On the role of informational privacy in connected vehicles: A privacy-aware acceptance modelling approach for connected vehicular services

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Modern cars are becoming increasingly connected. While connectivity enhances the car's functional portfolio, it fosters the relevance of information privacy in the private vehicle. This research paper sets out to elucidate the role of data disclosure in the acceptance of connected services in the car. Based on Davis' Technology Acceptance Model, we postulate an acceptance model which accounts for informational privacy in the connected car. In a high-fidelity driving simulator study, 116 participants interacted with a connected parking service and subsequently responded to an acceptance questionnaire. Structural equation modelling revealed a significant influence of privacy-related factors on attitude towards using the system, which in turn directly influences usage intention. The results underscore the relevance of informational privacy for the acceptance of connected vehicular services.

Keywords: connected vehicle; user acceptance; informational privacy; connected vehicular service

1. **Introduction**

Modern cars are equipped with a constantly growing number of sensors and communication capabilities, which enable the car to collect and share information with other cars, the infrastructure or further entities in real time (Coppola and Morisio, 2016). These so-called connected cars constitute a promising future market especially for connected services in the car, whose revenue is forecasted to double until 2023 in comparison to 2017 (Statista, 2019b). Moreover, connectivity enables new functionalities. Amongst others, connectivity is a cornerstone of automated driving (Lee et al., 2016) and thus provides higher security levels and promises to enhance the comfort of travelling (Papadimitratos et al., 2009). However, connectivity in the car is also closely associated with the disclosure of (personal) data. While the advent of these means of vehicular ambient intelligence fosters new functionalities, it might be in conflict with our current perception of the car as a private retreat (Gardner and Abraham, 2008; Walter and Abendroth, 2018).

With the introduction of connectivity, informational privacy becomes more important in the car. There is a plethora of studies demonstrating the technical vulnerability to privacy breaches (e.g. J. Joy, 2017; Garakani et al., 2018; Kaplun and Segal, 2019). Accordingly, a multitude of technical countermeasures have been developed so far (e.g. Hussain and Koushanfar, 2018; Zhang et al., 2018; Plappert et al., 2017). While the assurance of secure connected vehicles attracts a high amount of attention, there are only few studies elucidating the user's view on privacy in connected vehicles. Walter and Abendroth (2018) provide a short overview over existing relevant user studies on connected cars. In line with technical risk assessments, users are indeed critical towards privacy in connected cars. While a survey of the Federation internationale de l'automobile (2016) showed that users are interested in the promised functional enhancements of connected vehicles, a vast majority (88 %) of the respondents stated concerns about disclosure of private information. Likewise, Schoettle and Sivak (2014) found 69.3 % of their respondents to be moderately or very concerned about privacy breaches in a connected vehicle. Thus, users seem to have privacy concerns when being confronted with the concept of connected vehicles. This is well in line with research from neighbored location-based services (LBS), which use the user's current location to provide context-relevant information and thus share the context of data reliance with connected services in the vehicle. Zhou (2012) established a model to explain usage intention of LBS which comprises privacy-related factors such as privacy concerns. Moreover, Kowatsch and Maass (2012) surveyed a small sample of experts of the Internet of Things (IoT) domain and found that privacy concerns have an (indirect) effect on the intention to use an IoT device. Hence, these results underscore the relevance of privacy for the acceptance of connected devices. When it comes to acceptance of vehicular technologies, however, there is a lack of theoretical approaches which incorporate privacy-related factors in vehicular acceptance models. Though plenty of models for different vehicular domains (Moons and Pelsmacker, 2015; Madigan et al., 2016; Chen and Chen, 2009; Zmud et al., 2016; Park et al., 2013) have been proposed, no model has integrated explicitly privacy-related factors so far.

Therefore, this study sets out to test a new acceptance model for services in the connected vehicle which also considers the fact that connectivity introduces the relevance of informational privacy in the modern car. Since previous research indicates that users do not necessarily recognize connected services in cars as such (Endo et al., 2016), it shall be assessed if privacy plays a critical role in usage adoption of connected vehicular services. As suggested by growing evidence that the user's desire for privacy is driven by their perception of the technology (Lederman et al., 2016), users' privacy desires might be falsely reduced if connected features are less apparent in connected vehicles. Based on the above definition of connected vehicles, connected vehicular services are here conceived as single applications which exploit the network integration of the connected vehicle. In a high-fidelity driving simulator experiment, we exposed car drivers to a connected service and assessed both, the hypothesized relevant determinants of usage intention as well as the actual usage behavior. Based on Davis (1986) technology acceptance model (TAM) we integrated insights from research on data disclosure behavior and dedicated acceptance models from the neighbored IoT domain to predict intentions towards using connected vehicular services.

2. Theory and Hypotheses

Several studies have sought to explain acceptance of vehicular technologies. While early studies tried to explain acceptance of manual car driving (e.g. Bamberg and Schmidt, 2003; Gardner and Abraham, 2008), recent studies focused more strongly on electric (e.g. Moons and Pelsmacker, 2015, 2012) and automated driving (e.g. Payre et al., 2014; Madigan et al., 2017; Molnar et al., 2018). Moreover, connected aspects of modern vehicles have also been captured by existing acceptance models (Chen and Chen, 2009; Park et al., 2013). However, while these studies clarify the understanding of basic and advanced vehicular functions, privacy aspects are not integrated. Thus, it remains unclear if data disclosure affects acceptance of connected vehicular services in modern cars. In this paper, we derive an acceptance model starting with Davis' TAM and extend it by integrating factors that have been demonstrated to be relevant for data disclosure in other contexts.

2.1 Technology Acceptance Model

Among the theories to explain adoption of information systems, the TAM (Davis, 1989) is one of the most parsimonious and most widely applied models (Ayeh, 2015). Based on the Theory of Reasoned Action (Ajzen and Fishbein, 1980), the model proposes that the intention to use a system can serve as proxy for the acceptance of information systems. Two pragmatic factors (i.e. the perceived usefulness and the perceived ease of use) determine the intention to use either directly or mediated by the attitude towards using the system.

