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sCARy! Risk Perceptions in Autonomous Driving: The Influence of Experience on Perceived Benefits and Barriers

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The increasing development of autonomous vehicles (AVs) influences the future of transportation. Beyond the potential benefits in terms of safety, efficiency, and comfort, also potential risks of novel driving technologies need to be addressed. In this article, we explore risk perceptions toward connected and autonomous driving in comparison to conventional driving. In order to gain a deeper understanding of individual risk perceptions, we adopted a two-step empirical procedure. First, focus groups ($N = 17$) were carried out to identify relevant risk factors for autonomous and connected driving. Further, a questionnaire was developed, which was answered by 516 German participants. In the questionnaire, three driving technologies (connected, autonomous, conventional) were evaluated via semantic differential (rating scale to identify connotative meaning of technologies). Second, participants rated perceived risk levels (for data, traffic environment, vehicle, and passenger) and perceived benefits and barriers of connected/autonomous driving. Since previous experience with automated functions of driver assistance systems can have an impact on the evaluation, three experience groups have been formed. The effect of experience on benefits and barrier perceptions was also analyzed. Risk perceptions were significantly smaller for conventional driving compared to connected/autonomous driving. With increasing experience, risk perception decreases for novel driving technologies with one exception: the perceived risk in handling data is not influenced by experience. The findings contribute to an understanding of risk perception in autonomous driving, which helps to foster a successful implementation of AVs on the market and to develop public information strategies.

KEY WORDS: Autonomous driving; connected driving; conventional driving; experience; risk perception

1. INTRODUCTION

The way we travel is developing. Technological advances like intelligent transportation systems (ITS), smart infrastructure, connected driving, and autonomous vehicles (AVs) offer various solutions to a broad range of challenges in transportation and sustainable supply for society. Integrating novel driving technologies in cities and urban and rural areas possibly enables the sustainable supply of all residents. The state of health or age would not limit one's own mobility possibilities through the use of (autonomous) technology, but would benefit from it. In this way, the perceived quality of life could be improved, in particular, by supporting and optimizing the current situation of urbanization and demographic change. Nevertheless, to facilitate such an integration, critical issues like innovation, culture, the understanding of public acceptance issues, and the willingness of the public to adopt technologies in general need to be addressed (Rogers, 1995). This is inevitable for all technology innovations, but might

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be even more crucial in the mobility sector in general and driving technology in particular. Within the last century, cars, at least in Germany, evolved to one of the major pillars of individual mobility (Overy, 1975; Wolf, 1996).

Furthermore, using a car is not purely functional; a car has also an emotional value in terms of independence and flexibility, as well as control and perceived safety (Hagman, 2003; Hiscock, Macintyre, Kearns, & Ellaway, 2002). On top of that, cars provide social esteem, technological novelty, and branding (Sheller, 2002, 2004). The recent developments toward autonomous driving partially contradict the historically formed relationship between people and their experience with cars (Kirsch, 1997; Ziefle, Beul-Leusmann, Kasugai, & Schwalm, 2014). Further, studies on innovation culture (e.g., Birkinshaw, Hamel, & Mol, 2008) point out that change of familiar patterns and concepts in an innovation process leads to discomfort, independent of the type of innovation: "the introduction of something new to the state of the art creates ambiguity and uncertainty for the individuals in an organization. Ambiguity arises because of a lack of understanding of the intended value of the innovation, and uncertainty arises because of a fear that the innovation will have negative consequences for the individual and/or the organization" (Birkinshaw et al., 2008, p. 830). In addition, uncertainty is nurtured by the negative press, e.g., the Tesla crashes (Levin, Carrie Wong, & Woolf, 2016), which deeply unsettled car drivers and raised questions about risks and dangers of autonomous driving. From a social perspective, risk perceptions represent adaptive cognitions and emotions to cope with novel driving technology. Understanding risk perceptions for autonomous driving, their forms, extent, and reasoning might help to foster a successful roll-out and implementation on the market. To fully address the complexity of risk in autonomous driving, the next sections will take a closer look at the current mobility challenges and technological developments, followed by an overview of risk perception in technology. Furthermore, the public perception on and acceptance of autonomous driving will be considered in order to identify the addressed question.

1.1. Mobility Challenges

The German Federal Ministry of Transport and Digital Infrastructure predicts that the performance of motorized personal transport will increase up to 991 billion passenger kilometers per year, indicating a continuous rise of transport (BMVI, 2016). Hence, according to the German Federal Statistical Office, nearly 88% of traffic accident crashes are mainly caused by human error (Flannagan et al., 2016; StatistischesBundesamt, 2016). Consequently, one of the most important goals is to lower the number of traffic accidents using technological advances that can facilitate safer and more efficient traffic (Bansal, Kockelman, & Singh, 2016; Fraedrich & Lenz, 2014; Howard & Dai, 2014; Vlacic, Parent, & Harashima, 2001). Reportedly, the implementation and use of driver assistance systems like electronic stability control and adaptive cruise control (ACC) decreased the number of car crashes and alert rates in the past (Breuer, Faulhaber, Frank, & Gleissner, 2007; Flannagan et al., 2016; Kockelman & Li, 2016).

In addition, traffic safety could be increased even more by integrating intelligent communication systems into vehicles that enable the exchange of sensor data between the road users and the road infrastructure to broaden the information base for decision making of drivers and AVs in safety critical situations (Endsley & Garland, 2000; Picone, Busanelli, Amoretti, Zanichelli, & Ferrari, 2015). Through optimized routing and traffic flow management, resources will be used more efficiently, which reduces congestion and CO_2 emissions (Fagnant & Kockelman, 2015; Ross, 2014) and enables smart platooning (Haboucha, Ishaq, & Shiftan, 2017). As for AVs, they are supposed to drive even more efficiently and safely because they are equipped with artificial intelligence, which allows to sense and process all relevant information received from other vehicles or the surrounding infrastructure (Sanchez, 2015). Furthermore, AVs enable their "passengers" to spend the travel time on other tasks.

1.2. Risk Perceptions in Technology

Risk perceptions have been tackled in social science research for about 35 years (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Kasperson et al., 1988; Renn, 1998; Slovic, Fischhoff, & Lichtenstein, 1986). The term risk is—in a social context—defined as the possibility of consequently affecting what a person values through human actions or events (Renn & Benighaus, 2013). In a technological context, risk is defined as "the likelihood of physical, social, and/or financial harm/detriment/loss as a consequence of a technology aggregated over its entire life-cycle" (Renn & Benighaus, 2013).

From the large amount of knowledge that has been collected, findings show that perceived risks might not only differ from "factual" (technological) risks, but also represent meaningful social, cognitive, and affective adaptation processes that cope with the uncertainty of novel developments. In line with Renn (1998), "risk perceptions are fundamental mechanisms that most people employ to assess the potential of risk of an activity or technology and to justify the concern or the neglect of such risks."

