Computers in Human Behavior Reports 7 (2022) 100202

Contents lists available at ScienceDirect

Computers in Human Behavior Reports

journal homepage: www.sciencedirect.com/journal/computers-in-human-behavior-reports

# The moderating influence of life events on the acceptance of advanced driver assistance systems in aging societies

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A R T I C L E I N F O

*Keywords:*
Advanced driver assistant systems
Autonomous driving
Acceptance
Life events
Life course
Older drivers
Aging societies
Technology acceptance model

A B S T R A C T

Life events in the context of the different life courses of individuals can influence behavior in the acceptance of technology. In this context, driver assistance systems have the potential to create the basis for future mobility solutions. However, the systems should be accepted by the older generation, which can provide them with mobility into old age. Therefore, a literature review was conducted and life events were identified that may moderate the effect relationships in the acceptance of driver assistance systems. Based on the technology acceptance model, a research model was developed and validated by a study (n = 181). The results show that there are differences in the acceptance of driver assistance systems depending on different life events. The results show that the four life events "major illness," "retirement," birth of a grandchild, and "major accident" have a moderating influence on the acceptance of driver assistance systems. The study finds that regardless of the life event experienced, trust in technology is a major factor in acceptance, along with perceived usefulness. For example, retired individuals and those with major illnesses focus on the ease of use of the systems, while individuals with grandchildren value the opinion of their close environment.

## 1. Introduction

The acceptance of technology is a critical success factor in the implementation of technology in everyday life (Hu et al., 1999). The two studies by Steele et al. (2009) and Wang (2008) show that younger generations have a basic affinity for technology, enjoy using it, and have a positive attitude toward new technologies. This does not apply in the same way to older generations, as they are biased in their opinions and the majority are less interested in technology and its use than younger generations (Mitzner et al., 2010; Ryu et al., 2009). Integrating ongoing digitization and technological progress into the everyday lives of all people in the context of demographic change will therefore continue to be a major challenge (European Commission, 2018; OECD, 2016; Peine et al., 2015).

Individual mobility, particularly the automobile as a means of transportation, can be used as an outstanding example of technological change. Never before have older people been as mobile as they are today (Allgemeiner Deutscher Automobil-Club, 2018). In Germany, 51% of driving license holders are 50 years and older. Mobility thus represents an essential part of the independence of older people and thus their well-being (Adler & Rottunda, 2006; Dickerson et al., 2007; Molnar & Eby, 2009). The use of driver assistance systems in vehicle driving has a substantial supporting role within this context. They compensate for the declining abilities of older drivers while driving a vehicle and enable safe and individual mobility in later years (Eby & Molnar, 2012; Edwards et al., 2009; Musselwhite, 2018, pp. 235–251; Musselwhite et al., 2015; Musselwhite & Haddad, 2018). Driver assistance systems are designed to improve safety by avoiding collisions and minimizing energy consumption while increasing comfort for vehicle passengers (Gruyer et al., 2017; Naujoks & Neukum, 2014). Therefore, driver assistance systems provide an exciting opportunity to further investigate the technology acceptance of the elderly population.

There have been many studies on this topic in research, but a positive or negative trend on technology acceptance in the elderly has been lacking (Hauk et al., 2018), which indicates a need for further research on this topic. There is also evidence that acceptance and use of technologies is not based solely on perceived usefulness or perceived ease of use, but that social and cultural aspects of older users in particular can explain their acceptance or rejection of technologies (Chen & Chan, 2014; Knowles & Hanson, 2018; Mitzner et al., 2016; Waycott et al., 2016). Therefore, it is worth considering the life-oriented approach. Emerging from travel behavior research, the life-oriented approach seeks to provide a better understanding by implementing additional determinants and demographic factors into research models (Alemi

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https://doi.org/10.1016/j.chbr.2022.100202
Received 14 July 2021; Received in revised form 25 February 2022; Accepted 6 May 2022
Available online 11 May 2022

et al., 2018; Herrenkind et al., 2019; Lanzendorf, 2003). Regarding this, life events play an important role in that they can change daily routines and thus lead to a change in mobility behavior; they can also contribute to the willingness to use driver assistance systems (Janke & Handy 2019; Busch-Geertsema & Lanzendorf, 2017; Clark et al., 2016; Scheiner & Holz-Rau, 2013; Schäfer et al., 2012; Lanzendorf, 2010; van der Waerden et al., 2003). Life events thus represent an approach to investigate the acceptance of driver assistance systems in more detail. The influence of life events on technology acceptance in general and on the acceptance of driver assistance systems is still largely unexplored. This study therefore attempts to include life events in the consideration of technology acceptance to generate a better understanding.

