptance or reluctance towards the technology is essential for future research. Both, privacy and data security concerns constantly increase as can be seen in various research fields for developing technologies as the internet itself [15], [16], [17], social media [18], [19], online banking [20] or medical technology [21], [22]. However, there is a lack of research on privacy and data security issues on V2X-technology out of a social science perspective.

Furthermore, from a legal point of view, sharing personal information to others makes all entities with access automatically co-owners of that information [23]. This underlines that benefits of data sharing and the guarantee of protecting (and not imposing) personal data is an important and fragile part that needs to be transparently communicated to potential users – especially in connected technology as V2X. Otherwise, future scenarios like fully automated driving are hardly to be realized without public protest. Trust –in technology and those how design technology– could therefore be an essential acceptance trigger. Different strategies are known to gather trust in various fields of research: As is known, (previous) experience and domain knowledge can be a trigger for trust, which can be seen in Internet research [24], e-commerce [25], [26], information technology [27], or computer based systems [28].

III. Questions Addressed and Logic of Procedure

In this present work, V2X-technology is looked at out of a social science perspective. With focus on the users' perception of V2X-technology, its alleged benefits as well as a close analysis of different user profiles, a three-tiered empirical analysis procedure was performed. First, focus group studies were carried out in which we identified argumentation lines, daily situations the users would appreciate technical support in form of connected driving as well as general benefits and barriers. Based on the outcome of the focus groups, a quantitative study was undertaken to evaluate the users' (perceived) advantages and disadvantages of V2X-technology. A second quantitative study was carried out in order to evaluate users' willingness to share (private) data and to identify possible trade-offs (e.g. privacy vs. efficiency). With this procedure, an empirical identification of relevant social factors, which decrease or increase the willingness to share data (i.e. with the infrastructure) as well as the ascribed trust in connectivity in V2X-technology, was realized. Altogether, three main questions will be addressed:

- Which advantages and disadvantages are perceived in V2X-technology?
- Which data are the diverse users willing to share?
- Which role plays experience with driver assistance systems in the evaluation of data security and privacy?

IV. Study I: Public Perception of Advantages and Disadvantages

Using a questionnaire approach, the perceived advantages and disadvantages of V2X-technology were quantitatively assessed. All participants were instructed through an informative introduction, what vehicle-to-x-communication and –technology is. No prior knowledge was needed to participate. The items used in the questionnaire were based on a prior focus group studies (n=18).

A. Survey (I)

The advantages (as identified in the focus groups) were classified among three criteria: safety (road/traffic safety, driver safety), comfort (sense of security, driver support) and efficiency & costs (fuel savings, time efficiency). An overview is given in Table 1:

TABLE I. Item example of perceived advantages of V2X-technology

Usage of V2X-technology is positive, because…?	
safety	… safety in traffic will increase. … it increases the driver's safety.
comfort	… it reassures a sense of security. … it makes driving with unfavorable conditions (e.g. poor visibility) easier.
efficiency & costs	… it helps me saving fuel. … it helps saving time.

With respect to the disadvantages, the most prominent drawbacks (derived from focus groups) centered around privacy and data handling. Three main categories were specified and analyzed: the general impairment of privacy & data control, the possible illegal access to data and the identifiability in terms of spatial traceability (see Table 2).

TABLE II. Item example of perceived Disadvantages of V2X-technology

Usage of V2X-technology is negative, because…?	
privacy & control	… violation of privacy. … loss of data control.
illegal access	… collection of personal data. … second use of data. … data use by unauthorized entities.
(position) identifiability	… localization of position. … tracking of movements.

Items had to be answered on 6-point Likert scales [29] (with high confirmation indicated by high numbers). The acquired data was treated as interval-scaled [30] and checked for normality. Therefore, parametric statistical tests, i.e., analyses of variance (ANOVA), were used for data analyses. In addition, results were double checked with non-parametric tests, whenever permitted by functional scope. As it is common practice in empirical social science research, the significance level was at $\alpha = .05$. Results on the less restrictive level of $\alpha < .1$ are reported as marginally significant.