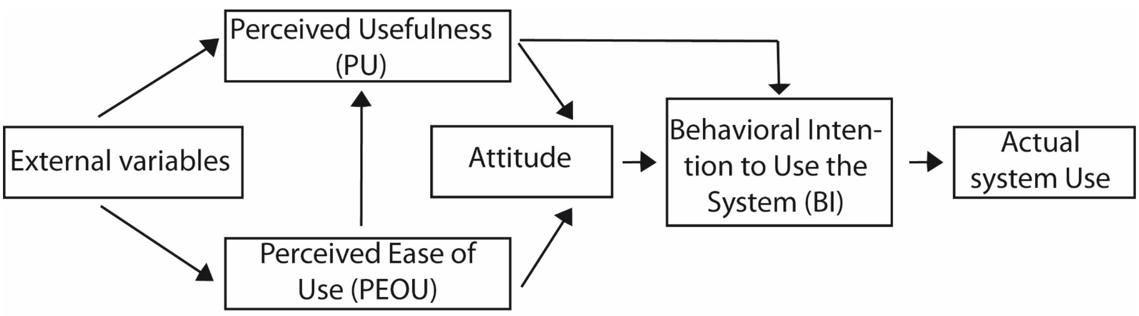

Figure 1. Technology acceptance model (model rebuilt in reference to Davis, 1989)

We chose TAM as our reference model since TAM is one of the most parsimonious models for technology adoption (Al-Momani et al., 2019) and has been found to be robust across different settings (Koul & Eydgahi, 2017; Motak et al., 2017). In the context of vehicular systems, the TAM was the basis for models explaining the adoption of telematics systems in vehicles (Chen and Chen, 2009) and intelligent infrastructure systems (Larue et al., 2015). The findings of these studies demonstrate that perceived usefulness and ease of use are important determinants of user acceptance of vehicular technologies. In reference to the original conceptualization by Davis (1989), perceived usefulness is defined in the present study as the extent to which a user believes that using the connected vehicular application enhances his driving experience. Previous studies suggest that perceived usefulness is one of the determinants of the attitude towards using a system and usage intention (e.g. Chung et al., 2010; Davis, 1989; Müller-Seitz et al., 2009). Therefore, the following hypotheses regarding the perceived usefulness in the context of connected vehicular services are formulated

- Hypothesis 1: Perceived usefulness has a significant positive effect on attitude towards using a connected vehicular service.
- Hypothesis 2: Perceived usefulness has a significant positive effect on behavioral intention to use a connected vehicular service.

Perceived ease of use is another elementary construct of the TAM. In accordance with the original definition by Davis (1989), perceived ease of use is here defined as the extent to which a user believes that using a connected vehicular service is free of effort. Previous literature has demonstrated that an effortless interaction with a system enhances the perceived usefulness, but also influences the attitude towards using the system positively across varying contexts (e.g. Boer et al., 2019; Chen and Chen, 2009; Davis et al., 1989). Hence, we expect that the belief of an effortless interaction with the connected vehicular service will drive both the belief that the service will enhance the driving experience as well as the attitude towards using the system. Thus, we postulate the hypotheses:

- Hypothesis 3: Perceived ease of use has a significant positive effect on perceived usefulness.
- Hypothesis 4: Perceived ease of use has a significant positive effect on attitude towards using a connected vehicular service.

Attitude towards using a system is a primary predictor of the proxy of acceptance, which is the behavioral intention to use a system. It is defined as an affective evaluation that is associated with using the system (Davis, 1986). Previous studies in the mobility context have already demonstrated the validity of the assumption that attitude is a primary predictor for the behavioral intention to use a system in the vehicular domain as well (e.g. Chen and Chen, 2009; Chen et al., 2007; Park et al., 2015). For connected vehicular services, we thus postulate the hypothesis

- Hypothesis 5: Attitude towards using the system has a significant positive effect on behavioral intention to use a connected vehicular service.

Behavioral intention to use a system is generally taken as a proxy for the adoption of a new technology (e.g. Davis et al., 1989; Davis, 1986). In analogy to previous studies (e.g. Roberts et al., 2012), behavioral intention to use the system is here defined as the subjective probability to engage in using the connected vehicular service.

2.2 The relevance of data disclosure

In the course of the formation of connected vehicular networks, informational privacy becomes relevant for the use of these connected cars (Walter and Abendroth, 2018). This is particularly interesting, as (physical) privacy has always been one of the dominant reasons for modal choice in favor of the car (Beirão and Cabral, 2007; Gardner and Abraham, 2008). However, by introducing connectivity in our car, the driver's informational privacy might be at risk (Walter and Abendroth, 2018). Therefore, the proposed model also considers privacy-relevant factors. Although this is new for vehicular acceptance models, the influence of privacy factors on acceptance has already been studied in closely related contexts such as IoT and LBS. A recurrent significant factor for privacy disclosure is privacy concerns. Privacy concerns refer to the users' concern about their informational privacy (Xu et al., 2013). The construct comprises aspects of data collection, control and awareness (Malhotra et al., 2004). While there are different multi-layered conceptualizations of privacy concerns (e.g. Li, 2012), privacy concerns in the connected car are defined here as the user's concerns about personal information disclosure during the interaction with a connected vehicular service. Numerous studies on information systems have shown privacy concerns to predict privacy-related behaviors (Dinev and Hart, 2006; Li et al., 2019; Lowry et al., 2011; Malhotra et al., 2004). Hence, if privacy becomes relevant in connected vehicles, privacy concerns should be a significant predictor of usage adoption of connected vehicular services. Users of connected vehicular services may be concerned with the service providers' handling of data in terms of information collection, storage and usage. Zhou (2012) demonstrated that privacy concerns significantly increased the perceived privacy risk in mobile LBS. For connected vehicular services, we thus postulate the hypothesis

- Hypothesis 6: Privacy concerns have a significant positive influence on privacy risk.

In addition, users with high privacy concerns mistrust the integrity of service providers to appropriately handle their data (e.g. Malhotra et al., 2004; Zhou, 2012). As for other applications and contexts, we expect trust in service providers of connected vehicular services to decrease with increasing privacy concerns. Hence, we hypothesize for connected vehicular services

- Hypothesis 7: Privacy concerns have a significant negative influence on trust in the service provider.

Trust has been conceptualized in manifold ways (for an early overview see Gefen et al., 2003a), but is here defined as the readiness of the trustee to expose oneself to vulnerability based on the positive expectations toward a trusted interaction partner's future behavior (Mayer et al., 1995). The prominent role of trust in contexts of exchange in digital surroundings, such as social exchange on social network sites (e.g. Dwyer et al., 2007), e-commerce (e.g. Gefen et al., 2003a) and data-intensive services (e.g. Wang and Lin, 2016), has repeatedly been demonstrated. Trust has been shown to foster usage intention as it leads to the expectation of positive future outcomes (e.g. Zhou, 2012). Hence, we expect that this also applies to the vehicular context and thus hypothesize

- Hypothesis 8: Trust in the provider has a significant positive influence on behavioral intention to use a connected vehicular service.

Moreover, trust might reduce the perceived privacy risk when interacting with a system (e.g. Pavlou, 2003; Gefen et al., 2003b; Wang and Lin, 2016). Essentially, uncertainty is a prerequisite of the relevance of trust, since in situations which are perceived to be risk-free, there is no need to rely on trust (e.g. Blau, 1964; Molm et al., 2000). Previous research has repeatedly demonstrated a strong tie between trust in providers and perceived risk in digital environments (e.g. Pavlou, 2003; Beldad et al., 2010; Zhou, 2012). Hence, we hypothesize for the context of connected vehicular services

- Hypothesis 9: Trust in the provider has a negative influence on privacy risk.

