Share to Protect

Quantitative Study on Privacy Issues in V2X-Technology

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Abstract. Currently, V2X-technology is a highly prominent research topic. The numerous advantages, possible applications and development opportunities of this intelligent technology connection into everywhere traffic situations encourage research associations worldwide to work together. Main goals are the reduction of traffic accidents, optimization and increase of energy efficiency and formation of a dense information network. However, without the acceptance of the technology from the users' side, the needed data and information may not be provided. In order to understand the users' attitude towards privacy and data security, the present study focuses the willingness to share data depending on different traffic situations. Using an empirical research approach, it can be stated, that users tend to be more willing to share (different types of) data to reduce the probability of a severe event. Although the necessity is transported, a general rejection of transferring (any kind of) data could be detected.

Keywords: V2X-technology · V2X-communication · Privacy · User acceptance data · Security

1 Research Perspective and State of the Art

The steadily growing motorized individual traffic in metropolitan areas and the urban environment is a significant part of the quality of life enhancing mobility today. With reports on more than 300,000 traffic accidents each year (in Germany), which involve personal injuries or mortality, it is still a dangerous and unsafe part of life. In these accidents, human error is still the most common cause [1]. Technology can be used to reduce traffic accidents, which can be confirmed by the decreasing number of automobile crashes during the implementation of driver supporting systems [2, 3]. This highlights the clear potential of improvement in the economic and ecological balance of road traffic through the implementation of novel technologies. A promising approach addressing the safety and economical problems is the use of innovative transport technology.

By networking traffic participants among themselves and with their environment (Vehicle-to-X), the transport may become not only safer, but more efficient, more environmental friendly and more comfortable. In this sense, driver assistance systems

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(e.g. adaptive cruise control), which work with information exchange through on-board sensors, have already been established. Vehicle-to-X-technology (V2X), is based on the exchange of transport-related real-time data. Given the extent of the obligatory data collection in the context of successful and effective V2X-communication, critical aspects arise on protecting the privacy of their users [4]. The many possibilities of surveillance and mass data collection are negative contrasts to personal (motion) freedom. However, the success of V2X-applications can only be secured if users are willing to disclose information about themselves. To launch V2X-technology into actual traffic scenarios, it is of utmost importance, that users are willing to share different types of data [5].

By sharing real-time data, the outcomes expect to relieve the driver warning and assistance systems, optimize the intelligent, centralized traffic management, and gain reductions in emissions through more efficient driving [6–9]. Further, connecting all traffic participants prospects an improvement of energy efficiency [10] as well as a reduction of fatalities [11].

Leading goals of the V2X-technology are therefore dependent on traffic participants to share different types of information about themselves with the infrastructure, the vehicle and other traffic participants. For this reason, the involvement of the potential user is indispensable in the system design. According to this claim, this present study analyses user acceptance patterns for privacy and data security aspects of V2X-communication in different traffic situations. With focus on the question if the severity of the situation determinants the willingness to share (personal) data.

Former studies showed, that a refusal of providing the information increases the more personal an information gets on the one hand [12] and on the other hand especially in comfort and infotainment centered contexts.

Overall, the results illustrate a skeptical attitude on behalf of potential users. This leads to the current research question, if an increasing severity of a traffic situation may shift the rejection of transferring data towards an approval.

2 Question Addressed and Methodological Approach

To explore, whether the severity of a traffic situation determinants the willingness to share (personal) data, this research follows a scenario based approach. First, we carried out potential user focus groups to identify traffic situations in which the use of V2X-technology seemed possible and helpful to the participant. Further, we conducted an online survey. To be able to communicate the vision of V2X-communication, we introduced three of the beforehand identified traffic situations with an illustration and informative text. Each scenario represents a situation with distinct characteristics (see Sect. 2.3). The described situation proceeds without damage due to the use of V2X-technology. The following research design was pursued (Fig. 1):