The article is organized as follows: In Section 2, a literature review is conducted on technology acceptance in old age and various life events in the life course of individuals that may have an impact on acceptance. In addition, the research hypotheses are presented. Section 3 describes the research before Section 4 provides the results of the study. Section 5 deals with the discussion of the results and concludes with implications and limitations.

## 2. Literature review, theoretical framework and research hypotheses

### 2.1. Technology acceptance model in old age

Davis et al. (1989) developed the Technology Acceptance Model (TAM) as an adaptation and specialization of the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980) which, with its extensions and further developments, has formed the basis of numerous technology acceptance studies (Agarwal, 2000; Bhattacherjee & Sanford, 2006; Gefen et al., 2003; Gefen & Straub, 1997; Herrenkind et al., 2019; Im et al., 2007; Koivumäkiet al., 2006; Koufaris, 2002; Li & Huang, 2009; van der Heijden, 2004; Zarmpou et al., 2012). It examines the probability of individual user behavior of technology for various research questions with the aim of providing a universal and at the same time as simple as possible explanation of the factors of information system use (Legris et al., 2003; Ma & Liu, 2004). The technology acceptance model, in line with TRA, states that perceived usefulness and perceived ease of use as constructs influence the attitude toward use and intention to use (Davis et al., 1989). The higher the usefulness and the easier the system or technology is to use, the greater the person's willingness to use the technology (Simon, 2001). In summary, based on intention to use, the technology acceptance model attempts to explain why individuals accept and use technology.

At the beginning of technology acceptance research, age received only little attention in previous studies (Venkatesh et al., 2003). More recent studies show that there are age-related differences in technology acceptance and use (Arning & Ziefle, 2007; Morris et al., 2005; Venkatesh & Davis, 2000). Although most older people have positive attitudes toward technology, they are less interested and less likely to use technology than younger people (Mitzner et al., 2010; Ryu et al., 2009; Steele et al., 2009; Wang, 2008; Yao et al., 2009). There are divergent findings in the literature on technology acceptance in old age. Some studies show that age has a positive influence on technology acceptance (Jimoh et al., 2012; Martins et al., 2014), while others postulate a negative or non-significant influence (Alexandrakis et al., 2020; Escobar-Rodriguez & Bartual-Sopena, 2013; Porter & Donthu, 2006; Shin, 2009). The meta-analysis by Hauk et al. (2018) sums up a rather negative influence of age on technology acceptance. More recently, the fundamentals of the technology acceptance model has also been applied in acceptance research in the context of driver assistance systems (Chen & Chen, 2011; Ghazizadeh et al., 2012; Kervick et al., 2015; Larue et al., 2015; Park & Kim, 2014; Roberts et al., 2012; Rodel et al., 2014; Xu et al., 2010). Souders and Charness (2016) examine the adoption of driver assistance systems and autonomous driving among older adults (55 years and older) and show that the intention to use a driver assistance system increases with age. Braun et al. (2019) provide evidence that take up of driver assistance systems are significantly higher in the 65 and older age group.

The technology acceptance model by Davis et al. (1989) as a basis is proven, robust, and the most influential model for investigating the acceptance of information technology (Carr, 2008; King & He, 2006; Koivumäki et al., 2017; Schepers & Wetzels, 2007; Wu et al., 2011). Therefore, the following hypothesis are formulated:

**$H_1$** : The greater the perceived usefulness, the greater the intention to use ADAS.

**$H_2$** : The greater the perceived ease of use, the greater the intention to use ADAS.

**$H_3$** : The greater the perceived ease of use, the greater the perceived usefulness of ADAS.

**$H_4$** : The greater the subjective norm, the greater the intention to use ADAS.

**$H_5$** : The greater the subjective norm, the greater the perceived usefulness of ADAS.

In many research studies, the validity is questioned because the technology acceptance model with its central constructs (perceived usefulness, perceived ease of use and subjective norm) is not meaningful enough to provide a complete and comprehensive description of technology acceptance (Königstorfer & Gröppel-Klein, 2007). To overcome this criticism, additional external variables and constructs are added to the model (Wu & Wang, 2005). The model is extended by the following two determinants to increase the explanatory power of the model.