Perceived risk can be conceptualized as the product of the potential loss associated with an action (e.g. data disclosure) and the perceived subjective certainty that the loss will occur (Cunningham, 1967; Zimmer et al., 2010). It is often viewed as a multi-dimensional construct which comprises performance risk, social risk, financial risk, time risk, physical risk and privacy risk (Jacoby and Kaplan, 1972). According to Featherman and Pavlou (2003), however, the dimensions of perceived risk can vary according to the service. As the current study focuses on vehicular services in the connected car whose new benefits are based on data exchange with entities outside of the vehicle, the focus is put on privacy risk. Privacy risk can be defined as the perceived certainty of losing control over personal information, including the potential misuse of that information (Lee, 2009). Under this definition, in the context of vehicular services in the connected car, privacy risks can be increased by the disclosure of highly personal data (i.e. health data) or the high subjective probability of data misuse by the data receiving party. Various research has demonstrated the direct link between perceived privacy risks and usage intention (e.g. Xu and Gupta, 2009; Wang and Lin, 2016). If the user's evaluative assessment of the potential loss of control over their personal information is high, they are more likely to be reluctant to adopt the respective product (Featherman et al., 2010). Moreover, privacy risk has also been found to influence the affective evaluation of the usage of a service (e.g. Lee, 2009). Hence, we hypothesize for connected vehicular services

- Hypothesis 10: Privacy risk negatively influences the behavioral intention to use a connected vehicular service.

- Hypothesis 11: Privacy risk has a negative influence on the attitude towards using a connected vehicular service.

Following WESTIN'S (1967) definition of general privacy, informational privacy can be defined as the selective control over the access to one's information (Smith et al., 2011). Thus, information control is likely to be a vital factor for data-intensive services such as connected vehicular services. In line with this notion, several studies have found information control to be an important predictor for usage adoption and data disclosure. Xu et al. (2013) and Xu et al. (2011) found privacy control perceived as high to mitigate privacy concerns and privacy risk (Xu et al., 2011). In the context of connected vehicles, users have repeatedly articulated their desire for higher information control (Federation internationale de l'automobile, 2016; Walter and Abendroth, 2018). Therefore, we hypothesize for connected vehicular services

- Hypothesis 12: Perceived information control negatively influences privacy risk.
- Hypothesis 13: Perceived information control negatively influences privacy concerns.

Social norm reflects the normative beliefs about the expectations of one's peers, meaning that it captures the perceived social pressure of a person who intends to use a system (Lee, 2009). The direct influence of these normative beliefs on usage adoption has been repeatedly demonstrated to be relevant in the context of information systems (e.g. Gao and Bai, 2014; Lee, 2009; Leung and Chen, 2017), but also in the vehicular context (e.g. Osswald et al., 2012). Persons who intend to use connected vehicular services might be more likely to adopt these services if they perceive their peer group to be supportive towards using connected services. Thus, we hypothesize for connected vehicular services

- Hypothesis 14: Social norm has a positive influence on the behavioral intention to use a connected vehicular service.

Figure 2 summarizes the hypothesized model.

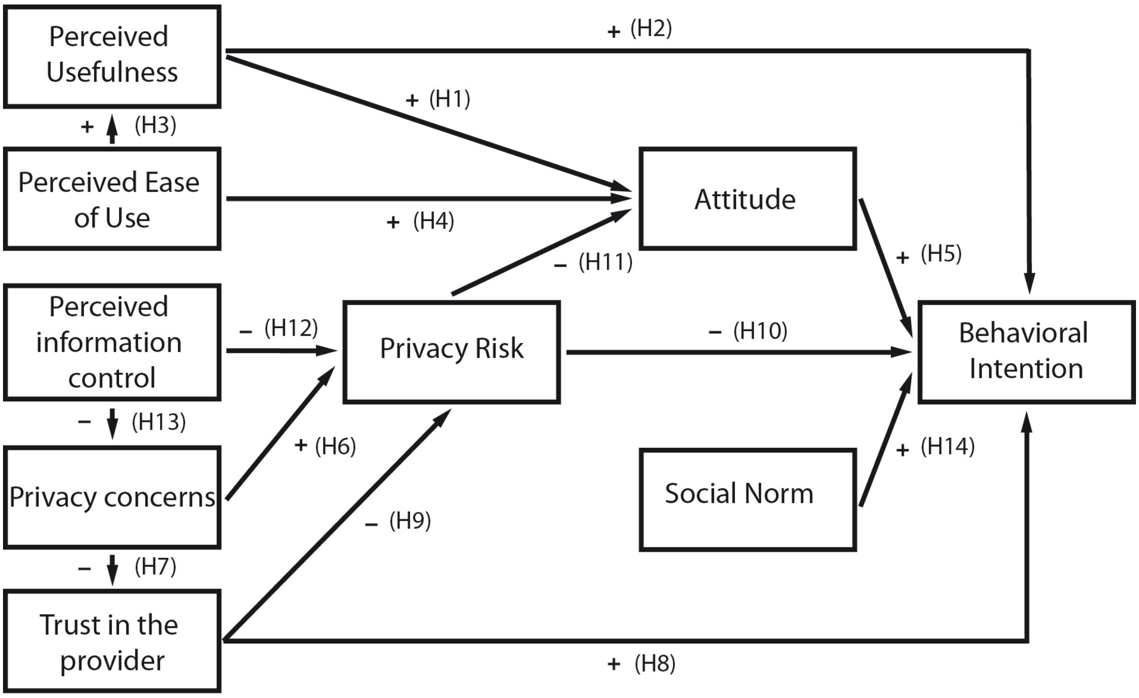

Figure 2. Hypothesized research model for connected vehicular services.

3. Methods

The study was carried out in a high-fidelity simulator of the *[blinded for review]*. Questionnaire data of all participants were collected using an online survey tool on a local PC at the driving simulator.

3.1 Participants

116 participants took part in the simulator study (50 females; M_{age} = 30.47 years, SD_{age} = 12.43 years). All participants had normal or corrected-to-normal vision, possessed a valid driving license and a smartphone which they had to bring to the driving simulator. We assessed prior smartphone usage as well as prior knowledge of

connected cars. Only two out of 116 participants did not use their smartphone on a daily basis. 83 out of 116 participants were aware of connected cars prior to this study. Table 1 summarizes the participant information. Participants were recruited from the university and through personal advertisement in the peer group of the researcher. Participants were paid 20 Euros for their participation. The experimental procedure followed our strict ethical guidelines which are based on the recommendation of the local research ethics committee. Accordingly, we obtained informed consent from all participants.

Table 1. Summary of participant information.

Age		Sex		Prior knowledge		Smartphone Usage	
Mean	30.47 yrs	M	66	Yes	83	Daily	114
SD	12.43 yrs	W	50	No	33	irregular	2

3.2 Measurement

Scales were derived from previous literature and were modified to the context of connected vehicular services. The scales of *perceived usefulness*, *perceived ease of use*, *attitude towards using a system* and *behavioral intention to use* were adopted from existing TAM-based studies (Davis, 1989; Chen and Chen, 2009; Ussat, 2012). The scales of *privacy concerns, privacy risk* and *trust in provider* were adopted from Zhou (2012). The scale of *information control* was taken from Xu et al. (2013). The scale of *social norm* was adopted from Osswald et al. (2012). All scales were rated on a five-point Likert-type scale with anchors ranging from strongly disagree (1) to strongly agree (5). For the scale of information control this meant a deviation from the original 7-point likert scale in Xu et al. (2013). However, all scales underwent a pretest procedure which was thought to ensure sufficient fulfillment of quality criteria. First, a review of the scientists by a panel of experts helped to ensure the validity of the scales in terms of content. Experts were provided with a definition of the constructs and were thus enabled to compare the appropriateness of the single items. Subsequently, an online pretest with N = 33 participants was carried out. Following recommendations by e.g. Hair et al. (2016), the expert review as well as the pretest led to the reformulation or, if necessary, the exclusion of single items. The final questionnaire can be retrieved from Appendix A1.

