Safety First?
V2X – Percived Benefits, Barriers and Trade-offs of Automated Driving

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Abstract: Today, we are on the edge of increasing population and urbanization with an increasing portion of older people. These far-reaching societal developments necessitate novel mobility infrastructure concepts, in which a diverse population and a higher population density are considered. Safety in traffic situations is one of the most important and needs to be taken into account. A highly potent approach is to combine in-vehicle systems and vehicle sensors. Whereby the public perception and user acceptance of V2X-technology in general is insufficiently explored. Using a two-tier approach, in which both qualitative and quantitative data are combined, this research gains insights into human perceptions of V2X-technology, plausible trade-offs and basic fears. Results show safety as an important factor which should be included in further future research.

1 INTRODUCTION

No matter if you travel by your personal car, use public transport or car sharing, all of the different mobility options share the necessity of an efficient transport infrastructure. With an increasing older population (United Nations, 2012), new concepts for mobility are needed. The quality, flexibility and adaptability of mobility concepts are crucial cornerstones for technology-developed societies (Dickerson et al., 2007, Schmidt et al., 2015, Ziefle et al., 2014). A promising way to improve today's traffic and transport infrastructure is to integrate technical solutions in form of a combination of in-vehicle systems and vehicle sensors. The technical solutions aim a more efficient and safer transport system by offering drivers a more detailed view of prevailing traffic situations (EU, 2006, van Driel 2007). Another technical solution refers to the connection of transportation means, namely V2X, specifically Car2X-communication. The exchange of information on the technical level between different road users, such as cars, signal systems or intelligent sensor technology in the road surface creates a cooperative environment, in which an assessment of the current traffic situation can be based on more information than there would be available for a single, isolated traffic participant (Endsley and Garland, 2000, Picone et al., 2015). Recent research in Car2X-technologies is concerned with predominately technical infra-structure, e.g. the development of networks for V2X-traffic management (Ardelt et al., 2012, Wedel et al., 2009, Trivisonno et al., 2015), standardization issues for V2X usage across European countries (Weiß, 2011), cooperative driving (Kato et al., 2002, Costeseque et al., 2015) or technical privacy matters (Ma et al., 2009, Lefevre et al., 2013).

When looking at the driver and its changed role within novel V2X traffic situations, the situation awareness and information requirements (Endsley and Rodgers, 1994, Schmidt et al., 2015), drivers' behavior in using automated cars (Merat et al., 2009, 2012) and usability issues in in-vehicle systems were studied. While the importance of the close interplay of social behaviors of drivers and the successful integration of Car2X-technologies into holistic mobility concepts is increasingly gaining attention (Rakotonirainy et al., 2014, simTD, 2013).

As such, users' acceptance of V2X-technology is insufficiently explored. Little is known about the perceived usefulness and the willingness to share information within transport systems or networks as well as the general acceptance of passing over the control to the car in different usage scenarios, especially when the use case requires a higher degree of automation.

In this context, there might be substantial acceptance concerns: both the possible withdrawal

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of perceived control and the sharing of information that may encourage the tracking of users may result in privacy and trust issues (e.g. Ziefle and Schaar, 2011, Schmidt et al., 2015). It is of utmost importance to consider users' perceptions of the usefulness of those technologies, the perceived benefits as well as the barriers of those technologies.

The present work addresses the mentioned knowledge gap and uses an exploratory two-tier approach towards a more complete picture for V2X-technology acceptance. We explore different variants of roadside scenarios, which request a fast reaction of all traffic participants, vehicles or road infrastructure. In order to understand users' acceptance, the scenarios can be addressed by a) either by an autonomous response (takeover of control by the technical system) or b) by assisting the human driver by information delivered by the vehicle system (driver control, but information and communication assistance).

2 METHOD

The empirical approach reported here was based on a prior focus group study in which we identified possible user scenarios and situations the users would appreciate technical support in form of automated driving. On the base of the findings, an empirical survey was constructed seeking to identify both, perceived trade-offs and barriers of the use of V2X-technologies, but also the impact of respective usage scenarios on acceptance.