B. Participants

In the first quantitative study, a total of 169 participants took part with an age range of 17 to 68 years (M=32.2; SD=12.6). The gender distribution is symmetrical with 85 men (50.3%) and 84 women (49.7%). All participants hold a driving license (age 17 holds a license for accompanied driving). The sample contains 42.6% with a university degree (n=71), followed by 41.4% with a technical college degree

(n=70) and 8.9% did vocational training (n=15) plus 7.1% stated another level of education (n=12).

C. Results

The result section is structured as follows: First we report on the perceived advantages of V2X-technology (alongside the dimensions "safety", "comfort" and "efficiency & costs"), followed by the perceived disadvantages of V2X-technology (alongside the dimensions "privacy & control", "illegal access" and "identifiability").

Advantages When focusing on the advantages, women throughout evaluated V2X-technology more positive than men (significant omnibus effect $F(1,157) = 2.1$; $p = 0.05$). Descriptive outcomes can be taken from Fig. 1. Beyond the prominent gender effect in the evaluation of V2X-technology, it is noteworthy that - overall - the benefits in safety issues (road safety and driver safety) received the highest scores (road safety: M = 3.4 out of 5 points max.; SD = 1.4; driver safety: M = 3.5; SD = 1.5), followed by comfort arguments (sense of security: M = 2.3; SD = 1.6 and driver support M = 3.2; SD = 1.6). Comparably, efficiency and cost arguments have the smallest share of positive evaluation (fuel savings: M = 2.2 ; SD = 1.6; time efficiency: M = 2.6; SD = 1.5).

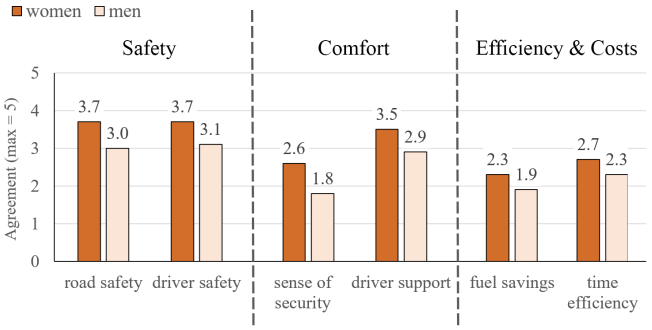

Figure 1. Perceived advantages of V2X-technology

Disadvantages In contrast to the perceived benefits, no statistically significant effect of gender showed up in the perceived disadvantages. Men and women reported to have similar caveats of V2X-technology in the context of privacy and data handling. It is evident from Fig. 2 that the extent of perceived disadvantages is quite high. From a scale of 5 points max. (highest extent of disadvantage), most of the items reach about 4 points, showing that privacy issues in V2X-technology receive high attention among respondents.