The risk adaptation process is not necessarily related to one specific technology, but applies to different (large-scale) technologies that are directly influencing societies and peoples' lives, as, e.g., energy infrastructure technology (Kluge, Kowalewski, & Ziefle, 2015; Midden & Huijts, 2009; Zaunbrecher, Arning, Falke, & Ziefle, 2016) and mobile communication systems (Arning, Kowalewski, & Ziefle, 2014; Dohle, Keller, & Siegrist, 2012). Also, data sharing in the Internet and privacy protection (Horst, Kuttschreuter, & Gutteling, 2007; Miyazaki & Fernandez, 2001) are further examples.

Characteristically, these different fields of application do evoke risk perceptions, which might contain similar patterns (Renn, 1998), e.g., in terms of personal or societal hazards and risks for health, the environment, and the economy. However, the respective extent of single concerns might differ across technologies.

Individuals connect high risks with low benefits (Slovic & Peters, 2006), when comparing them to the negative consequences. Furthermore, they rank risks not only on behalf of their cognition and their knowledge of a product or a technology. They are also affected by risk characteristics, which they are not necessarily aware of, but act as hidden drivers in favor of or against a specific technology (Alhakami & Slovic, 1994; Joffe, 2003). This leads to the conclusion that the perception of risks and benefits influences the acceptance of technology, which was recently confirmed by Bearth and Siegrist (2016) for the acceptance of food technology, suggesting that risk and benefit perceptions are moderately related to each other. Risk perceptions are influenced by different factors, like, e.g., the feeling of control, the associations with the source of the risk, the delay of the consequences, the catastrophic potential, and personal experience and knowledge (familiarity) (Renn, 1998). Moreover, the psychological distance (closeness to one's own person) as well as the abstractness or concreteness of risk decisions can influence risk perception (Lermer, Streicher, Sachs, Raue, & Frey, 2015; Raue, Streicher, Lermer, & Frey, 2015).

1.3. Acceptance of Autonomous Driving

Risk perception is not the only thing that can be influenced. The users' acceptance of autonomous driving can be influenced as well. Using a self-driving car means giving up control of the vehicle, which is very much feared by individuals (Howard & Dai, 2014). Persons are also concerned by safety-related facets, like system failure or hacker attacks (Bansal et al., 2016; Fraedrich & Lenz, 2014; Viereckl, Ahlemann, Koster, & Jursch, 2015). Previous studies (Schmidt, Philipsen, & Ziefle, 2016b) were able to identify people's general concerns and drawbacks, such as a steadily growing distrust toward sharing data. The more personal the data become, the less willing people are to share them with an ITS. Another fear addresses the financial aspect: it is assumed that novel technologies are expensive, e.g., increasing maintenance costs (Fraedrich & Lenz, 2014; Howard & Dai, 2014). In addition, the loss of control and the distrust of vehicle dependence are other serious barriers that reduce public acceptance (Schmidt, Philipsen, Themann, & Ziefle, 2016a). Haboucha mentioned yet another barrier to the use of AVs, namely, the impact on travel behavior. A change in the way we travel could possibly increase the road capacity (and demands) as well as the number of passenger kilometers due to increasing travel possibilities for children, elderly, and disabled people (Haboucha et al., 2017). There is an overall reluctance toward the adoption of AVs (Haboucha et al., 2017), which is possibly mediated and fostered by negative media coverage.

A considerable body of studies, which take the user perspective of autonomous driving into account, concentrates on usability and ergonomic issues, including data visualization and the transfer of control (Josten, Schmidt, Philipsen, Eckstein, & Ziefle, 2017; Rakotonirainy, Schroeter, & Soro, 2014; simTD, 2013), as well as perceived benefits and barriers in general. A recent study of the authors' group addressed the perceptions of autonomous driving in an expert group, focusing explicitly only on persons with a prior experience with automated driving functions (Brell, Philipsen, & Ziefle, 2018). Still, however, it is unclear if laypersons with no experience with automated car function accept autonomous driving. In addition, only little is known about risk perceptions in autonomous driving. Recently, Lee et al.

(Lee, Ward, Raue, D'Ambrosio, & Coughlin, 2017) explored the public acceptance of self-driving cars using a large American sample. They reported that there were both age-related and age-independent factors that are relevant for the acceptance of self-driving cars. Age and the technological generation were found to negatively impact the acceptance, mediated by little experience with, knowledge of, and trust in the questioned technology. Among the different ages, the ascribed usefulness of self-driving cars, affordability, social support, and lifestyle fit were important determinants for acceptance. This is consistent with previous studies on mobility (Hohenberger, Spörrle, & Welpe, 2016; Ziefle, Beul-Leusmann, Kasugai, & Schwalm, 2014), which show that user factors (e.g., age and gender) considerably impact risk perceptions and acceptance decisions.

Even so, the impact of user factors on risk perception in autonomous driving has not fully been explored yet. This involves the familiarity and the experience with driver assistance systems, which might be a prominent factor in risk perception (Lee et al., 2017; Tussyadiah, Zach, & Wang, 2017). In addition, risk assessments might differ for different driving technologies. In particular, the prior experience with technology in general, the experience with driver assistance systems, or the driving experience could modulate risk perceptions (Schmidt, Philipsen, & Ziefle, 2016b).

2. QUESTIONS ADDRESSED AND LOGIC OF EMPIRICAL PROCEDURE

The identification of influential acceptance factors is an essential step in a user-focused technology design. To understand which major obstacles and advantages of future driving technologies are in people's minds, we followed a two-step procedure.

Qualitative focus-group studies, in which possible future technology users with a western European background were questioned, forged a deep understanding of the currently available information and user perceptions. The categorized results of the discussions enabled us to identify the benefits and barriers of different driving technologies as well as to gather insights out of an average traffic participant's point of view. Taking the identified lines of argumentation into account, the presented research distinguishes between three driving technologies (connected, autonomous, and conventional driving), which uncovered an overall picture of the perceived risks.

Furthermore, the results of the qualitative prestudies were integrated into the methodological concept of the subsequent quantitative questionnaire study. The presented work focuses on the attributing and risk perception of the driving technologies. The methodological concept shows two main research branches: (1) the comparison of the driving technologies with a detailed look at the risk assessment of data, traffic environment, vehicle, and passengers as well as (2) the perceived benefits and barriers of the novel driving technologies with a detailed look at the users' experience with driver assistance systems as an influencing factor. The following research questions guided the empirical approach:

- How do individuals perceive connected, autonomous, and conventional driving?
- Which impact does the driving technology have on different levels of risk assessment?
- What are the perceived benefits and barriers of the technologies?
- Does experience with driver assistance systems influence the risk assessment on different levels?