2.1 The Survey

The online survey was divided into three main parts.
Demographics: The first section addressed demographic data as well as information about the mobility experience, attitudes towards trust and privacy of personal information and control behaviour in general. Also, the technical self-efficacy was measured (Beier, 1999), the individual confidence in one's capability to use technical devices.
Roadside scenarios: In the second section, roadside and user scenarios were introduced to help the participants envision the possibilities to use V2X-technology actively. In the first scenario participants were encouraged to imagine different roles in an intersection situation. The second roadside scenario introduced an intelligent traffic light, which is able to communicate via V2X-technology.
V2X-technology: A set of seven items (6-point Likert scale, 5=full agreement) questioned the usage of V2X-technology in form of benefits (see Table 1) and barriers (see Table 2).

Table 1: Item example of benefits of V2X-technology.

I see benefits using V2X-technology, because…?
… it helps me saving time.
… it gives me a feeling of safety.
… I reveal only information that is mostly public.
… safety in traffic will increase.
… it helps me saving fuel.
… it makes driving with unfavourable conditions (e.g. poor visibility) easier.
… life can be saved with it.

Further, participants were requested to rank different factors due to their own perception of importance: control, cost, comfort, safety, privacy, time (saving), time (flexibility).

Table 2: Item example of benefits of V2X-technology.

I see barriers using V2X-technology, because…?
… I lose control over the collected data.
… I do not want a permanent observation.
… others can keep track on my movements.
… it violates my privacy.
… I do not want to rely on external information.
… it incites me to be inattentive.
… it makes driving boring.

At the end of the last part of the survey a general evaluation of V2X-technology closed this section (see Table 3).

Table 3: Item example of general evaluation of V2X-technology.

General evaluation: Do you agree with the following statements?
- I think V2X-technology is useful.
- V2X-technology would help me with daily trips and journeys.
- I as a driver must have full and instant control.
- V2X-technology has to be strictly regulated.
- I would pay a premium to have V2X-technology in my car/on my smartphone.
- V2X-technology is threatening.

2.2 Participants

In total 81 participants took part with an age range of 22 to 65 years (M=31.5; SD=10.4). With 63% men (n=51) and 37% women (n=30) the gender distribution is quite asymmetrical. The sample contains 67.9% participants with a university degree (n=55), followed by 19.8% with a technical college degree (n=16) and 7.4% (n=6) did vocational training plus 5% stated another level of education. To investigate the mobility-related effects we partitioned the subjects by experience with new mobility service technologies; cruise control and brake assistant, automatic parking assistant, lane assistant and distance control. The first group needed at least to have experienced (or still use) one of the following systems (n=34; 46.6%): the automatic parking assistant, the lane assistant or the distance control. The group consisted of 24 men and 10 women (M=31.4 years, SD=9.8). The second group stated to have no experience with these systems (n=39; 53.4%), and consisted of 23 men and 16 women (M=31.4 years, SD=10.7). All participants reported to be highly technically self-confident (M=4/5 points max.).

2.3 Roadside Scenarios

I. Intersection: The first scenario invited the participants to envision a situation in which they are driving a car towards a pedestrian crossing (see Figure 1). Covered by a house or a parked vehicle and thus not visible, a pedestrian wants to cross the street right in front of them. Distraction or bad weather could also be reasons for a limited vision (Le, 2009).

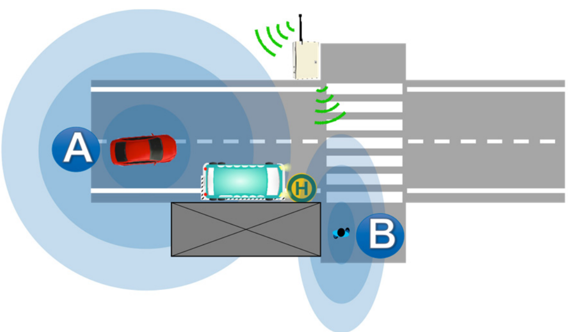

Figure 1: Intersection situation. A car (A) drives towards an intersection and a pedestrian (B) crosses the street at the same time.