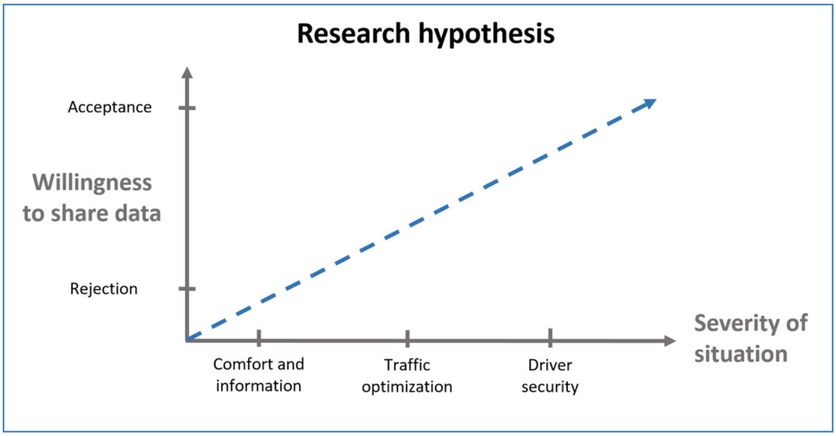

Fig. 1. Research hypothesis: the willingness to share data will increase when the traffic situation becomes more severe.

2.1 Questionnaire Design

The online survey comprises the following elements:

Demographical data of the user was questioned in the first part of the survey. Followed by a question about the driver's licence(s), the experience as driver of a vehicle due to a previous or current job (parcel service, truck driver, emergency service etc.) was queried as well as the frequency of vehicle usage. Further, the technical self-efficiency was measured [13], the individual confidence in one's capability to use technical devices. Closing this part, the participants should indicate their individual driving behaviour with a set of 11 items (6-point Likert scale, 5 = full agreement) regarding risks in traffic.

The next section introduced the traffic situations, which let participants envision the use of V2X-technology on different levels. A closer description follows (see Sect. 2.2).

The following section comprised privacy and data security. With a set of seven items (6-point Likert scale, 5 = full agreement), the type of (possibly shared) data was questioned. Here, we divided the data types as follows:

- 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)

Further, the storage duration (capture and process, short term, long term) of the data and possible recipients (local road users, local road infrastructure, central servers of traffic management and public authorities, central servers of companies) were identified.

2.2 Scenarios

The following traffic situations were introduced to demonstrate different possibilities of interaction between the vehicle, the driver, the infrastructure and other traffic participants.

Driver (and Vehicle) Security. Participants had to envision to be the driver of a car, which drives on a highway towards the end of a traffic jam. However, the end of the traffic jam is hidden behind a curve, but as all cars are equipped with V2X-technology, the information about the jam arrives in the participant's car early enough to start a slow down. The severity of the situation is classified high (see Fig. 3).

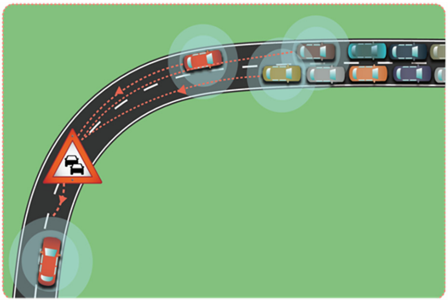

Fig. 2. Medium severity classified traffic situation.

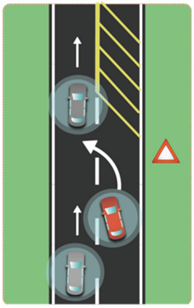

Fig. 3. High severity classified traffic situation.

Optimization of Traffic. Again, out of the perspective of the driver, the second scenario described a situation in which the participants are driving on a multilane way. With the right lane ending, their car need to rearrange to another line with the zipper method. To improve or maintain the traffic flow, the communicating vehicles use V2X-technology, which also allows a reduced fuel consumption. The severity of the situation is classified as medium (see Fig. 2).

Comfort and Information. The participants had to envision to drive through an unknown city. The smart vehicle is able to actively give them information about touristic spots, shopping malls or cultural events. Using V2X-technology, the car communicates with the infrastructure or city itself and displays all possibilities onscreen in the car. Information about opening hours or entry fees, e.g. of a nearby museum can also be displayed. The severity of the situation is classified low (see Fig. 4).

2.3 Sample

In total 169 people participated in this study. Their age ranged from 17 to 68 years with an average age of 32.18 years (SD = 12.63). 50.3 % (n = 85) participants were male, 49.7 % (n = 84) female. The most-often stated educational attainment was a university degree (43.2 %, n = 73), followed by the graduation from high school (41.4 %,

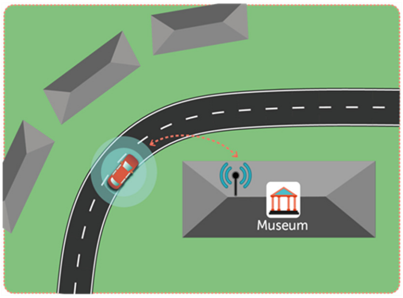

Fig. 4. Low severity classified traffic situation.

n = 70) and vocational trainings (8.9 %, n = 15). The remaining participants completed secondary school (6.5 %, n = 11). The technical self-efficiency in the sample was rather high with M = 3.68 (SD = 1.12, scale min = 0, scale max = 5).