3.3 Materials and Apparatus

The fixed-based driving simulator was equipped with a 180° field of view. Three high definition projectors with a resolution of 1920 × 1200 pixels and a luminance of 6000 lumens were used to realize this field of view. The mock-up consists of a full size Chevrolet Aveo. A 10-inch tablet (resolution: 1920 x 1200 pixels) was attached to the center stack and served as central touch display.

A click-dummy of a connected parking service was created for this study. Based on a functional concept of He et al. (2014), the interactive interface was built in AXURE RP 8 and was iteratively improved prior to this study employing the human-centered design approach (EN ISO 9241-210; 2011). Figure 3 depicts two screenshots of the connected parking service.

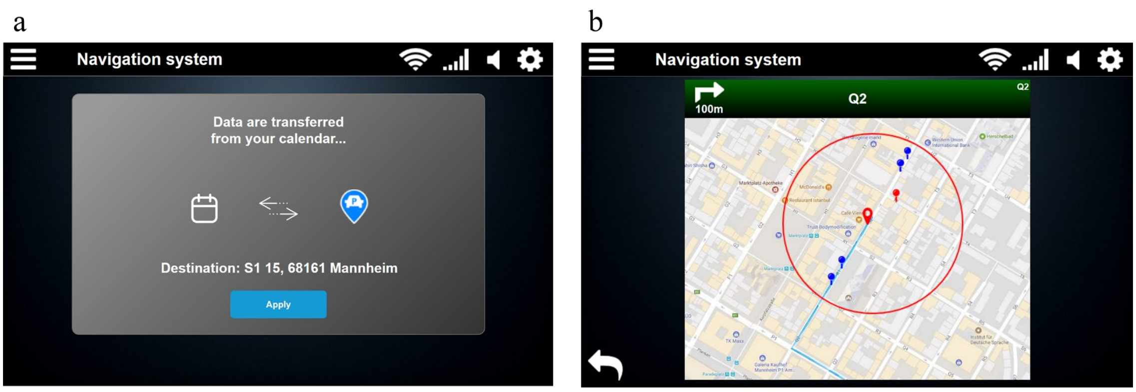

Figure 3. Screenshots of the connected parking application. a) depicts the screen which informs the user about the calendar retrieval while b) shows the choice of the preferred parking space. Translated, original screenshot was presented in German.

The parking service enables users to automatically reserve parking spaces in close distance to their attended destination. Once a parking space is identified, the connected service reserves the parking space in a database on a backend server and thus blocks the respective space for other connected cars. In order to use these functions users are required to provide their consent to data disclosure. The data types were described in detail in a privacy notice screen. Data to be disclosed were: the user's identity, calendar entries, driving behavior, data from environment sensors, location and time.

We chose the parking service to represent connected vehicular services, as it is thought to enhance comfort and transport efficiency, both of which are central categories of (intelligent) vehicular infotainment and assistance systems (Golias et al., 2002; Martínez-Torres et al., 2013).

3.4 Procedure

The reported study was part of a larger driving simulation study which took approximately 90 minutes in total. However, all participants always started with the task sequences described here, to avoid confusing influences resulting from the experimental sequence. The experimental session reported here consisted of a first phase in which participants were seated in the simulator mock-up and a second phase which took place outside of the simulator. The second phase comprised the online questionnaire as well a post-experimental interview which included verbal manipulation checks.

After a short habituation period in which participants could get used to the driving simulator, participants were provided with the pre-installed connected parking service. In the course of the first screens of the click-dummy, they were presented with a cover story in written format, which introduced them to a supposed pre-market product test of a new parking service. Previous user surveys revealed that trust in car manufacturers was average with a high variance in user ratings whereas an (commercial) app provider was trusted the least (Walter and Abendroth, 2018). To avoid unauthorized usage of real company names we introduced ConCar AG as a spin-off of a German car manufacturer. Consecutively, participants were asked to imagine that they would meet a friend in a café bar in Mannheim. We chose Mannheim as the city for the cover story since it is close enough to the location of the simulator study (approximately 50 km) in order to maintain the realism of the scenario, but also distant enough so that participants are less likely to be familiar with the local café bars. In order to get a free and comfortable parking space close to the café bar, participants were suggested to use the parking service. To do so, they were asked to connect their smartphones to the car system via Bluetooth in order to retrieve relevant calendar entries. A pop-up screen for a successful Bluetooth connection was manually triggered by the experimenter using the wizard-of-oz technique. An animated screen visualized the simulated data transfer. In fact, no Bluetooth connection was established, however. Consecutive verbal manipulation checks revealed that no participant noticed the experimental simulation. All participants were convinced that their smartphone had been connected to the car. After the Bluetooth connection was supposedly established, participants were asked to disclose a set of required data. In fact, at no point of the experiment data were assessed. Again, however, post-experimental verbal manipulation checks confirmed that participants believed that they had indeed released their data. The dialogue design resembled the privacy pop-up from Android smartphones (see Figure 4). As with smartphone applications, participants had an all-or-nothing choice: revealing one's data enabled the participants to use the parking service while a denial was supposedly associated with no access to the service. We recorded the disclosure decision of each participant and used it later on for analysis purposes which are not included in this report. After the data disclosure decision was made, an information screen within the click-dummy asked all participants (independent of their disclosure decision) to proceed in order to test the functionalities of the service within the supposed pre-market test. Thus, independent of their disclosure, all participants were presented with the same parking service.

Once the decision on data disclosure had been made, participants were suggested several parking spaces in short distance to their destination of which they could choose one manually. Using the navigation function of the parking service, participants drove approximately five minutes on a virtual urban track which resembled the real infrastructure of Mannheim. The navigation function was again simulated using the wizard-of-oz technique.

After arrival at the parking space, participants were asked to leave the driving simulator and fill out the online questionnaire on a laptop. Consecutively, we interviewed participants regarding their perception of the manipulation checks and critics about the parking service. Finally, participants were debriefed.