II. Green light: Participants had to envision the roadside scenario in which they are again the driver of a car. In this scenario, they are driving towards a traffic light (see Figure 2). The traffic light receives the information of all upcoming vehicles with the help of V2X-technology. The traffic light can adapt the green light phases to the traffic load in order to minimize the average waiting times for all vehicles. This situation could also be helpful for light control by emergency warning (Le, 2009).

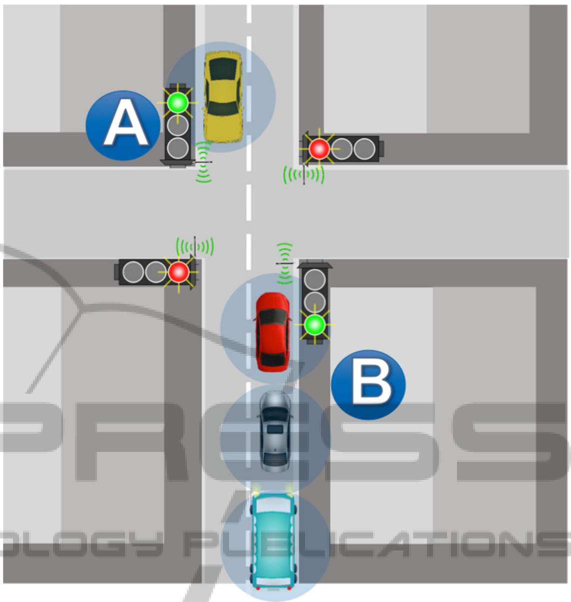

Figure 2: Green light situation. Traffic light sensors the traffic load and minimizes the average waiting times.

3 RESULTS

Data was analysed with parametric statistical evaluation methods (Analysis of variance (ANOVA)). The level for significance was set at $p=.05$. We report the perceived concerns and benefits related to V2X-technology. First, the participants were invited to agree or disagree to different pro and contra V2X-technology statements. Further, they were instructed to rank different measurement criterions by perceived importance.

3.1 Perceived Benefits

The highest approval values were found at statements regarding safety-related benefits. On average, the participants agreed that V2X-technology can save human life (M=3.8/5 points max, SD=1.4) and increase road safety in general (M=3.7, SD=1.2). In addition, it was considered a benefit that the technology could be able to simplify driving under difficult circumstances, such as poor visual conditions (M=3.4, SD=1.5).

Although an increase in safety was basically attested, there was neither a clear agree nor disagree to the question whether "increasing the subjective sense of security would be a positive aspect of V2X-technology" (M=2.5, SD=1.5). A similar ambiguous picture was found for the participants' evaluation of the reduced fuel consumption by V2X-technologies (M=2.4, SD=1.7) or saving of time (M=2.7, SD=1.7) as possible benefits of V2X-technology.

Also, gender differences showed up (see Figure 3). While men had an almost neutral attitude towards fuel savings as a benefit of V2X-technology (M=2.7, SD=1.7), women tend to disagree (M=2.0, SD=1.6) (F(1,78)=4; p <.05). Similarly, female participants disapproved the benefit of saving of time of using V2X-technology (M=2.1, SD=1.7), while men agreed (M=3.1, SD=1.5) (F(1,77)=7.1,p<.05).

3.2 Perceived Barriers

With regard to the possible barriers to the use of V2X-technology especially statements dealing with privacy and data protection provoked serious concerns (high approval ratings). On average, the participants agreed that both the perceived loss of control regarding which data is collected at the end (M=3.5, SD=1.4) and the felling of being permanently observed (M=3.4, SD=1.7) are reasons to consider technology as negative. Furthermore, participants disliked both the alleged traceability of personal movements (M=3.1, SD=1.7) and the felt violation of privacy (M=2.9, SD=1.7). A similar pattern was found regarding the question whether V2X-technologies could lead to inattentiveness (M=2.8, SD=1.6), while the wish to avoid a reliance on external information got almost neutral agreement levels (M=2.4, SD=1.7). The highest level of disagreement was found at the statement that V2X-technology could make driving more boring (M=1.1, SD=1.5).