All participants hold a driving license for passenger cars. With regard to the private vehicle use the following frequencies arise: 59 participants (35.1 %) used their car(s) on a daily base, 46 used it 1-3 times a week (27.4 %), while the rest drove less than one time a week. Furthermore, 29 participants (17.2 %) were professional drivers, i.e. taxi or bus drivers, courier drivers or truck drivers. Almost half of the participants (47.3 %, n = 80) had previous experience with driver assistance systems, e.g. park assistance, distance control or lane assistants. The average willingness to take risks in road transport was rather low (M = 1.70, SD = 0.81, scale min = 0, scale max = 5).

3 Results

The presentation of the results is structured as follows: First, the willingness to share different types of data in the scenarios studied will be presented. Second, the consent to the capturing, processing and storing of data by various possible users will be described.

3.1 Willingness to Share Data

The willingness to share data varied to a great extend depending on the type of data and the purpose of use (see Fig. 5). Significant main effects of data types were found in all scenarios (*Security*: F(7,162) = 81.844, p < .001, *Optimization*: F(7,162) = 68.594, p < .001, *Comfort*: F(7,160) = 27.747, p < .001). However, the effect sizes decrease from the security-related scenario to the optimization-related and finally the comfort-related scenario.

Besides the effects of data type scenario-based effects could be observed. Pairwise comparisons of the scenarios revealed that the willingness to share a certain type of data differs significantly depending on the purpose of use. For most of the data types the following rule was observed: The higher the severity of the usage context the more likely participants were willing to share information (p < .05 for all pairwise comparisons). Exceptions were found regarding the current motion data, information about the intention to move and the demographic data of the driver: First, the participants did not distinguish between the security- and optimization-related scenario regarding their willingness to exchange data about their current motion (pairwise comparison n.s.). Second, highest approval rates regarding sharing information about the intention to move and the driver's demography were found in the scenario related to comfort improvements.

Statistical analyzes with gender, age, technical-self-efficiency or risk taking in road transport as between subject factors in the repeated measurement design revealed no significant effects on the differences between the scenarios regarding the willingness to share data.

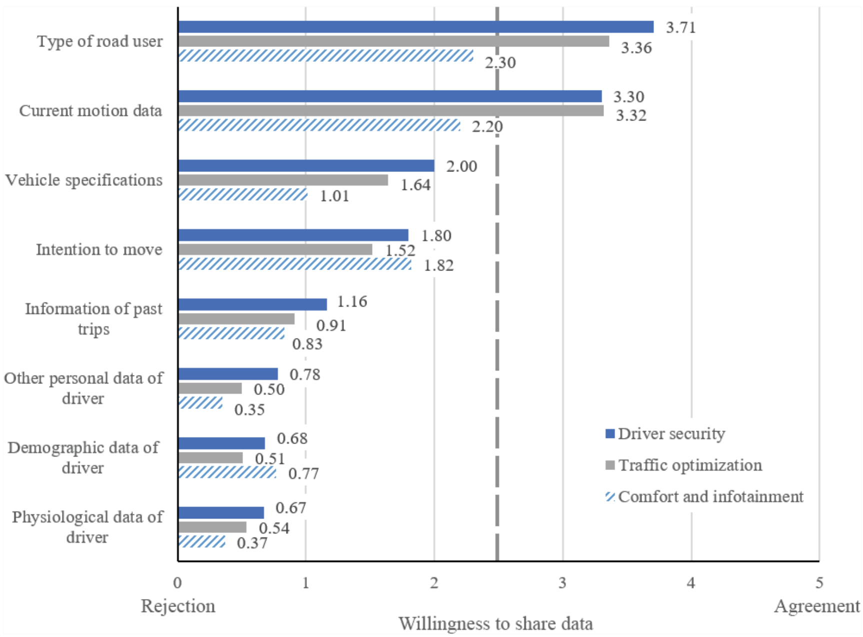

Fig. 5. Average willingness to share various types of data differentiated by the purpose of use

Overall, a willingness to share data could only be shown for two types of data in two specific scenarios. Only information about what type of road user the participant is, e.g. pedestrian, bicyclist, or car, (*Security*: M = 3.71, SD = 1.64; *Optimization*: M = 3.36, SD = 1.91) and current motion data (*Security*: M = 3.30, SD = 1.68; *Optimization*: M = 3.32, SD = 1.72) achieved positive approval ratings (M > 2.5) regarding the data exchange for the purpose of security or optimization. Regarding comfort-based scenarios a neutral to slight rejecting position could be shown for the same types of data.