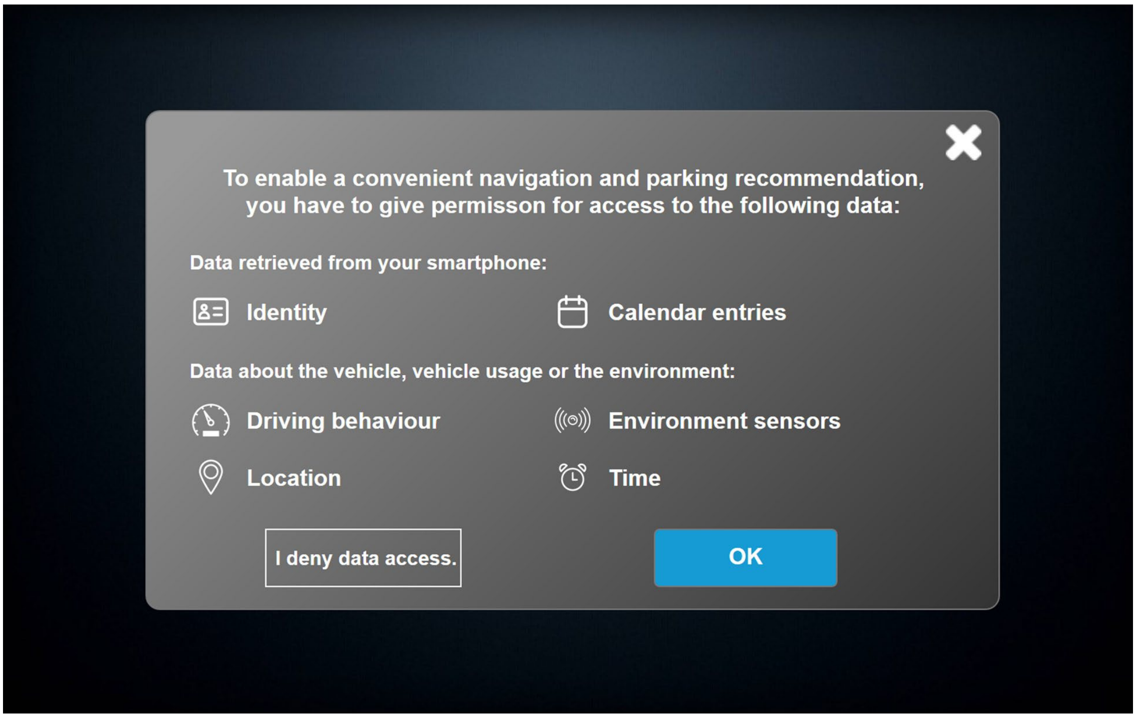

Figure 4. Screenshot of the parking service. Users are presented with a list of data which need to be disclosed in order to use the parking service. Translated, original screenshot was presented in German.

3.5 Data Analysis

The resulting data were prepared for analysis. All 116 participants met the inclusion criteria of having a valid driving license and possessing a smartphone. The data were screened for incomplete responses, but no such data sets were found. Thus, a valid sample of 116 datasets was fed into the measurement analysis. The model was estimated using the partial least squares (PLS) structural equation modelling technique with the SmartPLS 3.0 software application (Ringle et al., 2015). PLS was chosen over other alternative techniques as it does not require the distributional assumption of normality (Hair et al., 2011; Lowry and Gaskin, 2014).

4. Results

4.1 Evaluation of the Measurement Model

Prior to the structural model analysis, we assessed the adequacy of the measurement model by conducting PLS factorial validity tests. The measures were validated considering convergent and discriminant validity. PLS factorial validity tests revealed that all standardized factor loadings were significant and above the .70 threshold. Moreover, all averaged variances extracted (AVEs) exceeded .5, while the ρ and α of each latent construct were larger than .7. Discriminant validity of the measurement model was established by comparing the square root of AVE of each latent construct with the correlation of the respective construct with other constructs. In all comparisons, the square root of AVE exceeded the correlations with other constructs (Fornell and Larcker, 1981). As shown in Table 2, the examination of the indicator's cross loading showed that no indicator loads higher on an opposing construct (Hair et al., 2011). Hence, the measurement model parameter estimates provide strong evidence for the validity and reliability of our construct measures.

4.2 Structural Model and Hypothesis Testing

After demonstrating the adequacy of our measurement model, we tested the hypothesized structural model. After correction, the proposed model could account for 69.9 percent of the total variation in behavioral intention. Moreover, 70.4 percent of the variation in privacy risk and 41.1 percent of the variation in attitude towards using the system could be explained. Figure 2 displays the results. To assure the predictive validity of the three latent variables, the Stone-Geisser's Q^2 Test was applied. The resulting Q^2 values for behavioral intention, privacy risk and attitude were all significantly above zero (0.54, 0.57 and 0.27 for behavioral intention, privacy risk and attitude, respectively), thus providing evidence for the model's predictive relevance.

Table 2. Cross-loadings and Average-Variance Extracted (AVE)

	ATT	BI	PU	PEOU	IC	PC	PR	TR	SN
ATT	0.829								
BI	0.802	0.896							
PU	0.635	0.543	0.817						
PEOU	0.327	0.258	0.532	0.815					
IC	0.258	0.349	0.194	0.033	0.900				
PC	-0.344	-0.377	-0.338	-0.194	-0.313	0.933			
PR	-0.326	-0.340	-0.286	-0.265	-0.330	-0.313	0.918		
TR	0.514	0.416	0.413	0.157	0.301	-0.339	-0.355	0.810	
SN	0.739	0.763	0.536	0.225	0.295	-0.323	-0.304	0.475	0.849

Note: The diagonal comprises the AVE values.

We tested the significance of our predicted path relationships applying a bootstrap analysis of 5000 samples (Hair et al., 2011). Eight out of 14 hypothesized relationships were significant. *Hypothesis 1* which dealt with the positive effect of perceived usefulness on attitude was supported ($\beta = 0.61$, $t = 6.44$, $p < .001$). In contrast, there was no significant direct effect of perceived usefulness on behavioral intention (*Hypothesis 2*; $\beta = 0.02$, $t = 0.22$, $p > .05$). Perceived ease of use had a significant positive effect on perceived usefulness (*Hypothesis 3*; $\beta = 0.52$, $t = 4.62$, $p < .001$). However, *Hypothesis 4* which claimed a positive effect of perceived ease of use on attitude was not supported ($\beta = -0.02$, $t = 0.30$, $p > .05$). As predicted by *Hypothesis 5*, attitude had a significant positive effect on behavioral intention ($\beta = 0.52$, $t = 6.10$, $p < .001$). Moreover, privacy concerns positively affected privacy risk (*Hypothesis 6*; $\beta = 0.80$, $t = 19.90$, $p < .001$). As anticipated in *Hypothesis 7*, privacy concerns had a negative influence on trust (β = -0.35, t = 4.24, p < .001). Trust in the provider had no significant influences on either of the hypothetically associated constructs privacy risk (*Hypothesis 8*; β = -0.07, t = 1.43, p > .05) and behavioral intention (*Hypothesis 9*; β = - 0.07, t = 0.97, p > .05). Contrary to *Hypothesis 10*, privacy risk had no negative influence on intention to use the connected vehicular service (β = -0.08, t = 1.22, p > .05).