**Trust in Technology**: The willingness to put oneself in a vulnerable position with a technology, combined with a positive expectation, can influence the form of the use of driver assistance systems in a sustainable way (Mayer et al., 1995)

**Personal Innovativeness**: The enthusiasm of the individual to try out new technology and his/her willingness to accept a new innovation earlier than others (Agarwal & Prasad, 1998).

Therefore, the following additional hypotheses arise:

**$H_6$** : The greater the trust in ADAS, the greater intention to use ADAS.

**$H_7$** : The greater the trust in ADAS, the greater the perceived usefulness.

**$H_8$** : The greater the trust in ADAS, the greater the perceived ease of use.

**$H_9$** : The greater the personal innovativeness, the greater the intention to use ADAS.

**$H_{10}$** : The greater the personal innovativeness, the greater the perceived usefulness.

**$H_{11}$** : The greater the personal innovativeness, the greater the perceived ease of use.

### 2.2. Life events

Since acceptance research cannot provide a clear result, it is assumed that other factors, such as the individual life course with different life events, like retirement, becoming a grandparent and illnesses, can have an influence on the acceptance of driver assistance systems (Elder, 1994; Ryu et al., 2009). The beginning of life event research was initiated by the work of Lindemann (1944) in the 1940s, used in many areas of psychology (Filipp, 1995; Horlacher, 2000; Jonas & Lebherz, 2005; Montada, 2008), and describes "life event" as situations or events in the life course of an individual, which can initiate a change in behavior (Filipp, 1995). Life events are thus considered stressors (Lazarus, 1990). As a result of the stress caused by an event, an individual may experience an adaptation that affects a person's further psychological development and behavior (Selye, 1984). According to Goodyer (1991), life events are social experiences that have psychological effects on the individual. In doing so, life events are also always dependent on an individual's social circumstances and may affect each person to a different degree. Although the understanding of life events varies in the literature (Filipp, 1995; Montada, 2008), they are considered important in the individual's life course and can be divided into age-related events (e.g., marriage, birth, retirement), history-related events (e.g., war), and non-normative events (e.g., unemployment) (Filipp, 2007).

Starting in the 1990s, the life course approach emerged within mobility research and was applied in various research fields (Dykstra & van Wissen, 1999; Mayer & Tuma 1990). Initially, it was used to explain long-term mobility behavior (Mulder & Wagner, 1993), and later it was also used for short-term mobility behavior decisions (Scheiner & Holz-Rau, 2013). According to the approach, human (travel) behavior can be explained by its continuity over the lifetime of an individual and by certain (key) events that can have large impacts on several life domains. Within the mobility biography approach, the stability and change of travel behavior is investigated. In this context, key events can influence and change people's travel behavior over time (Lanzendorf, 2003). Van der Waerden et al. (2003) classified two types of events: key events and critical events. Key events are "major event[s] in a person's life that will trigger a process of reconsidering current behavior" (e.g. reaching the legal age for a drivers' license). Critical incident is "an event that has major impact on one's attitude" and in contrast to key events occurse unexpectedly (e.g. involvement in an accident). Despite different definitions of events in the literature which can influence and change behavior (Klöckner, 2005; Marsden & Docherty, 2013; van der Waerden et al., 2003), "key event" is the most common term within mobility biography research (Lanzendorf, 2003, 2010; Scheiner, 2007; van der Waerden et al., 2003). Other terms include "life (course) event" (De Groot et al., 2011; Klöckner, 2005; Schäfer et al., 2012), "disruptive event" (Marsden & Docherty, 2013), "life-cycle event" (Sharmeen et al., 2014), "turning point" (Beige & Axhausen, 2012), "event" (Beige & Axhausen, 2008). Especially in recent years, mobility research has shown increased interest in life events and their influence on mobility behavior (Beige & Axhausen, 2008, 2012; Chatterjee & Scheiner, 2015; Clark et al., 2016; Herrenkind et al., 2019; Lanzendorf, 2003; Müggenburg et al., 2015; Scheiner, 2014; Scheiner & Holz-Rau, 2013; Schoenduwe et al., 2015; Uteng et al., 2019; Wang et al., 2018). Lanzendorf (2003) can examine how a new place of residence (and other changes in personal life) affect travel behavior. In addition, Beige and Axhausen (2012) provide evidence of the relationship between life events (e.g., personal, private events) and long-term mobility decisions over the life course. Furthermore, Chatterjee and Scheiner (2015) find that life events have an impact on mobility behavior related to bicycle use. In addition, Müggenburg et al. (2015) examine and summarize the existing literature of mobility biographies and identify a variety of events (birth of a child, separation from a partner, death of a partner, illness) and suggest that private and professional life events have an influence on people's mobility behavior. The influence of life events on vehicle ownership can be demonstrated by Clark et al. (2016). In the study on the relationship between life events and carsharing by Uteng et al. (2019), it is found that events (birth of a child or moving house) have an influence on behavior regarding the choice of carsharing.