2.1. Hypotheses

The following hypotheses were formulated:

1. The driving technologies (connected vs. autonomous vs. conventional) differ regarding the perceived risks.
2. Experience with driver assistance systems decreases risk perception.

3. METHODOLOGY

The qualitative focus-group studies were carried out to identify relevant risk and acceptance factors for novel driving technologies. Based on these findings we developed a questionnaire, in which (1) the conventional vehicle, the connected vehicle, and the AV had to be described by means of a semantic differential (allocation of emotional characteristics); (2) the perceived risk levels regarding different risk categories had to be evaluated, again comparing the conventional vehicle with novel driving technologies (connected vs. autonomous); and (3) a detailed analysis of the perceived benefits and barriers of the novel driving technologies was carried out.

3.1. Focus-Group Studies

Prior to the questionnaire studies, three focus groups were conducted in the beginning of 2017.

3.1.1. Sample and Procedure

Each discussion, led by a trained interviewer, lasted approximately 110 minutes and focused on fully automated vehicles, i.e., driving that does not require the passengers to monitor the vehicle—Level 5: full driving automation (SAE, 2016), hence the terms "automated driving" and "autonomous driving" are used synonymously. Participants were informed about autonomous driving and the different levels of automation to ensure an equal basic knowledge of the technology. The discussions consisted of general questions (e.g., on the knowledge about the technology), specific questions regarding the perceived benefits and barriers, and questions on the necessary usage conditions that could result in people using AVs willingly.

Seventeen participants (nine men and eight women, 22–45 years) volunteered to take part in the discussions. They were not compensated for their efforts. The participants reported that they are aware of the public discussions on automation in the car industry. Even though they indicated that they have little technical knowledge, they showed a high interest in vehicle innovations.

After providing the short information about autonomous driving, the participants were invited to discuss the perceived benefits and barriers and the trust-related questions in the context of autonomous driving. In order to understand the participants' reasoning and lines of argumentation, as well as to uncover any hidden drivers in favor of or against the novel technology, discussions were kept rather unrestricted. Data were collected through audio recording and note taking by assistants, who were not involved in the discussion.

3.1.2. Argumentation Lines and Further Results

Overall, the discussion was vivid, revealing both positive and negative aspects. Positive perceptions regarded the increased comfort and safety of autonomous cars and their high usefulness for everyday mobility. With respect to the drawbacks, the fear of losing control over self-determined mobility and the low trust in automation raised concerns. Other barriers were the matter of data security and the protection of privacy, which were believed to be highly compromised. In this context, a considerable distrust in the authorities was expressed, not only concerning the reliability of the data and privacy protection, but also concerning the vulnerability of the technology for software errors with possible hazardous consequences for the people. Finally, unexpected and incalculable costs were discussed as a potential barrier for autonomous driving. In addition, a noticeable amount of affective discomfiture was expressed regarding the idea of self-driving cars on the street (*"spooky, risky, out of control, unrecognizable, dangerous, creepy, scary"*). There was a high distrust in technological reliability as well as a great uneasiness caused by the lack of knowledge how to deal with autonomous cars or how to behave in its closer distance. Sometimes, the statements seemed to be triggered by movies that focus on autonomous cars. Interestingly, the participants' cognitive frame of reference revealed three categories of vehicle technology: conventional driving (with which they were all familiar), connected driving, in which several vehicles are interconnected and exchange information and sensor data, and autonomous driving. The first two categories were thereby mentioned in comparison to each other whereas the autonomous technology was mentioned separately. The autonomous driving technology was predominantly perceived as being self-driving and fully automated, even though AVs are—of course—also connected.

Briefly worded, the discussion revealed a low amount of technical knowledge about, and familiarity with, car automation (levels). Nevertheless, a high interest in technological innovations in general and driving technology in particular was prevalent. Furthermore, in line with Slovic et al. (1986), the participants' vision on the use of autonomous driving was found to be highly impacted by emotional and symbolic mental models of driving.

3.2. Questionnaire Instrument

Based on the results of the focus groups, the questionnaire was developed. Mirroring the focus groups' lines of argumentation, the questionnaire captured tacit and affective "knowledge" (using semantic differentials), data on generic risk assessment (using sliders), and ratings on the perceived benefits and barriers (using Likert scales). The questionnaire was divided into four main parts.

3.2.1. Demographics and Mobility Behavior

The questionnaire started with some questions to determine the participants' demographic data, followed by a question about the participants' driver's license(s) and possible occupations (previous driving experience) for which driving different vehicles was necessary. Furthermore, the frequency of vehicle usage was questioned, as well as the common usage role (driver vs. passenger) of the participants. Further questions addressed the annual mileage, the possible ownership of a vehicle, and the system features of the used vehicle. Finally, the experience with driver assistance systems (brake assistant, lane assistant, automatic parking, distance control, and cruise control) was questioned.

3.2.2. Experience and Attitudes

The next section addressed the individuals' need for control, the attitude toward privacy and data security, and the technical self-efficacy (Beier, 1999), which is the individual confidence in one's capability to use technical devices. Moreover, the individuals' driving behavior (risk assessment in driving) was assessed.

3.2.3. Driving Technology Scenarios

The third section was divided into three different technology scenarios. To help the participants to envision the possibilities and limitations of the different technologies, all of the driving technologies (conventional vs. connected vs. autonomous) were introduced by an informative text and a scenario-specific passage. The introduction text for all technology scenarios was as follows:

> The connection of vehicles and infrastructure is summarized as V2X (Vehicle-to-X). This technology realizes the interaction of vehicles with different communication partners (X) to make the traffic more safe and efficient. V2X-technology uses data and information exchange via wireless connection. Vehicles can communicate with other road users (e.g., with other vehicles, pedestrians), or exchange information with the on-site infrastructure (e.g., traffic lights, parking lots). This allows various application possibilities to be implemented: traffic optimization by means of regulated traffic light phases, early warning of danger points or assistance in the search for free parking spaces.
>
> Autonomous driving allows the driver to take on a new role as a passenger. No driver is required for this level of automation and the system can autonomously deal with all situations while driving.

In addition to the introduction text, we used the following instructions for the three scenarios:

Scenario 1 (Connected driving): Imagine you are traveling in a city with a car that is capable of exchanging information with other road users and the surrounding infrastructure.

Scenario 2 (Connected and autonomous driving): Imagine you are traveling in a city with a car that takes you autonomously to your desired destination. Your vehicle can also exchange information with other road users and the surrounding infrastructure.