Regardless of the scenario, the transmission of all remaining types of data was rejected averagely, e.g. information of future (*Intention to move*, M_{max} = 1.82, SD = 1.95) or past movement (*Information about past trips*, M_{max} = 1.16, SD = 1.60). The lowest openness was found regarding personal data. There was a strict rejection to share demographic or physiological data, as well as other personal data of the driver (M < 1.0 for all scenarios).

3.2 Data Users

Beside the types of data, the information's possible users and usage was analyzed and will be presented in the following section. To begin with, the possible users who should be allowed to capture and process data will be described. Afterward, the short- and long-term storage of data will be explored.

Capturing and Processing: In summary, a majority approval for the acquisition and processing of data was found for all queried user types and all purposes of use (see Table 1). However, significant main effects of user type were found regarding all scenarios (*Security*: Cramer-V = .235, $p < .001$, *Optimization*: Cramer-V = .205, $p < .001$, *Comfort*: Cramer-V = .114, $p = .032$). Regardless of the specific scenario, the highest approval rates were found for local road users (> 64.5 %), followed by the local infrastructure (> 59.8 %) and central servers of traffic management (> 52.7 %). Overall, the lowest agreement was found for companies as potential data users (> 50.3 %).

Table 1. Consent to the **acquisition and processing** of data by various users differentiated by the purpose of use.

	Driver security	Traffic optimization	Comfort and information
Local road users	81.7 %	78.7 %	64.5 %
Local road infrastructure	68.6 %	66.9 %	59.8 %
Central servers of traffic management	58.6 %	59.8 %	52.7 %
Central servers of companies	52.1 %	52.1 %	50.3 %

In addition, main effects of the scenario type were identified that have to be considered in relation to the potential users: There was a clear and significant distinction between the security- and optimization-related scenarios on the one hand and the comfort-related on the other hand for local road users and infrastructure as well as for servers of traffic management ($p < .05$ for all pairwise comparisons between *Security* and *Comfort* or *Optimization* and *Comfort*). Basically, the approval rates were significantly lower in the comfort-based scenario regarding the aforementioned user groups. In contrast, the presented scenario had no significant effect on the approval rates for companies as potential user that captures and processes data.

Short-term Storage: In addition to the plain acquisition and processing of data, the short-term storage of information up to one week was explored. As indicated in Table 2, the local road users are no longer the preferred data handlers in terms of retention. In fact, the participants expressed higher approval to local road infrastructure and central servers of traffic management as potential storage locations regardless of the presented scenario. Again, companies got the lowest agreement rates. Regardless of the differences between the individual users, short-term storage of data was refused by a majority of the participants for all potential users and purposes of use (max approval rate: 24.3 %).

Table 2. Consent to the **short-term storage** of data by various users differentiated by the purpose of use.

	Driver security	Traffic optimization	Comfort and information
Local road users	15.4 %	15.4 %	10.1 %
Local road infrastructure	24.3 %	20.7 %	14.2 %
Central servers of traffic management	24.3 %	18.3 %	10.7 %
Central servers of companies	11.8 %	10.7 %	8.3 %

Again, main effects of user type and presented scenario could be identified. Pairwise comparisons revealed the already known distinction between the security- and optimization-related scenarios on the one hand and the comfort-related on the other hand for all user groups but companies. Their approval ratings were again independent from the given scenario.

Long-term Storage: Last, the long-term storage in terms of a permanent storage with undefined retention time was analyzed. As shown by Table 3, the overall agreement rates were rather low (< 10 %) for all users and scenarios, whereby a clear rejection of this storage period could be identified.

Table 3. Consent to the **permanent storage** of data by various users differentiated by the purpose of use.

	Driver security	Traffic optimization	Comfort and information
Local road users	1.8 %	2.4 %	3.0 %
Local road infrastructure	5.3 %	5.3 %	3.6 %
Central servers of traffic management	7.1 %	5.9 %	5.3 %
Central servers of companies	5.3 %	4.7 %	5.3 %

Clear preferences in terms of preferred data handlers did not emerge in any of the described scenarios. Accordingly, there were no significant main effects of the scenario type and the potential user group.