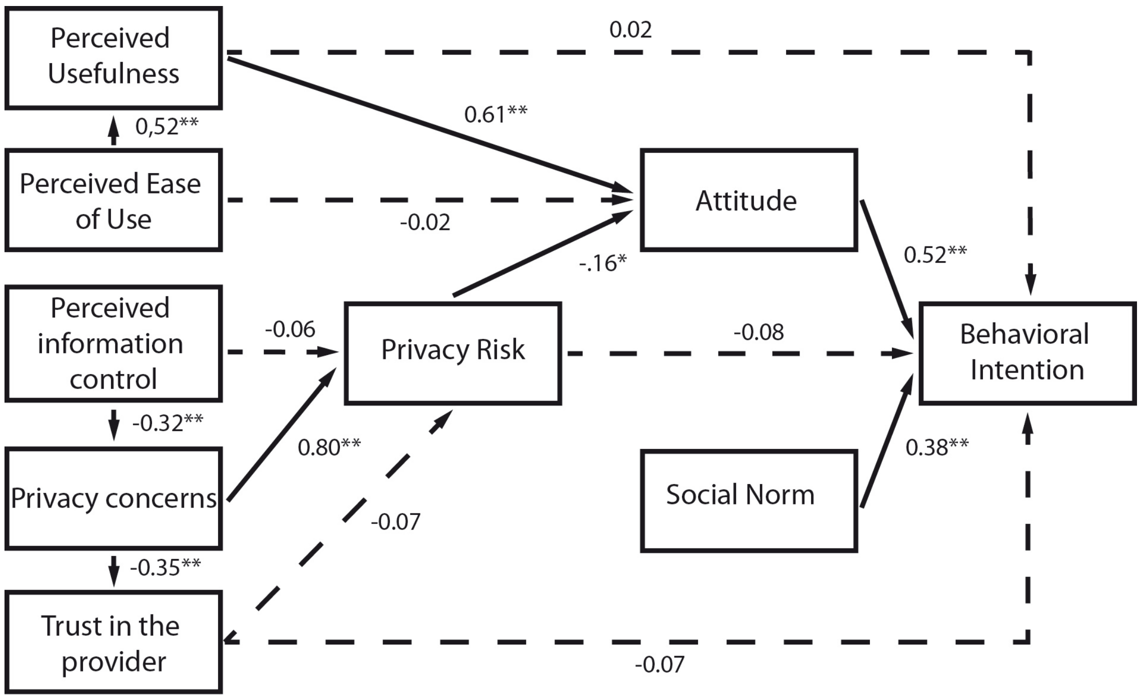

Figure 5. Structural equation model for connected vehicular services. Dashed lines represent weights of non-significant paths. **: p < .001; * p < .05.

There was a significant negative influence of privacy risk on attitude, however (*Hypothesis 11*; β = -.16, t = 2.29, p < .05). The hypothesized role of information control was only partly supported. While a negative influence of information control on privacy risk could not be found (*Hypothesis 12*; β = -0.06, t = 1.05, p > .05), there was a significant negative effect on privacy concerns (*Hypothesis 13*; β = -0.32, t = 3.78, p < .001). Furthermore, social norm had a direct positive effect on behavioral intention

(*Hypothesis 14*; $\beta = 0.38$, $t = 5.11$, $p < .001$). Figure 5 and table 3 summarize the results.

Table 3. Results of hypothesis testing

	β	t	p	
PU → ATT	0.612	6.44	<.001	H_0 rejected
PU → UI	0.02	0.22	>.05	H_0 not rejected
PEOU → PU	0.52	4.62	<.001	H_0 rejected
PEOU → ATT	-0.02	0.30	>.05	H_0 not rejected
ATT → UI	0.52	6.10	<.001	H_0 rejected
PC → PR	0.80	19.90	<.001	H_0 rejected
PC → TR	-0.35	4.24	<.001	H_0 rejected
TR → UI	-0.07	0.97	>.05	H_0 not rejected
TR → PR	-0.07	1.43	>.05	H_0 not rejected
PR → UI	-0.08	1.22	>.05	H_0 not rejected
PR → ATT	-0.16	2.29	<.05	H_0 rejected
IC → PR	-0.06	1.05	>.05	H_0 not rejected
IC → PC	-0.31	3.78	<.001	H_0 rejected
SN → UI	0.38	5.11	<.001	H_0 rejected

Note: Significance level was $\alpha = .05$.

5. Discussion

This paper set out to test a hypothetical model for the usage adoption of connected vehicular services which is based on the TAM and factors relevant for data disclosing behavior. To the author's knowledge, this is the first acceptance modelling approach exclusively dedicated to the vehicular context which takes privacy relevance of connected cars into account.

5.1 Key results

The model test yielded mixed results for the classical TAM predictions. While perceived benefits associated with using the connected parking service did enhance a positive attitude towards using the connected service, there was no direct influence of perceived usefulness on usage adoption. This seems to be surprising as it stands in contrast to the classical predictions of TAM. However, these results replicate previous studies on acceptance in the vehicular domain (Chen and Chen, 2009). Likewise, perceived ease of use drove perceived usefulness, but did not have an effect on the affective response of users towards using the connected parking service. In the context of connected vehicular services, functionality is thus subject to an affective appraisal and does not have a direct influence on the usage intention. The perception of usefulness itself is mainly driven by the user's perception of the effort required when using connected vehicular services. In accordance with numerous previous studies we found social norm to directly drive usage intention. The participants were concerned about their peers' opinion on connected vehicular services.

Motivated by studies on data disclosure in mobile and classical internet contexts, we hypothesized a second model branch which comprised factors associated with informational privacy. In accordance with Zhou (2012) we expected perceived privacy risk to be driven by trust in the provider and privacy concerns. Moreover, trust was thought to have a direct effect on the intention to use the connected vehicular system. In the context of connected vehicular services, we could replicate a significant positive effect of privacy concerns on perceived privacy risk and a significant negative effect on trust. However, trust neither had a significant positive effect on usage intention nor a significant negative effect on perceived privacy risk. As in various other contexts (Bansal et al., 2010; Zhou, 2012), users of connected vehicular services are worried about the treatment of their disclosed data. If these concerns increase, the trust in the service provider might be reduced, while the perception of a privacy risk in course of the adoption of the connected vehicular service might be intensified. It should be noted that previous studies reported effects of privacy risk on privacy concerns (e.g. Xu et al., 2013; Xu et al., 2011). This is an effect inverse to the one reported here. In contrast to Zhou (2012), these studies predicted information disclosure rather than usage intention. As these are two different target variables of the models and Zhou's (2012) target variable resembled our target variable, we decided to rely on the reasoning as exemplified in Zhou (2012). Trust in the service provider did not have any significant effects, which seems to be in stark contrast to manifold previous studies (e.g. Zhou, 2012; Evjemo et al., 2018). A possible explanation for this discrepancy might be associated with differences in the experimental manipulations. As Gefen et al. (2003a) showed trust becomes less influential with experience. When experience had been gained with a system, reliance on trust as antecedent for usage adoption was reduced while other factors became more influential (Gefen et al., 2003a). While previous studies predominantly relied on the presentation of text- or image-based scenarios as part of online-surveys, the participants of this study gained real interaction experience in a high-fidelity driving simulator. Thus, the influence of trust might be reduced as a consequence of the simulation study which included real interaction experience. Alternatively, the presentation of the data receiving party as spin-off of a car manufacturer might have influenced participants trust towards ConCar AG. Since ConCar AG belongs to a car manufacturer that can already access plenty of sensitive data during the purchase of the car, participants might have trusted ConCar AG more easily. On average, trust scores were $M = 3.62$ ($SD = 0.68$) on a five-point likert scale, which deviated significantly from the center of 3 ($t(1\ 1\ 5) = 9.78$, $p < .001$). Thus, our data tend to support the above explanation. Based on our supplementary analysis we cannot explain why our participants trusted the data receiving party, but we can assess that their trust level in ConCar AG was significantly above average. As outlined above, the non-significant effect of trust in our model might be explained by the fact that users acknowledge that the data receiving party might already have access to sensitive data. In a different scenario (e.g. a data receiving party is not a subsidiary of a car manufacturer) trust might play a more significant role in explaining the usage adoption of connected vehicular services.