Again, gender was revealed to significantly impact evaluations (see Figure 4). They were most prominent for the questions regarding privacy and data protection issues. First, while the female participants, on average, strongly agreed that the loss of control regarding which information are collected is a reason for a negative rating of V2X-technology (M=4.1, SD=1.2), the assent of men to this statement was significantly lower (M=3.2, SD=1.5) (F(1,79)=7.8, p<.05). Second, there was a consent of women to the violation of privacy as a considerable barrier (M=3.5, SD=1.7), while men on average hold a neutral opinion (M=2.6, SD=1.7). This difference was significant, too (F(1,78)=5.8, p=.019). Furthermore, women showed significantly (F(1,79)=12.7, p<.05) higher agreements to the statement that the reliance on external information would be a reason for a negative techno-logy evaluation (M=3.2, SD=1.4) in comparison to men, which even expressed slight disagreement (M=1.9, SD=1.6). A final difference between women and men was found regarding the question whether an incitement to inattentiveness could be a possible barrier. On average, women confirmed that question (M=3.4, SD=1.4) more strongly than men which showed a more neutral point of view (M=2.4,

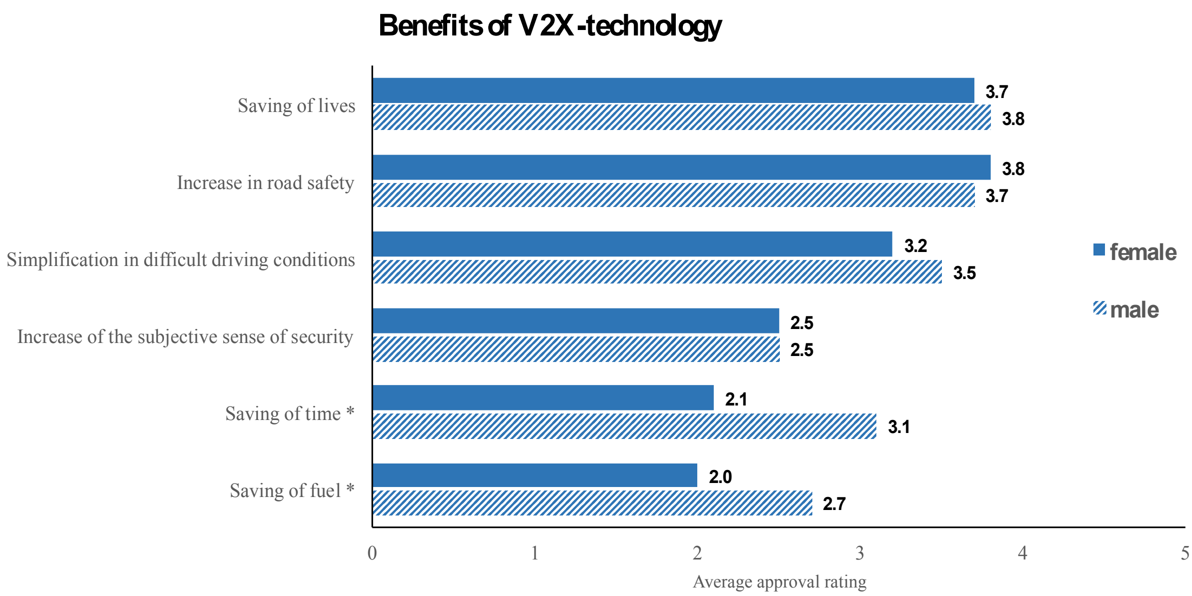

Figure 3: Means of approval regarding perceived benefits (0=full disagreement, 5=full agreement) of male and female participants * indicates significant gender differences.

SD=1.5) (F(1,78)=9, p<05). Interestingly, the prior experience with in-car assistance technologies did not play a major role, revealing no significant differences between participants with and without prior experience with driver assistance systems regarding both possible benefits and barriers.