Scenario 3 (Conventional driving): Finally, we would like you to reflect on the situation with the mobility technology you use today. Imagine traveling in a city with a normal car. It does not drive autonomously and is not connected to the surrounding infrastructure.

The introduction texts were followed by a semantic differential (Bradley & Lang, 1994; Osgood, 1952), which aimed to allocate characteristics of the different driving technologies (using categorized results from the focus-group studies).

Next, the participants had to evaluate different risk categories. Here, the perceived percentage of risk was presented as a slider on a scale from 0 to 100. In order to avoid biases, the default position of the slider was in the middle of the scale. The evaluations of perceived risks had to be done for all three driving technologies (connected, autonomous, conventional). The questioned categories for which risk perceptions had to be given were data (e.g., personal, car, and movement data), traffic environment (other road users and surrounding infrastructure), vehicle (e.g., used car), and passenger (driver and co-driver(s)).

3.2.4. Statements on Benefits and Barriers

Eight statements questioned the benefits of the driving technologies using a six-point Likert scale (with $0 =$ strongly disagree and $5 =$ strongly agree; see Table I). Reliability analyses revealed that the scale was highly consistent, with Cronbach's $\alpha = 0.93$ for the connected and Cronbach's $\alpha = 0.94$ for the autonomous scenario.

A second set of eight statements, using the same approach, questioned the barriers of the driving technology (see Table II). Again, the scale was highly consistent for both scenarios: Cronbach's $\alpha = 0.96$ (connected driving) and Cronbach's $\alpha = 0.97$ (autonomous driving).

Table I. Statements on the Benefits of the Technology

I have a positive view on the use of this technology, because …
… it spares time.
… it conveys a sense of security.
… I feel in control of private information.
… it increases traffic safety.
… it helps to reduce fuel consumption.
… it increases the ease of driving.
… it helps to save lives.
… it increases my flexibility.

Table II. Statements on the Barriers of the Technology

I have a negative view on the use of this technology, because …
… it violates my privacy.
… I lose control over my data.
… it collects my personal information.
… I fear misuse of my data.
… it can give nonauthorized people access to my data.
… others can keep track of my movements and locate me.
… others can get access to my data and my movements.
… my movements can be used to identify me.

4. SAMPLE

In this section, the acquisition of participants, the characteristics of the drawn sample, and the correlations between user characteristics and demographic attributes will be reported.

4.1. Selection of Participants

The survey was implemented as a web-based questionnaire and distributed to the participants with the assistance of a professional market research company and its panel in May 2017. The quota-based polling aimed to acquire a sample that was representative for the German population regarding the distribution of gender and age. In order to focus on actual car users, the survey was only distributed to people who own a driver's license.

To ensure data quality, questionable responses were removed prior to the actual analysis. This was done by applying predetermined criteria to the participants' answer pace and self-contradictory response behavior.

4.2. Demographics and Characteristics of the Sample

In total, $N = 516$ responses were included in the analysis. Half of the participants were male ($n = 258$) and half were female ($n = 258$). The participants' ages ranged from 18 to 76 years, with an average age of 46.0 years ($SD = 15.1$). In comparison, the current average age in Germany is 44 years and 2 months (StatistischesBundesamt, 2017).

The participants' level of education was quite diverse: the largest group (34.3%, $n = 175$) had received a secondary school certificate as their highest achieved level of education. Further, 27.9% of the participants ($n = 142$) reported having a university degree as their highest achieved level of education, while 24.3% ($n = 124$) graduated from high school. The remaining participants (13.3%, $n = 68$) owned a school-leaving certificate.

The average technical self-efficacy was $M = 3.3$ ($SD = 1.2$) on a scale of 0 to 5. Therefore, the sample can be assumed to be slightly tech-savvy.

4.2.1. General Mobility Behavior

In accordance with the selection criteria, all participants owned a driver's license; 98.1% ($n = 506$) of the participants owned a car and the majority (58.9%, $n = 304$) used cars on a daily basis; 91.9% ($n = 474$) reported that they use their vehicles predominantly as drivers, whereas 8.1% ($n = 42$) are usually the passenger. The distribution of the annual mileage was approximately a normal distribution with a peak plateau at 5,001–10,000 (29.8%, $n = 153$) and 10,001–15,000 km a year (25.5%, $n = 131$), which is consistent with the actual average annual vehicle mileage in Germany of almost exactly 14,000 km (Kraftfahrtbundesamt, 2016); 6.4% ($n = 33$) of the participants even stated that their annual mileage exceeds 25,000 km.

4.2.2. Experience with Advanced Driver Assistance Systems

Concerning the prior experience with driver assistance systems, we focused on advanced speed regulation systems (ACC) with automation level 2 (SAE, 2016), as this is the system with the highest automation level that is currently available on the mass market. The reason for segmenting participants in experience groups is referred to the assumption that familiarity with vehicle automation levels might decrease risk perceptions (Rödel, Stadler, Meschtscherjakov, & Tscheligi, 2014). To

Table III. User Characteristics of Experience Groups

		Experience		
		Low	Medium	High
N		73	335	108
Sex	Male	32.9%	52.2%	54.6%
Age (in years)		$M = 45.8$ ($SD = 14.8$)	$M = 47.8$ ($SD = 15.1$)	M=40.5 (SD=16.1)
Technical self-efficacy (max = 5)		$M = 3.1$ ($SD = 1.2$)	$M = 3.4$ ($SD = 1.3$)	$M = 3.5$ ($SD = 1.0$)
Education	University degree	16.9%	23.9%	47.3%
	High school diploma	26.8%	25.1%	20.4%
	Secondary school certificate	35.6%	36.9%	25.0%
Car usage	Daily	46.6%	58.8%	67.6%
Annual mileage	>20,000 km	6.8%	12.6%	29.0%
	>10,000 km	37.0%	39.1%	52.3%
	>5,000 km	38.4%	33.5%	12.1%

be able to classify groups, we distinguished between three levels of experience with ACC:

low experience participants with no experience at all (14.1%, $n = 73$);
medium experience participants with theoretical knowledge about ACC's operating principles (64.9%, $n = 335$);
high experience actual users of ACC systems (20.9%, $n = 108$).

As shown in Table III, the classified groups differ regarding their demographic and user characteristics. While the participants in the low experience group are mainly female, the other groups show a slight male majority. Moreover, the group with the most experience with ACC has the lowest average age. Accordingly, ACC experience correlated negatively with age ($\rho = -0.13$, $p = 0.003$). In contrast, ACC experience correlated positively with the participants' highest level of education ($\rho = 0.21$, $p < 0.001$), frequency of car usage ($\rho = 0.11$, $p = 0.011$), and annually driven mileage ($\rho = 0.25$, $p < 0.001$). There was no significant correlation between the technical self-efficacy and the prior experience with ACC ($p > 0.05$).