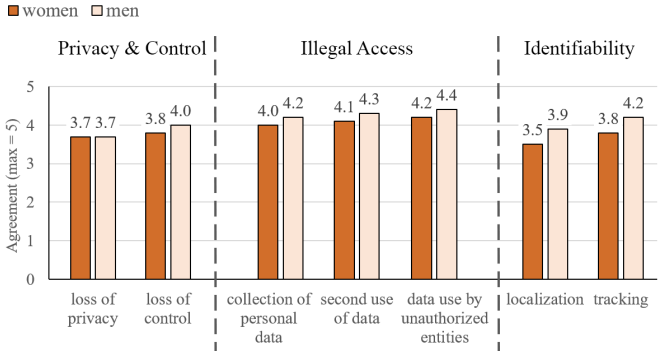

Figure 2. Perceived disadvantages of V2X-technology

D. Discussion

The findings of study I show insights into the public perception of positively and negatively evaluated characteristics of V2X-technology. Among the positive characteristics, safety and comfort are prominent. Especially women report to acknowledge the increased driver safety (saving lives) and the increased safety for the traffic situation as such (including all road users). Perceived concerns are directed to the complex issue of privacy loss and the alleged illegal data access by illegal entities. In this context, distrust and need for control are quite prominent, corroborating the high concerns observed in the focus groups that were carried out prior to this quantitative study. From a psychological point of view, it is noteworthy that participants see both sides of the coin at a time. On the one hand they report to be convinced about the general utility of V2X-technology and they also acknowledge a stronger feeling of "being safe" through V2X-systems. On the other hand, they express their insecurity about loss of control over the data sent by the car and their discomfort facing the risk for illegal data access. What is interesting here is the higher acceptance of women towards the perceived benefits of V2X-technology. This gender effect is special out of two reasons: Firstly – traditionally – men show a higher interest in technology in general (e.g. [31], [32]) and car technology in particular [33]. Secondly, women were found to have a higher responsiveness to risk and uncertainty in novel technologies that manifest themselves in a higher reluctance and chariness in the adoption process of technology (e.g. [34], [35]). On the base of the present findings we cannot resolve this controversial finding. Future studies will have to continue in this line of research and zoom into these gender differences.

So far, we gained first insights into a quite coarse view on public perceptions on V2X-technologies. Especially the identified disadvantages, which center the concerns of the widespread privacy debate, need a closer look. This will be undertaken in study II.

V. Study II: Role of Experience and Type of Data

In this study we set two foci. The first was directed to respondents' willingness to share data, thereby varying different data sensitivities. A second focus was on the effects of participants' previous experiences with driver assistance systems. The latter seems of considerable interest as the familiarity with using novel devices might shape the implicitness of technology as part of our lives. From many other contexts in the area of information technology it is well-known that the more familiar people become with devices, function and services, the more natural the interaction with the technology acceptance becomes [36]. On the other hand, if there are serious acceptance barriers in technology that might interfere with deeply anchored cultural values the smaller is the habituation and the familiarization to novel technologies.

A. Survey (II)

A set of different questions about which types of data users would share had to be answered on Likert scales (high confirmation indicated by high numbers). We asked to evaluate the openness to share (1) driver-related data (demographic information, e.g., age, gender), physiological data (e.g. blood pressure, heart rates), or other personal data (e.g. driving experience, driving habits, health status) and (2)

vehicle-related data (vehicle specifications, information about past trips, intention to move). In addition, we were interested, (3) which reasons for sharing data might be prevalent and acceptable for participants (increased efficiency, increase in driving comfort or getting just timely information).

B. *Participants*

In the second study, a total 145 participants took part with an age range of 21 to 80 years (M=39.9; SD=16.3). The gender distribution is also symmetrical with 74 men (51.0%) and 71 women (49.0%). Of all participants hold 140 a driving license. The sample contains 62.5% with a university degree (n=90), followed by 16.7% with a technical college degree (n=24) and 13.9% did vocational training (n=20) plus 7.0% stated another level of education (n=10). In order to analyze the previous experience with assistance systems (brake assistant, lane assistant, automatic parking, distance control) we divided the sample in two groups; experienced participants and laypeople, depending on the availability and use of the driver assistance technology (see Table 3). 38% (55 out of 145 participants) of the sample reported to neither have nor use those systems; these persons were categorized as laypeople. 70 persons (49%) indicated to have experience with more than three out of the four assistance systems – they were categorized as experts. Persons (N = 20) which do have the systems in their cars but never use them were not included into the analysis.

TABLE III. CLASSIFICATION OF PREVIOUS EXPERIENCE GROUPS

	assistance systems available	assistance systems **not** available
use of assistance systems	experienced	experienced
no use of assistance systems		laypeople