3.3 General Evaluation of V2X- Technology

In the following the results of the general evaluation of V2X-technology will be presented.

One of the highest average agreement rates was found regarding the usefulness of the technology with M=3.6 (SD=1.3). Although a general usefulness was attested, there was no clear agreement on the question whether V2X-technology would help users with their daily trips and journeys (M=2.6, SD=1.7). When asked about their willingness to pay a premium for the implementation of V2X- technology in their cars or smartphones, the participants expressed even a slight rejection on average (M=2.0, SD=1.8). Next to usefulness, regulation and control were further evaluation criteria. Both topics were important for the participants: On average, participants agreed that V2X-technology has to be strictly regulated (M=3.5, SD=1.7). The strongest consent was found regarding the ability of full and instant control by the driver as prerequisite for V2X-technology (see Figure 5). In particular, participants expressed their wish to be able to disable and enable the technology at any time (M=3.9, SD=1.6).

The clearest denial was found regarding the statement that V2X-technology might be threatening (M=1.5, SD=1.5).

With the exception of one statement, there were no differences between both genders. A distinction was only found at the question whether “V2X-technology has to be strictly regulated”. Women agreed on this item significantly more strongly (M=4.1, SD=1.5) than men (M=3.2, SD=1.8) (F(1,77)=4.7, p <.05).
The previous experience with driver assistance systems had a significant effect on the perceived usefulness of V2X-technology (F(1,79)=7.1, p<.05). On average, experienced participants evaluated the usefulness of V2X-technologies as significantly higher (M=4.0, SD=1.1) than participants without prior experience (M=3.2 SD=1.5).

3.4 Ranking of Most Important Criteria

Finally we asked participants to prioritize seven criterions according to perceived importance. An overview of the general sample ranking can be taken from Figure 6. Note that the higher the ranking the