In accordance with the willingness to share different types of data, the scenario-related effects were not influenced by the researched user factors.

4 Discussion and Outlook

This research was directed to privacy issues and acceptance patterns in V2X-technology out of a socio-psychological perspective. With an increasing research attention worldwide, the idea of integrating smart vehicles, able to communicate not only with their infrastructure, but also with other (and weak) traffic participants, raises new research directions and ambitions [14, 15]. It is strived for a higher energy efficiency, saving time through traffic [16, 17] and a more secure mobility behavior [18], but also questions about public perception, privacy and technical acceptance rise steadily [19–21].

Therefore, an understanding of perceived data security and the participants' willingness to share data is an inevitable necessity for future V2X-research. Based on different traffic scenarios, this quantitative research approach focused on the question, whether the willingness to share data increases with the severity of the traffic situation. Taking (potential future) users into account and looking at three different traffic events, the results show, that the more severe a situation is perceived, the more willingness to share data can be detected. Although, it seems rather logical to decrease the possibility of a fatal event for "a small price", the trade-off of providing information to ensure the higher safety level is still questionable for the user, which is displayed in the results.

By giving the user the opportunity to offer or decline eight different data types, it became evident, that all data types differ significantly in their likeliness to be shared (in all scenarios and overall).

Although it should be mentioned, that the effect of differentiating likeliness to share data in terms of the data type decreases, the less severe a situation gets. Or in other words: if a situation is not hazardous, there are no perceived differences of data types, but a full rejection.

Overall, a strong rejection to share data is prominent. Only the data types "current motion data" and "type of road user" are agreed upon in all traffic situations. A very strong rejection was given to "physiological data, demographical data and other personal information". From a communicational point of view, user mostly agree on transferred data which relate to a current status (current motion data, type of road user, vehicle specifications). The agreement decreases slightly, when it comes to data, which relate to future information (intention to move). Even less approval was given to data, which maintained information about what happen in the past (information about past trips) and an absolute rejection could be identified to personal data (as mentioned beforehand).

Further, the results show that participants despite the overall rejection show a tendency to be more willing to share personal data in a situation, which increases comfort and provides information compared to increasing safety or optimize traffic.

Possible reasons could be the understanding, that an information about the “intention to move” may be important to generate better information (and/or offers) from the system towards the user. A perceived importance to gather more information about a target location. Also, “demographic data” could be perceived as important for infotainment scenarios, in order of suitable suggestions (e.g. special entry fees for a museum for elderly).

In addition to the willingness to share different types of data, potential users and storage periods of the information have been explored. It became clear that the usage context’s severity effects the agreement to share data with certain user groups. In particular, participants made a significant distinction between security- and optimization-related scenarios on the one side and purposes of use that only aim to increase comfort on the other side. Interestingly, this distinction was not made for companies as potential data distributors, which were not accepted to capture, process or store data by a majority of the sample at all, which hints at a general lack of confidence in commercial exploitation of user information. A similar unambiguous rejection was found regarding the long-term storage of data. Here, even the main effects of the scenario and the user group found for data capturing and short-term storage were covered.

Consequently, the results lead to implications for the development of V2X-technologies: Data exchange in transport cannot be generalized. User’s clearly distinguish between the types of information, the potential receivers and the purposes of use. However, currently a predominantly negative attitude towards sharing data can be identified. Hence, the question arises, what advantages need to be provided, so that the user agrees on the transfer of data and communication. A step forward would be to identify the accepted trade-offs out of a users’ perspective. Not only the user requirements of the so-called early adopter are necessary, but also insights of opponents of this technology should be taken into account in order to integrate a holistic users’ perspective into the early stages of the design circle of new technology, specifically V2X-technology.

Therefore, our next research step will focus on the identification of trade-offs between perceived advantages and drawbacks. Using a conjoint analysis method, which offers the combination of a statistical estimation algorithm and a measurement model. Here, we focus on the future communication and acceptance of V2X-technology in order to include potential users (as active part) and possible opponents (as passive part) in today’s research. To enhance the acceptance of V2X-technologies, it is important to integrate users in the future development. In that way current barriers can be dismantled, because only then can a holistic launch of V2X-communication succeed and gain the full potential of this technology. In order to gain more protection, we need to share information. Share to protect.

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