C. *Results*

Data was analyzed by analyses of variance (ANOVA), with expertise as independent variable and the willingness to share data in different contexts as dependent variable. Results on the openness to share data with respect to driver-related and vehicle-related data are presented in Fig. 3. First, results on driver-related data are reported (Fig. 3, left side). A significant main effect of data type was found ($F(2,122)=3.1$; $p=0.05$), but no difference between laypeople and experience users. As main effect, participants are more willing to share demographic data in comparison to personal and physiological data, which participants want to hide. Overall, though, it is more than obvious that opinions –beyond the statistical difference– show a homogeneous "No" towards sharing of driver-related data. A different picture emerges with respect to vehicle-related data (Fig. 3, right side). Inference statistical testing revealed a significant effect of data type ($F(2,122)=64.4$; $p<0.001$) as well as a marginally significant effect of experience with driver assistance systems ($F(2,122)=2.6$; $p<0.1$) on the willingness to share data. The biggest openness was identified for the intention to move, followed by information on past trips. The lowest openness was found for vehicle specifications. With respect to the sharing of vehicle-related data, people with higher experience with driver assistance systems tend to be more open in comparison to laypeople, which have a more negative perception of sharing data in this regard.

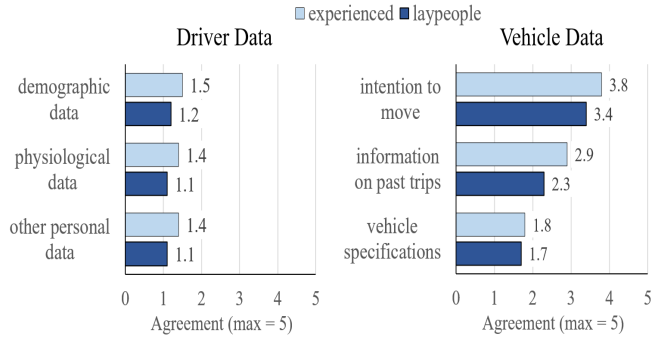

Figure 3. Openness to share driver-realted data (left side) and vehicle-related data (right side)

Beyond the openness to share data we wanted to learn if there are reasons that would justify data sharing out of the perspective of participants (see Fig. 4). A significant difference ($F(2,111)=25.6$; $p<0.001$) between the reasons to share data was found. The reasons "get timely information" and "increase driver and road safety" were evaluated as more convincing in comparison to "increase driver comfort". Although, there was no significant effect, the persons, which have experience in using driver assistance systems, show an overall higher agreement to the reasons for data sharing.

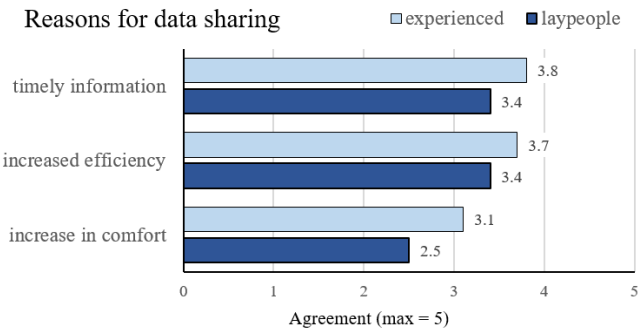

Figure 4. Reasons for data sharing

A final analysis was directed to the question how data – if at all – should be collected. Participants had to indicate whether they prefer an active data transmission (e.g. by car, or smartphone) or a passive data capturing (by external sensors) or a combination of both. Fig. 5 shows the outcomes. As found, experienced persons indicate more often to prefer a passive acquisition of data in contrast to laypeople which do not show a clear preference for either of the alternatives presented.