4.2.3. Correlations Among the User Characteristics

Next to the ACC experience, there were differences between genders: on average, male participants were significantly older ($t(514) = -4.18$, $p < 0.001$, $d = 0.368$), drove significantly more kilometers per year ($z = -2.825$, $p = 0.005$), and more often owned a car ($z = -2.552$, $p = 0.011$). In addition, men reported a significantly higher technical self-efficacy ($t(514) = -3.84$, $p < 0.001$, $d = -0.338$). There were no significant differences between men and women regarding their highest level of education and how frequently they use a car. Furthermore, age correlated slightly negatively with the level of education ($\rho = -0.14$, $p = 0.002$) and the annual mileage ($\rho = -0.22$, $p < 0.001$). Finally, the frequency of car usage and the annual mileage correlated positively ($\rho = 0.35$, $p < 0.001$). Consequently, participants who frequently drove, also drove, on average, many kilometers in a year.

5. RESULTS

First, this section describes the outcomes of the semantic differentials, thereby comparing the three driving technologies (conventional vs. connected vs. autonomous driving). Second, the levels of risk assessment in respect of data, traffic environment, vehicle, and passengers are displayed for all technologies. Finally, the results on the perception of benefits and barriers for novel driving technologies are reported while comparing connected and autonomous driving. In order to understand if the level of experience with driver assistance systems (ACC) influences risk assessment, we analyzed both the levels of risk perception and the perceived benefits and barriers, depending on the participants' experience.

5.1. Data Analysis Statistical Testing Procedure

The data were analyzed using multivariate procedures with repeated measurements and Spearman rank correlation analyses (determining relations

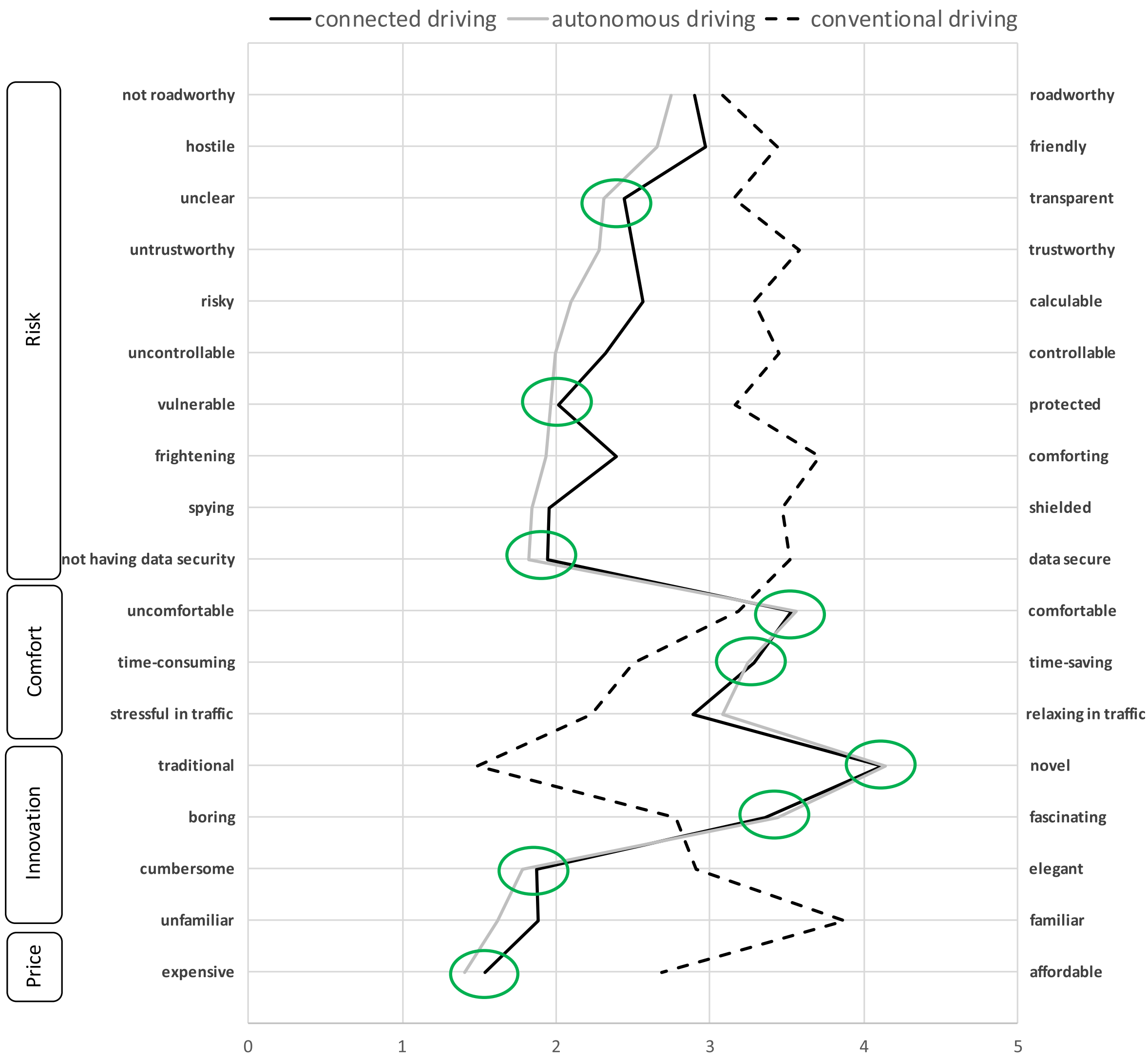

Fig. 1. Attribution of descriptive adjectives to driving modes. Circles indicate nonsignificant comparisons of attributions between driving modes.

between variables). The level of significance was set at $\alpha = .05$. MANOVA procedures were used to determine the interacting effects between the participants' experience with driver assistance systems and their risk perceptions.

5.2. Semantic Differentials

Using semantic differentials allows to identify the affective connotations of the vehicle technologies under study. Participants had to evaluate which of the adjectives given in the differential applies to which technology to which extent. Each attribute is represented by a positive (risk-free) and a negative (risky) adjective. Findings show that there was a significant effect of technology on the attribution ($\Lambda = 0.435$, $F(36, 478) = 17.239$, $p < 0.001$). However, as can be seen in Fig. 1, the ratings for the novel technologies, connected and autonomous driving, are very similar for all pairs of adjectives, whereas the ratings for the conventional driving scenario were almost, with a few exceptions, assessed contradictorily. To uncover similarities and differences, four semantic attribute categories were defined based on categorizations in the focus groups: risk, comfort, innovation, and price.