Within acceptance research, only Ryu et al. (2009) have measured the influence of life events on the adoption of user-generated video content by older people. They surveyed the amount of life events experienced and measured a direct significant influence on adoption. However, a more detailed influence of life events on the adoption of driver assistance systems is still unexplored. Based on the definition of van der Waerden et al. (2003) and the understanding of a life event as a stressor, it is assumed that experiencing a specific life event not only changes an individual's mobility behavior, but also behavior in broader domains, e.g., by changing habits and decision strategies, as already described in behavioral models (Theory of Planned Behavior, Ajzen, 1991). As life events change the behavior of the individual, they also influence the acceptance of technology and thus the acceptance of driver assistance systems. In the context of acceptance and mobility research, it is shown that (mobility) behavior changes with age and thus as a result of life events (Uteng et al., 2019). Therefore, selected life events (Fig. 1) are used to investigate the influence of life events on acceptance and their influencing factors (see Fig. 2).

Research considers the experience of (mild or severe) illnesses to be critical life events, but so far only a few studies have investigated their influence (Chatterjee & Scheiner, 2015; Klöckner, 2004; van der Waerden et al., 2003). Major illnesses in particular represent a critical point in an individual's life and influence personal consciousness and behavior. For this reason, it is assumed that a serious illness changes the premises in life and therefore moderates the influences that determine the intention to use an advanced driver assistance system.