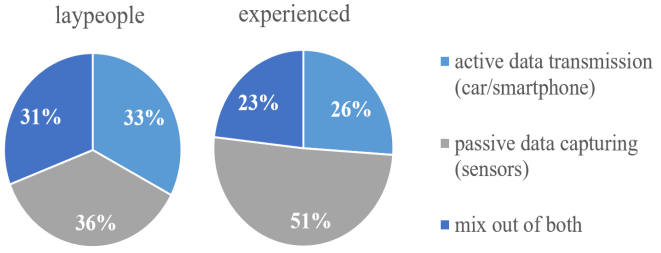

Figure 5. Perceptions on how data should be collected

D. Discussion

The results of study II show insights into the public perception of privacy protection and data security in connected vehicles and evaluated users' reasons for data sharing. The need for privacy and data security was examined with a close analysis on possible differences between experienced users of driver assistance systems and laypeople. In contrast to a strong experience effect on acceptance in other technologies [37], experienced users did not show large differences in their perspective on privacy and data security. Overall findings reflect a broad reluctance toward sharing driver-related data. Interestingly, the more personal the data are, the less willing the users are to share them. As reasons, a lack of trust in the handling with private data of "co-owners" can be suggested or a general non-understanding why e.g. demographic data is needed for connected vehicles at all. While the first reason might be addressed by a transparent communication policy, the latter is a matter of information which is needed by the public.

Regarding vehicle-related data, a willingness to share the intention to move for both groups was found. An effect of experience was found in this context: The experienced group had an even higher agreement score compared to the laypeople, which supports the assumption that experience with a technology increases the trust in it [38]. Today, navigation systems work with the same kind of localizing data (via destination input) and they are frequently used and accepted at this time [39]. But in this particular case, the information is not only shared with the technology in his/her own car, but with the whole infrastructure as well. Surprisingly, this does not seem to be a major disadvantage (at least, participants did not express it). The strong reluctance to share vehicle specification data was unexpected. We cannot finally exclude that users did not exactly understood for which functions vehicle specifications are needed and why this would be useful. Possibly, the information level about which data is already shared and why is low. This should be examined in further studies.

As for the reasons of data sharing, experienced people show – again – more agreement to all given reasons. Here the benefits of using the technology seem to be either more clear, appear more attractive or the technology itself enjoys a higher trust, because users might simply transfer previous (positive) experience with one vehicle to another.

Of course, the lack of hands-on experience with V2X-technology should not be underestimated. Nonetheless, a given experience with assistance systems (e.g. distance control or lane assistance) seem to play a role for data sharing. Here, the preference of passive data transmission hints an understanding of needed data for improved performance. However, testing experienced and laypeople on-site with V2X-technology is a must for future research in order to substantiate effects of experience as major acceptance factor.

VI. Conclusion and Outlook

The present work portraits a social science perspective of V2X-technology. We conducted empirical studies focusing perceived advantages and disadvantages in V2X-technology. It was questioned which data would be willingly shared and if experience with driver assistance systems plays a role in the evaluation of data security and privacy. In the matter of advantages, foremost the increase of safety in traffic and for the driver were perceived the strongest. Driver support was also perceived positively. Time efficiency, fuel savings or the given sense of security are perceived as weaker arguments. Disadvantages were perceived stronger than advantages. Illegal access to personal data, the second use of it, unauthorized use as well as privacy issues are the strongest drawbacks so far. Here, a transparent and honest communication to future users about data handling and security options is strongly recommended.

When it come to the question which data the diverse users are willing to share, a broad "no-go" was identified with respect to the sharing of driver-related data. Vehicle-related data, in contrast, (e.g. intention to move) was seen less critical.

Last, the experience with driver assistance systems seems to play a role in the evaluation of data security and privacy, even if it is a minor one, with the limitation that we did not consider real V2X experience, but solely experience with automated drive assistance (what still could make a difference). Further future research should therefore aim at capturing the effect of experience V2X-technology. In this context, two major foci should be set: one is the understanding of experience and expertise in order to sensitively understand, if more experience with V2X-technology is accompanied by a reduction of perceived risks (regarding privacy loss, fear of surveillance) or an increase in trust (regarding higher road and driver safety). Secondly, V2X-technology should be examined in a more realistic context (rather than merely capturing attitudes or options). As such, customers should have the possibility to use and interact with connected cars in experimental studies in order to allow a more practice-oriented and transferrable valid evaluation of such a novel technology.

Several implications for future research and practical development emerge from these findings. An empirical research approach over a three-year period of time is planned, for the on-site investigation of users' perceived advantages and disadvantages of V2X-technology. Questioning a possible trust-shift via test-experience, user diversity in combination with acceptance issues will be used as an integral part of technical development.

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