The most elaborate category comprises all attributes that are directly related to risk, e.g.,

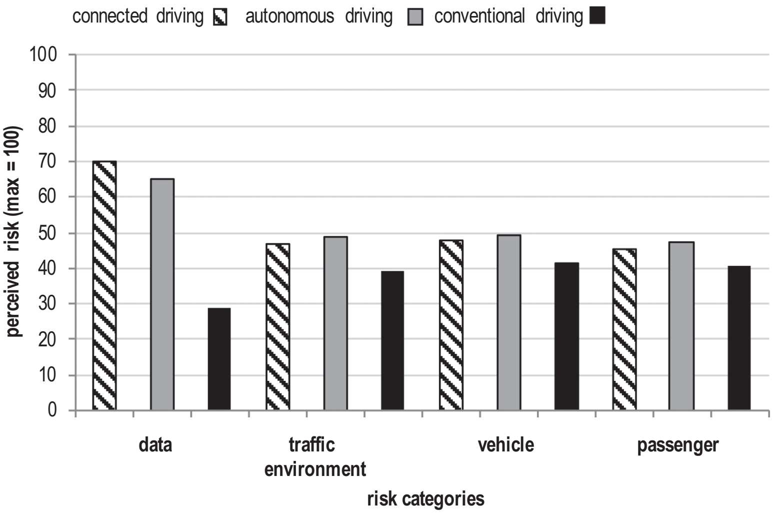

Fig. 2. Risk levels for the experience groups.

riskiness, road worthiness, or transparency. Fig. 1 shows that for the different driving modes, the results differ from each other: for conventional driving the attribution of the adjectives was more positive, and therefore more risk free. In contrast, for both connected and autonomous driving the attribution ranged from indifferent attributions, e.g., for road worthiness and friendliness, to attributions slightly tending to the more risky adjective, e.g., for frightening and not having data security. The next category includes attributes dealing with comfort (i.e., comfort in general, time saving), and the emerged picture changes entirely. Here, the attribution of the adjectives was more positive for the novel driving technologies. The participants seemed to perceive a high potential for comfort, time saving, and relaxation. Although the ratings for conventional driving tend more toward the negative adjectives, the attribution of the adjectives was not completely contradictory. The third category comprises the evaluation of the technology's novelty, fascination, elegance, and familiarity. Again, connected and autonomous driving received comparable ratings. The novel driving technologies were perceived as more fascinating, but less elegant (see Fig. 1). The last category addresses the issue of the perceived price–value ratio. While there was no clear attribution for conventional driving, the connected vehicles and AVs were perceived as being expensive.

5.3. Connected Versus Autonomous Driving

Across all categories, the results for connected and autonomous driving (see Fig. 1) seem to have a similar pattern. However, pair-wise comparisons revealed that there were significant differences ($p < 0.001$) between the attributions for these two driving technologies for all adjectives, apart from comfort, time saving, novelty, and fascination ($p > 0.05$). The differences between the novel driving technologies can be labeled as marginal in consideration of their clear distinction from conventional driving.

5.4. Risk Perception

Next to the attribution, the participants rated the overall risks using a visual analogue scale ranging from 0 to 100 by setting it to their individual mark. Risk assessments for all driving technologies were requested for four areas: "How high is the perceived risk for you when driving (connected - connected and autonomous - today) for your (data - traffic environment - vehicle - passenger)?"

5.4.1. Risk Perception for Different Risk Categories

In the following paragraph, specific risk assessments are analyzed in order to understand if participants assess risk differently for different areas when considering the different vehicle technologies. For the three vehicle technologies, the perceived risk was assessed for four different areas: risks concerning data, traffic environment, vehicle, and passengers.

As can be seen in Fig. 2, risk levels differed significantly for the different areas ($F(8, 2048) = 66$; $p < 0.001$). Across driving technologies, the highest risk was attached to data ($M = 55.0/100$ points max), while the perceived risk levels for the other areas were, on average, about the same

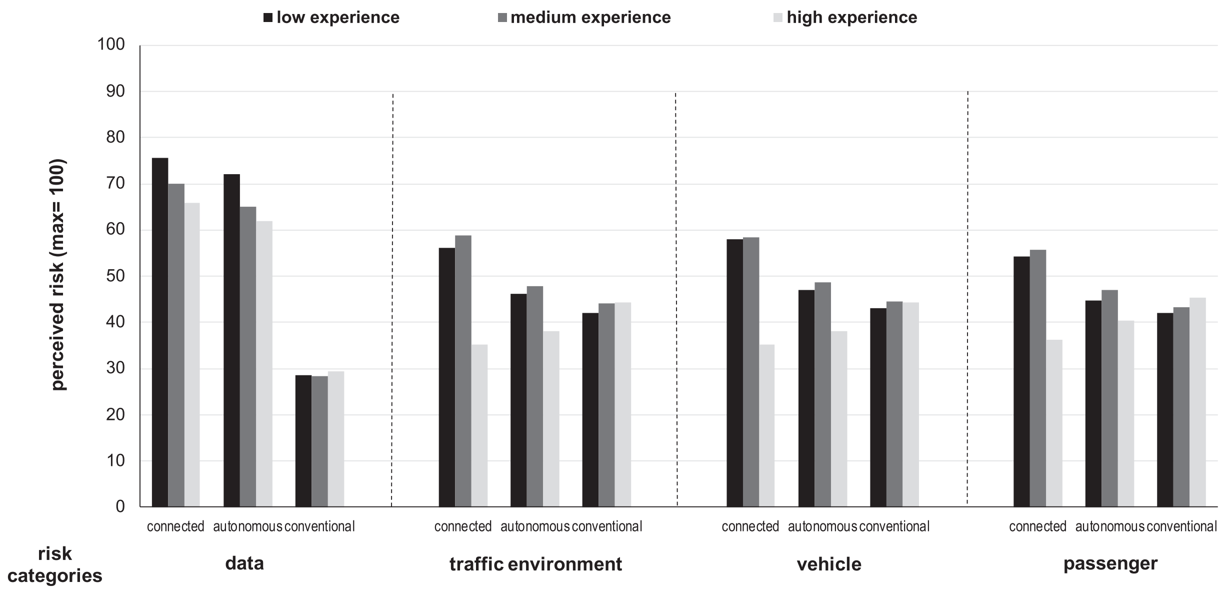

Fig. 3. Risk assessment in different risk categories and driving technologies.

(risk for the vehicle: $M = 45.9$; risk for the traffic environment: $M = 46.8$; risk for passengers: $M = 45.4/100$ points max). The significant effect of the interaction between the risk areas and vehicle technologies ($F(8, 2048) = 2.2$; $p < 0.005$) revealed that risk perceptions vary among the vehicle technologies. Again, conventional driving is perceived as being significantly less risky in all areas. This difference is most pronounced in the area of data, with the least perceived risk for conventional driving ($M = 28.6$). Connected ($M = 70.0$) and autonomous driving ($M = 65.3/100$ points) were perceived as being more risky. These assessments do not necessarily reflect the factual technical risks of the technologies.