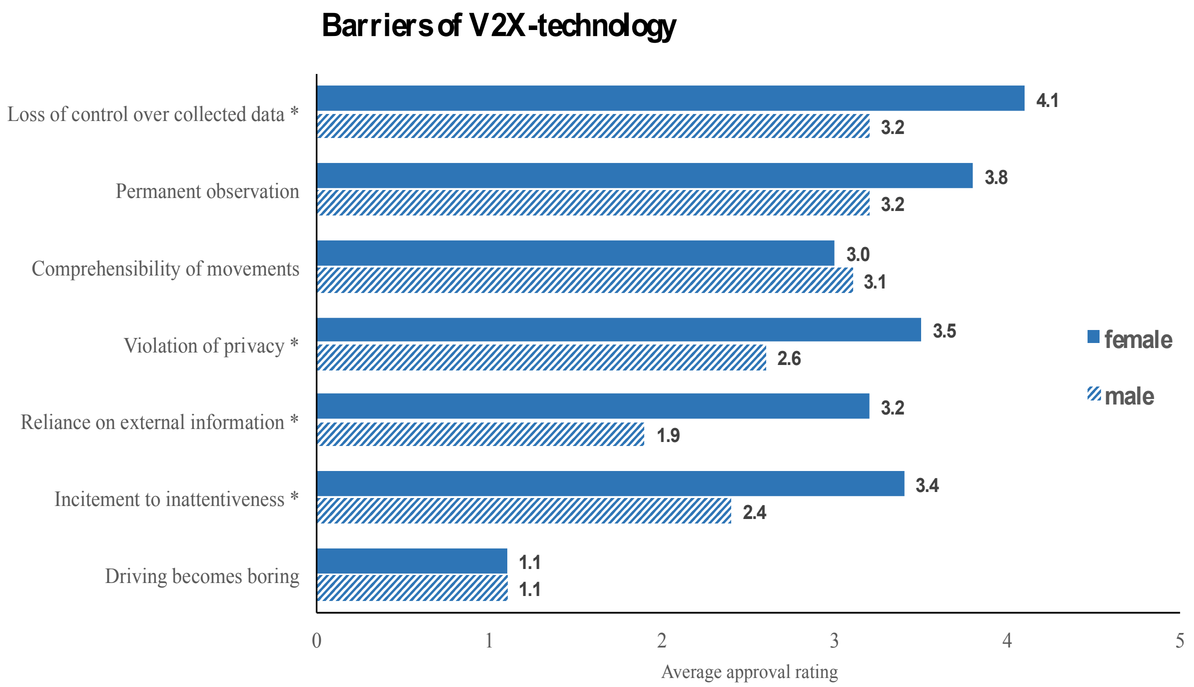

Figure 4: Means of approval regarding perceived barriers (0 = full disagreement, 5 = full agreement) of male and female participants * indicates significant gender differences.

more important is the relative criteria. As can be seen from the evaluations, safety is the most important factor (M=1.8, SD=1.1), followed by perceived control (M=3.0, SD=1.6) and privacy (M=3.3, SD=2.0).

In contrast, costs (M=4.3, SD=1.4), comfort while driving (M=4.5, SD=1.4) or time savings (M=4.9, SD=1.6) are regarded as only medium important. Last, the possibility of flexible time during the use of V2X technology was regarded as not important (M=6.2, SD=1.2).

What strikes here, is, that neither gender nor the previous experience with driver assistance systems does affect the importance rankings, hinting at a quite general attitude across participants (see Figure 5).

4 DISCUSSION

The present paper was concerned about gaining insights of human perceptions of V2X-technology, plausible trade-offs and basic fears. We addressed a technical affine sample of people in order to reveal the possible perceived ad- and disadvantages of (partly) automated driving in everyday traffic situations. After introducing the participants to two different roadside scenarios (I: Intersection, II: Green light), a general evaluation of V2X-technology was assessed. Further, a ranking of measurement criteria was conducted.

We conclude from the results of our study that - overall - a basically positive attitude and a high openness towards using V2X-technology is available. Among the perceived benefits, the increase in safety is for drivers important and for traffic situations in general an important advantage. Also the decrease of the mental load during driving manoeuvers had been seen positive. However, there were also drawbacks that should be seriously considered for the further development and implementation of future V2X-technologies. Basically, two sources of concerns were revealed. One is the uncertainty of participants about data safety and concerns about privacy, in connection with the disliked feeling of being permanently under observation. The other main source comes from the feeling of a loss of control over driving and data collection. In addition, there is missing trust in the reliability of the external information.

When it comes to effects of user diversity on acceptance, gender and previous experience with driving assistance systems were surveyed. Findings show that gender did affect the perceived benefits and barriers. It is an interesting finding that male participants tend to see the benefits more strongly (e.g. the saving of time and costs when using V2X-technologies) while women see the barriers more strongly (e.g. with respect to loss of control in data