In addition to Zhou's (2012) triad of privacy-related factors, we also included information control as direct antecedent of privacy risk and privacy concerns in our model. In contrast to Ando et al. (2016) who elucidated usage intention in the IoT context there was no direct effect of information control on privacy risk. According to Ando et al. (2016), the perception of control over one's personal information decreases privacy risk perception. Our study suggests that this direct relation does not hold true for the connected vehicular services. Instead, our data suggest an indirect effect of information control on privacy risk, which is mediated by privacy concerns. This finding is well in line with the notion that privacy concerns will be reduced in individuals when they have a greater sense of control over their personal information (Culnan and Armstrong, 1999; Xu et al., 2011). Though the perception of control over one's personal information does not reduce the perception of privacy risk directly, it lowers privacy concerns, which in turn reduces the perceived privacy risk. Our study therefore suggests that information control is an important factor for data-driven applications in the vehicular context.

In reliance on the privacy calculus, i.e. the assumption that usage adoption of data-intensive services and products is based on the weighing up of risks and benefits (Dinev and Hart, 2006, 2003; Laufer and Wolfe, 1977), we structured our model in two sections. While the classical TAM section can be received as a representation of beneficial factors, the section concerning privacy risk perception might be interpreted as a detailed representation of the risks associated with the usage adoption of connected vehicular services. In accordance with the privacy calculus model we expected perceived privacy risk and the TAM-related beneficial factors to merge in usage intention. However, the perception of privacy risk did not influence usage intention directly, but influenced the attitude towards using the connected vehicular service negatively. As in Lee (2009), perceived privacy risk is integrated in an affective appraisal of the usage of the system. Despite the lack of a direct relationship to usage intention, our results suggest that perceived privacy risk and its antecedents are relevant factors for the explanation of usage adoption of connected vehicular services. Thus, minimizing privacy risk perception should be a strong motivation for providers of connected vehicular services. Our model suggests that trust-enhancing measures are less fruitful than measures which foster the perception of control over one's personal information.

5.2 Implications

Connected services in the automobile bear manifold advantages for the individual user as well as for the community of road users in general (Lee et al., 2016). Our acceptance model demonstrates that, if perceived as being useful and easy to use, users appreciate these advantages. However, users also consider privacy-related factors for their cognitive and affective appraisal regarding the usage of a connected vehicular service. A primary contribution of our work is the integration of privacy-related factors with classical acceptance model factors in the vehicular context. By referring to both, classical TAM theory and insights from research on data disclosure in various contexts, this study elucidates the effects of the introduction of ambient intelligence in the automobile. The findings suggest that classical TAM factors are still main drivers of usage adoption in connected vehicular services, but also demonstrate that informational privacy becomes relevant for the acceptance of modern vehicular applications.

From a managerial view, this study underscores the relevance of privacy-aware designs for car manufacturers and service providers. By meeting the user's preferences and acknowledging the relevance of privacy, practitioners can design connected vehicular services which fit the user's functional needs while keeping privacy preferences in mind. Service providers should take measures to enhance the user's control about personal information in order to lessen the perceived privacy risk and thus eventually enhance a positive attitude towards using the connected vehicular service. System designers have two main mechanisms for technology-related privacy protections at hand: Privacy-by-design and privacy-by-policy (Lederman et al., 2016). By following at least one of these mechanisms, system designers and decision makers can apply technical and organizational measures to ensure a privacy-preserving data processing. Current privacy policies in Europe (i.e. General Data Protection Regulation) already formulate clear prerequisites for the collection, processing and analysis of data and demand privacy-by-design. This also applies to connected vehicles, (Plappert et al., 2017; Wachter, 2018). Moreover, our model guides practitioners towards a balanced application of privacy-aware, but functionally attractive and usable services. In addition to privacy-aware solutions, the current study underscores the relevance of perceived usefulness and intuitive interaction design. As in previous research in other technology contexts (Slovic and Peters, 2006), privacy risk perception in the connected vehicle is evaluated affectively. Accordingly, future users should be integrated into early phases of technology development in order to foster trust in the technology and to increase the reliability of public information (Brell et al., 2019; Zaunbrecher et al., 2016). A vital part of public communication strategies should support the risk-benefit trade-off by informing users about actual risks of data disclosure while communicating the benefits of the connected system (Rohunen and Markkula, 2018).

5.3 Limitations

The design of this study allowed us to expose the participants to an interactive connected service in a high-fidelity simulation environment which enabled immersive interaction experience. However, despite our efforts to design a realistic set up, our study remains a simulation study. Therefore, participants might be aware of the simulated context. We checked the immersive quality of our set up by conducting post-hoc interviews which ensured that none of the wizard-of-oz manipulations was realized by any participant. All participants thought that they had interacted with a functionally complete connected service. Moreover, previous literature reports high correlations between real driving behavior and behavior demonstrated in driving simulation studies. This underscores the transferability of the results of simulation studies (Lee et al., 2003; Lee, 2003; Bédard et al., 2010). Although the above literature supports the appropriate immersive qualities of our simulated scenario, one might wonder whether there is a significant difference between interaction with an application in a (simulated) vehicular context and smartphone-based application usage. In fact, we have used some design elements from smartphone applications as examples for our interaction screens, such as the pop-up screen that asks users for their informed consent to share data. Despite these graphic similarities, we believe that usage context (here: connected vehicle) has a substantial impact on intention to use and thus on data disclosure. While connectivity and internet access are apparent in smartphone usage, users perceive the car as a means of transport (Steg, 2005). The internet connection is less evident (Federation internationale de l'automobile, 2016). Hence, connected car services are not sufficiently recognized as such Ando et al. (2016). Following Dienlin's (2014) privacy process model this difference in saliency of being connected gains relevance for technology adoption and data disclosure. The privacy process model posits that privacy behavior does not rely directly on the objective privacy situation but rather on the user's perception of the objective situation. Hence, if the privacy context is less apparent in connected vehicles, decisions on usage adoption and data disclosure should differ from smartphone-based scenarios. There is indeed growing evidence that the users' desire for privacy is influenced by their perception of the technology. This also applies for connected vehicles which are unique in their potential to collect locational and movement data without consumer consent and choice (Lederman et al., 2016). However, this study does not provide a proof for our assumption. Therefore, it remains a task for upcoming studies to elucidate potential differences in saliency of privacy relevance in different contexts, e.g. in connected vehicles compared to smartphones. The analysis of users' mental models in both scenarios might be a fruitful approach.