5.4.2. The Impact of Experience on Risk Perception

The focus is now on the participants' level of experience, by looking at the perceived risk levels for the groups with low, medium, and high experience with driver assistance systems (Fig. 3).

Statistically, a significant omnibus interaction effect between experience, risk area, and driving technology was found ($F(16, 4140) = 2.1$; $p < 0.005$). Two major findings become apparent from Fig. 3. Again, experience has a considerable effect, i.e., with increasing experience, novel driving technologies are perceived as significantly less risky for the defined areas. The effect was also significant in the single areas passengers ($F(2{,}513) = 2.5$; $p < 0.05$), vehicles ($F(2{,}513) = 3.2$; $p < 0.04$), and traffic environment ($F(2{,}513) = 3.2$; $p < 0.04$). The only exception to this is the second major finding. For the area of data, experience does not significantly affect risk perception ($F(2{,}513) = 2.2$; $p > 0.05$). All experience groups came up with comparable risk assessments for connected driving (low experience: $M = 75.5$, medium experience: $M = 70.1$, high experience: $M = 66.0/100$ points max.), autonomous driving (low experience: $M = 72.1$, medium experience: $M = 65.0$, high experience: $M = 62.0/100$ points), and conventional driving (low experience: $M = 28.6$, medium experience: $M = 28.3$, high experience: $M = 29.5/100$ points max.). Apparently, the increasing familiarity with driver assistance systems does not decrease the perceived risks in the context of data safety and the fear of losing privacy in novel driving technologies.

5.5. Perceived Benefits and Barriers

The final analysis refers to the perceived benefits and barriers for connected and autonomous driving. Participants rated how much they agreed with eight statements on benefits and eight on barriers. Overall, the perceived benefits and barriers did not differ significantly between either technology (Table IV). Further, we analyzed the impact of the participants' experience on the perception of benefits and barriers.

Table IV. Perceived Barriers and Benefits (Average Agreement, Max = 5) of Connected and Autonomous Driving Depending on Experience

	Barriers						Benefits						
	Connected			Autonomous			Connected			Autonomous			
Experience	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High	
Privacy violation	3.0	2.8	2.8	3.3	3.1	2.8	2.5	3.0	3.4	2.2	2.9	3.3	Time savings
Loss of data control	3.2	3.0	3.0	3.5	3.2	2.9	2.3	2.6	3.1	1.6	2.5	2.9	Sense of security
Illegal data collection	3.4	3.3	3.1	3.5	3.3	2.9	2.2	2.6	3.0	1.7	2.4	2.7	Feeling control
Misuse of my data	3.7	3.5	3.3	3.6	3.4	3.1	2.3	2.9	3.3	1.9	2.8	3.2	Traffic safety
Nonauthorized access	3.7	3.4	3.4	3.8	3.4	3.1	2.5	2.9	3.2	2.1	2.9	3.3	Fuel reduction
Unwanted localization	3.4	3.2	3.3	3.5	3.3	3.1	2.5	3.1	3.5	2.3	3.1	3.4	Ease of driving
Illegal data access	3.5	3.4	3.4	3.4	3.3	3.1	2.6	3.1	3.3	2.3	3.0	3.2	Life saving
Detection of profiles	3.5	3.3	3.3	3.5	3.3	3.2	2.2	2.8	3.1	2.2	2.8	3.1	Flexibility

When looking at the effect of experience, a mixed picture was found. Overall, experience did significantly affect the risk perceptions in both connected and autonomous driving. However, a closer look showed that experience significantly affected the perception of benefits ($F(16, 1014) = 1.8$; $p < 0.05$), but not the perception of barriers ($F(16, 1014) = 1.3$; $n.s.$). Apparently, experience increased the positive perspective (in terms of agreement with the benefits), but did not decrease the negative perspective of the barriers. Table IV shows the descriptive findings.

6. DISCUSSION AND FUTURE RESEARCH DUTIES

In the following, the findings are discussed alongside the two main hypotheses and the methodology used. The section closes with possible limitations of the research approach and an outlook for further research duties.

6.1. The Perception of Novel Driving Technologies

Starting with a qualitative approach to understand the perceived attributions of, and the characteristics that were ascribed to, the novel driving technologies compared to conventional driving, the results showed a clear "mental" distinction between new (connected and autonomous) and traditional driving modes. Alongside the classification of the attributes (the categories of which were risk, comfort, innovation, and price related), it became clear that the negative terms in the risk category were more often assigned to the novel driving technologies (connected and autonomous driving). Moreover, the higher risk levels attached to the novel driving technologies in comparison to conventional driving revealed two things: on the one hand, they showed the often reported reluctance to adopt novel innovations when people do not have any own experience with it or know how to handle these novel driving technologies (Renn, 1989; van Heek, Arning, & Ziefle, 2017; Ziefle & Schaar, 2011). The findings indicate a focus on perceived barriers, thereby confirming the research by Slovic and Peters (2006). Referring to Hypothesis 1, which postulated a difference in the perceived risks of the three driving technologies, it can be stated that a distinction was found between the "new" and "old" technologies, but not between the two intelligent technologies. Conventional driving—even though factually much more risky in terms of accident hazards—was perceived as being less risky, mirroring the attribute results in the semantic differentials. One could speculate that the perceived risk perceptions are not solely restricted to the characteristics of novel driving technologies, but mirror the extent of familiarity with driving technology. The positive evaluation of conventional driving and the reluctant evaluation of the novel driving technologies could represent a fear of innovation as such (Birkinshaw et al., 2008), especially in Germany, where there is a long tradition regarding the security of a well-structured and economic welfare (Dakhli & De Clercq, 2004). Keeping this in mind, the results could also represent a reluctance toward changes (Online, 2015; Sheth & Stellner, 1979). Thus, it might not just be the novel driving technologies that are attributed as being risky. Also, the technological innovations in general could be refused (Online, 2015; Sheth & Stellner, 1979).