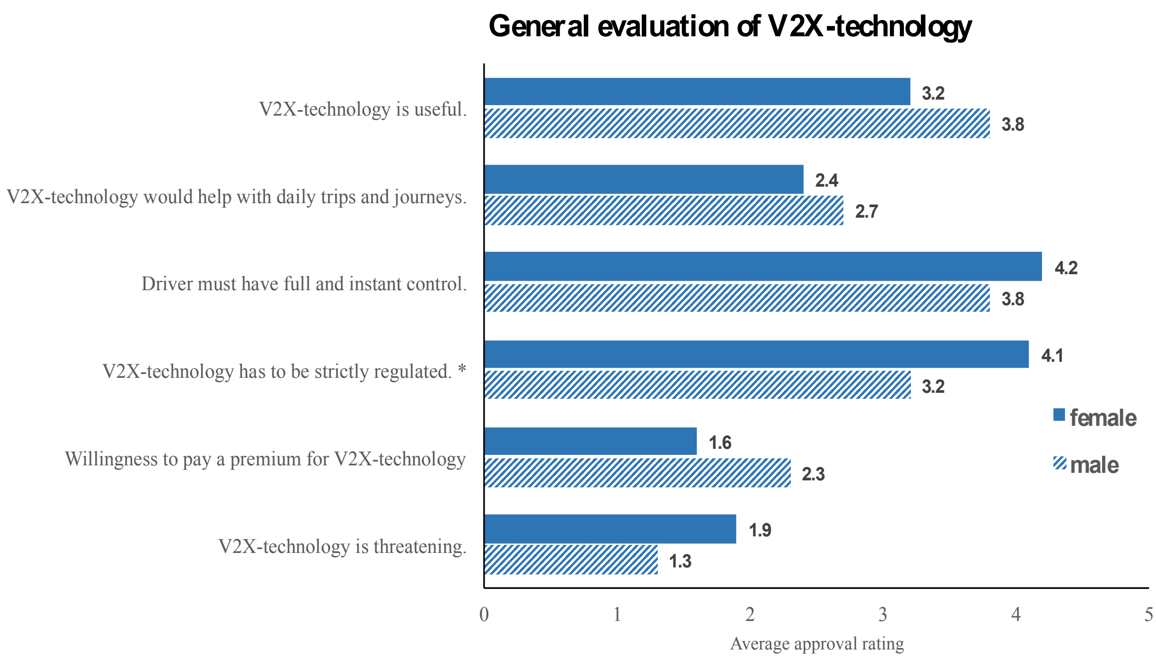

Figure 5: Means and standard deviations of general evaluation ratings (0 = full disagreement, 5 = full agreement) of male and female participants regarding V2X-technology in the cases of significant gender differences (*).

collection, the missing trust in external information, the fear of privacy violation or the fear to get inattentive by using V2X-technologies). This evaluation pattern though is not specifically directed to V2X-technologies, but reflects rather a general evaluation gender stereotype that had been reported also for medical technologies (Ziefle and Schaar, 2011).

However, the importance rankings of the evaluation criteria for V2X-technologies – in contrast to perceived benefits and barriers - are not affected by user diversity. Independently of prior experience with driving assistant systems or gender the ranking was consistent. Safety, the possibility to take control and the claim for privacy protection are the key factors and can be used as leading measures for further development of the technology and also for the development of a transparent information and communication strategy.

Further studies have to investigate how the safeness of V2X-technology can be effectively communicated to the users. There is a strong request for control over both the collected and transmitted data and the technology itself via on/off switch. We think that this option should seriously be recommended for the future development in V2X-technology. Although the control should be a given opportunity, contrary to expectations, V2X-technology is not expected to make driving boring. This could introduce as a kind of "landscape"-driving where all passengers of an automated vehicle could enjoy the view of the given surroundings.

The overall approval and positive attitudes towards the technology encourage the possibilities of new infrastructure concepts via V2X-communication. It is obvious, that more advantages of the technology are perceived in an overall level due to only slightly differences on the benefits of the technology, namely fuel saving and saving of time.

Due to the results, the V2X-technology may contribute to future infrastructure concepts not only for experienced drivers, but also elderly road users. As outcomes show a clear demand towards safety, privacy and control, these factors should be integrated and taken into account from a user perspective. On-side user tests would make it possible to check, if such a criterion ranking is reliable, if the technology is used in reality. Testings before and after the first time usage can be compared to support the strategy to integrate user perceptions, acceptance and ideas in future V2X-technology development and research. The insights of this technology as implemented in vehicles, infrastructure and smartphones may become useful in long-term usage, where the subjects are on their own with the technology.

Another challenge is to cope with user-diversity. Beyond gender and previous experience with driving assistance systems, effects of age and technology generation on acceptance patterns should be explored. Studying cultural effects – especially regarding the cultural impact differences of trust and obedience in novel technology, could reveal further valuable insights. Therefore a more heterogeneous sample will be necessary. Also it is mandatory to not only study acceptance by using more or less artificial scenarios in a questionnaire study but to explore V2X-acceptance in more realistic driving scenarios, revealing still different effects of gender, culture or age-related differences in practical situations. In all future studies should one thing be taken into account: Safety first.

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