Second, our sample was relatively small for SEM samples. In current scientific literature, there are papers claiming PLS SEM to be suitable for small sample sizes (e.g. Hair et al., 2011), while there also are critiques doubting this claim (e.g. Goodhue et al., 2012). However, we assert to overcome this debate by calculating our sample size based on the power recommendations of Cohen (1992). For a statistical power of 80%, a significance level of five percent, an expected minimum $R^2 = .25$ and a maximum number of independent variables for a construct of five, the suggested minimal sample size is 45. Hence, with $n = 116$, we significantly exceed this lower sample size boundary.

However, the relatively small sample size increases the importance of an adequate reflection of the variation of the decisive demographic variables in our sample. Amongst others, experience with application usage might influence the ease of use and thus the usage adoption. We assessed smartphone usage as a proxy for experience with applications. With 97.4% of participants using their smartphone regularly, our sample reflects the distribution of smartphone usage in the German reference population aged 18–49 years (95%; Statista, 2019a). Third, our sample did not solely comprise participants with experience regarding connected vehicular services. We tried to overcome this problem by ensuring that all participants possessed a driving license and exceeded a minimum level of driving experience. Moreover, we assessed the participant's awareness of connected vehicles prior to this study. With 72% of our participants having heard of connected cars before, this reflects the distribution of awareness found in previous user surveys (Federation internationale de l'automobile, 2016). However, it remains a task for upcoming studies to elucidate whether prior long term experience with connected vehicular services affects usage adoption as studies from other contexts suggest (e.g. Shen et al., 2011). The experimental procedure of Keith et al. (2013) who manipulated critical variables systematically constitutes a good example of experimental control over potentially confounding variables. Fourth, we chose TAM as our base model. Our choice was motivated by the fact that TAM is one of the most commonly applied models for technology adoption (Al-Momani et al., 2019) and has proven to be robust across different settings (Koul and Eydgahi, 2017). As with several other acceptance models, however, TAM postulates an elaborated decision-making process. Although the model factor attitude towards using a system also includes an affective evaluation of the system, TAM does not sufficiently represent affective components of decision-making. An alternative, more affectaware approach might be the Motivation and Opportunity as Determinants model (MODE) by Fazio (1990) which assumes an individual's information processing to be either elaborate or affective/spontaneous. It is an interesting task for upcoming studies to reflect affective processing more prominently in acceptance model. Fazio's MODE model might be a good starting point. Moreover, we included all participants with valid and complete answers in our sample. Doing so, we did not differentiate between those who were ready to release their data (i.e. disclosers) and those who denied data disclosure (i.e. deniers). Hence, we recalculated our model based on the disclosers only (N = 103). As shown in Appendices A2 and A3, we were able to replicate the findings for the whole sample, with the exception of the influence of privacy risk on attitude towards using a system and behavioral intention to use the system. While there was a significant effect of privacy risk on attitude, but not on behavioral intention in the whole sample, the opposite was true for the disclosers. Here, the valuation of a perceived privacy risk has a direct negative influence on usage intention. As in Featherman et al. (2010), disclosers were less likely to adopt the connected vehicular service if their evaluative assessment of the potential loss of control over their personal information was high. Finally, we used a specific connected vehicular service. Doing so enhanced the plasticity of the scenario. However, it allows claims for comfort related connected vehicular services only. Follow-up studies are required to elucidate whether our identified model also applies to connected vehicular services which serve other functionalities, such as safety. Results from user surveys suggest a higher relevance of safety functionalities (e.g. Walter and Abendroth, 2018). For these services the influence of privacy-related factors might be lessened.

6. Conclusion

Overall, this study provides a valid modelling approach for the study of the acceptance of connected vehicular services. We tested the acceptance of connected vehicular services in a high-fidelity simulation environment and found usage adoption to be influenced by privacy-related factors. Thus, to our knowledge, this paper constitutes the first acceptance study exclusively dedicated to the vehicular context, which takes privacy relevance of connected cars into account. Our results suggest that a connected vehicular service's perceived usefulness remains a strong predictor of usage adoption. However, privacy perception also drives the affective evaluation of the connected service. Thus, enhancing the users' perceived information control while minimizing privacy risk perception should be a strong motivation for providers of connected vehicular services. By acknowledging the integration of privacy-relevant technologies in the modern car, the proposed model can serve researchers and practitioners as foundation to further elucidate this promising field and to derive design recommendations for highly accepted service solutions. Our results motivate policy makers and service providers to foster communication strategies which support a risk–benefit trade-off, e.g. by transparently informing users about actual risks of data disclosure.

Declaration of interest

None

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Appendix A1. Factor loadings of single items and quality criteria

Construct/Item	*Loading*	*Cronbach's Alpha*	*Composite Reliability*	*AVE*
Attitude		0.772	0.869	0.688
Using the parking app would be pleasant while driving.	0.837			
I dislike the idea of using the parking app.	0.790			
Using the parking app enhances comfort while driving.	0.860			
Behavioral Intention		0.877	0.924	0.803
I do not want to use the parking app while driving.	0.889			
To the extent possible, I would use the parking app while driving.	0.874			
Whenever possible, I intend to use the parking app while driving.	0.924			
Perceived Usefulness		0.833	0.889	0.668
Using the parking application saves me time.	0.848			
Using the parking app simplifies the search for a parking space.	0.824			
I do not find the parking app useful while driving.	0.854			
The advantages of using the parking app outweigh the disadvantages.	0.739			
Perceived Ease of Use		0.830	0.888	0.665
Learning to operate the parking app would be easy for me.	0.781			
I would find it easy to get the parking app to do what I want it to do.	0.808			
I would find the parking app easy to use.	0.898			
My interaction with the parking app would be clear and understandable.	0.769			
Information Control		0.883	0.927	0.810
I believe I have control over who can get access to my personal information.	0.895			
I believe I have control over how personal information is used by the parking app.	0.917			
I think I have control over what personal information is released by the parking app.	0.888			
Privacy Concerns		0.925	0.952	0.870
I am concerned that the information I disclosed to the service provider could be misused.	0.940			
I am concerned about providing personal	0.916			

information to the service provider, because of what others might do with it.				
I am concerned about providing personal information to the service provider, because it could be used in a way I did not foresee.	0.942			
Privacy Risk		0.907	0.942	0.843
Providing ConCar AG with my personal information would involve many unexpected problems.	0.936			
It would be risky to disclose my personal information to ConCar AG.	0.913			
There would be a high potential for loss in disclosing my personal information to ConCar AG.	0.905			
Trust in Provider		0.739	0.851	0.656
This service provider keeps customer interests in mind.	0.777			
This service provider keeps its promise.	0.758			
This service provider is trustworthy.	0.890			
Social Norm		0.806	0.886	0.721
I would be proud to show the system to people who are close to me.	0.847			
People whose opinions are important to me would like the system too.	0.825			
In general, people who I like would encourage me to use the system.	0.875			

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