6.2. The Impact of Experience

The second hypothesis postulates a decrease in risk perception when ACC experience increases. The findings revealed that this hypothesis holds only partially true and therefore cannot be maintained at such a general level: consistent with the hypothesis and with previous studies in other technological contexts (Bearth & Siegrist, 2016), risk perceptions decreased with the increase of ACC experience for risks connected to the vehicle itself, the passenger, and the traffic environment. In contrast, risk assessments regarding data security and privacy were not influenced by prior experience with ACC. Apparently, the effect of ACC experience that decreased the perception of the aforementioned physical risks might be overshadowed by participants' experience with ICT, e.g., general Internet or smartphone usage, which allows the assessment of cyber risks for data and privacy. However, it should be kept in mind that we defined experience on the basis of participants' prior experience with ACC (as this function has a high automation level). Though, none of the participants had a real experience with autonomous driving because there are currently no vehicles available in the market that utilize this level of automation. The public perception on the risk of autonomous driving might decrease with ongoing dissemination of transport methods with higher automation levels. One might speculate that the vehicle-related risk perceptions for autonomous cars will vanish whenever people gain practical experience with fully automated car functions. Still, it is an open question whether the public concerns about data handling and privacy loss will also decrease, or, possibly, stay as a serious issue for autonomous driving. Further research is necessary to gain a better understanding of the users' mental models of future cars and their perceived risks while taking the combination of the technologies into account.

6.3. Appropriateness of the Methodology

Another important point to discuss is the appropriateness of the methodology for the findings at hand. In our approach, the participants were laypeople. Thus, we focused on affective beliefs (focus groups, semantic differential) in novel driving technologies and collected prevailing mental models on perceptions of specific benefits and barriers. The approach thus captured fuzzy, not necessarily cognizant, information, but also conscious attitudes. One could critically argue that laypeople—who did not drive automated cars themselves—naturally hold on to irrational beliefs, misconceptions, and false information. It might also be argued that if laypeople are asked to express risk perceptions, they will come up with some, and that this "triggering" might lead to an overestimation of barriers as it is also known from other domains (Ziefle & Schaar, 2011). From a social science perspective, the analysis of laypeoples' perceptions is decisive. They do not only mirror the understanding of average citizens, they also might inform technical designers and persons in charge about prevailing public attitudes and mental models about a novel technology. These attitudes do not come out of nowhere, but represent affective adaptation strategies (Joffe, 2003; Schwarz, 1998) that have deeply been shaped by life experience and culture. Understanding this tacit public knowledge might be a crucial cornerstone of innovation management (Mascitelli, 2000). Consistent with Renn (1998), it can be concluded that the understanding of risk perceptions is inevitable, not only for the implementation process, but also for the development of risk control strategies and individually tailored public information and communication strategies.

6.4. Limitations and Further Research

Even though the study provided deeper insights into risk perceptions in intelligent driving technologies, the approach only represented a first glimpse into the diverse impact of user factors on autonomous driving, which therefore still needs refinements and extensions in future studies.

A first limitation is with regard to the fact that we captured attitudes toward autonomous and connected driving, not behaviors. All participants—even though their experience with autonomous driving functions varied—had never used a self-driving car themselves, which might have considerably influenced their attitudes. For that reason, future studies need to explore a group with sufficient hands-on experience with driving AVs and use a more realistic approach (e.g., simulation environment or real-site testing) to validate the current findings.

A second limitation is with regard to the narrow view caused by the fact that all participants live in one country: Germany. Germany might be a special case in the history of the car industry, and Germans, especially the older ones, are quite car-mobility centered and therefore represent a special (non)acceptance group, which might not be represented as much in other countries (Davey, 2007). It is therefore meaningful to do a cross-country comparison with other nations that have different cultural values, behaviors, and norms. First intercultural insights into public opinions about self-driving vehicles have been examined, comparing China, India, Japan, the United States, the United Kingdom, and Australia (Kyriakidis, Happee, & de Winter, 2015; Schoettle & Sivak, 2014). Results show that the Asian cultures seem to have a more positive initial opinion about autonomous cars, thus share another innovation culture in comparison to the other countries under study. Still, all cultures had concerns about riding in self-driving vehicles and expressed distrust feelings about system reliability of autonomous cars in comparison to human drivers, which were perceived as more reliable. Moreover, a recent study revealed that—beyond national cultures—age and generation cultures also impact the adoption willingness for AVs (Lee et al., 2017).

The question on whether the perceived risk levels and their extents predominately refer to novel driving technologies, or whether they are also identifiable for other technologies, should also be researched further (Birkinshaw et al., 2008). Thus, it should be clarified whether the (un)willingness to adopt autonomous driving technology is restricted to cars or to changes in mobility patterns, autonomous systems as such, and innovations in general. It would then be possible to derive a public information and communication strategy that is specific for autonomous driving. In this context, the morality, ethics, and social dilemma of autonomous driving need to be focused on (Bonnefon, Shariff, & Rahwan, 2016; Marcus, 2012).

So far, we only separately assessed the levels of perceived benefits and barriers. However, acceptance studies (Arning et al., 2014; Zaunbrecher, Arning, Falke, & Ziefle, 2016) show that the overall acceptance in favor of or against a technology is a weighing of benefits and barriers, which thereby identifies individual tradeoffs in the risk decision. Future studies will therefore have to explore tradeoff decisions for novel driving technologies.

Moreover, a closer look into other personal factors needs to be taken. We learned from acceptance studies that beyond the classical demographics (age, gender) and experience with technology, it is useful to connect personality variables to risk perceptions of autonomous driving, e.g., individual levels of morality, the openness to technical innovations, the level of risk avoidance, the need for control, and individual anxiety levels (Hohenberger, Spörrle, & Welpe, 2017; Huijts, Molin, & Steg, 2012; Rogers, 1995; van Heek, Arning, & Ziefle, 2017).

Finally, legal issues, such as distributive fairness (Gross, 2007) and procedural justice (Tyler & Wakslak, 2004), need to be considered in order to understand what is—from the perspective of different stakeholders—legally possible and still perceived as efficient and safe. In this context, research could inform policy and governance authorities on their role in public acceptance and risk behaviors.

7. CONCLUSIONS

Autonomous driving in Germany is perceived as being beneficial in terms of efficiency and road and driver safety, as well as individual comfort. On the other hand, there are severe concerns, which especially regard the uncontrollable collecting of data and the uncertainties about illegal access, in combination with a considerable distrust in industrial and public authorities. Other serious concerns reflect the archaic fear of losing control, the uncomfortable feeling of continuously being monitored, and the low trust in the responsibility and the safety of vehicles. The narrative here is that self-driving vehicles are perceived as spooky, mechanic, not controllable, and somehow "unmoral."

In comparison to conventional driving—which is perceived as safe, reliable, and comfortable—connected as well as autonomous driving are perceived as being more risky (especially in the area of data, but also regarding traffic environment, vehicle, and passenger).

Experience with ACC prominently impacts risk assessments. People with low experience with autonomous driving functions underestimate the risk of conventional driving while overestimating the risk of novel driving technologies. With increasing experience the risk perceptions for the connected and autonomous driving technology decreases. The findings call for action regarding the provision of more hands-on experience with autonomous driving and the development of an informative, transparent, and objective public press strategy.

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