**$H_{12}$** : The life event "Major illness" moderates the influences that determine the intention to use ADAS.

The birth of a (grand-)child generally brings about a change in living

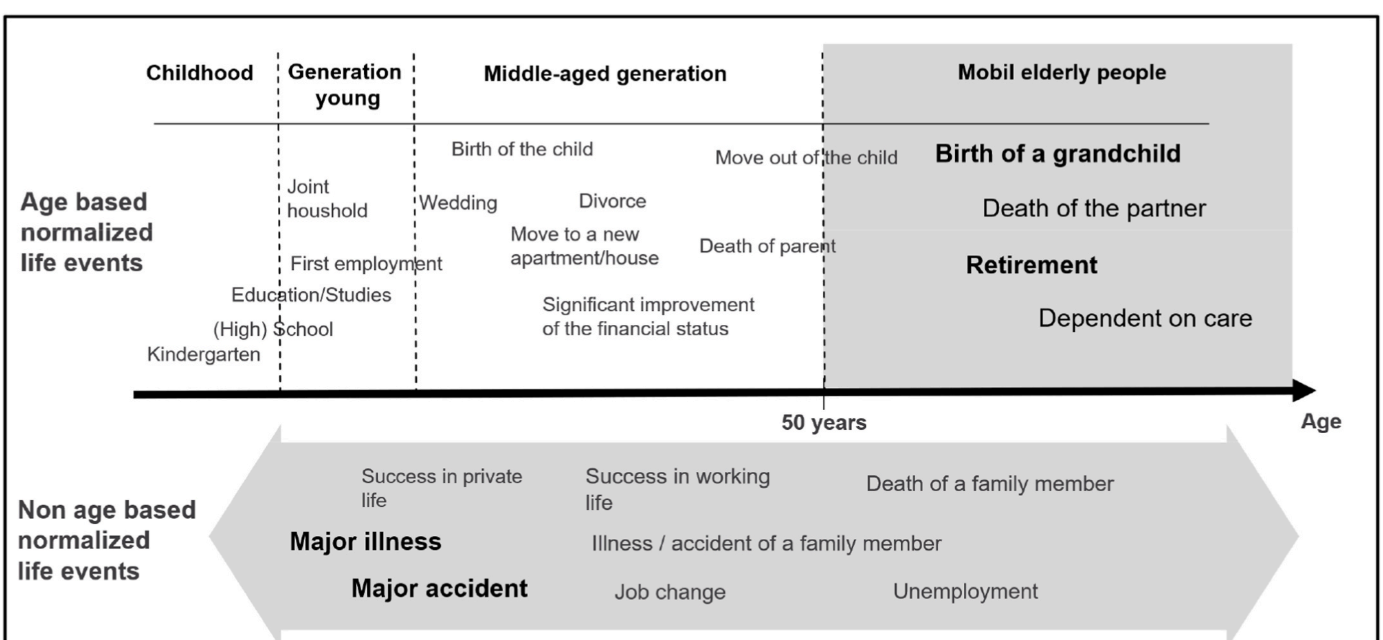


**Fig. 1.** Life events (based on Filipp, 2007).

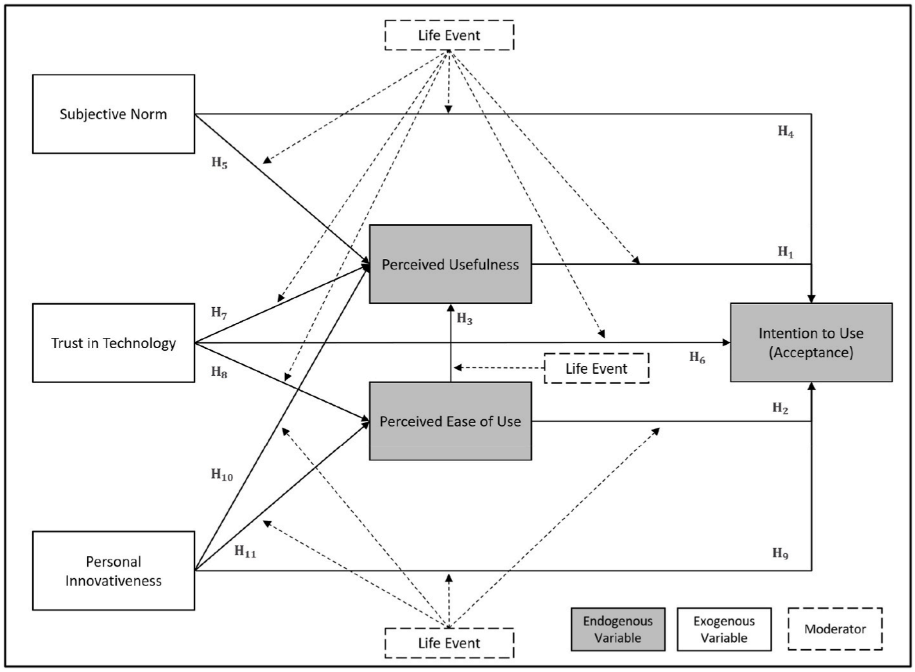


**Fig. 2.** Acceptance model.

conditions and thus in mobility behavior (Beige & Axhausen, 2012; Clark et al., 2014; Lanzendorf, 2010). It can be assumed that the need for safety will increase and that this will lead to greater benefits for driver assistance systems. Adapted to this study, the birth of a child is therefore equal to the birth of a grandchild and it is assumed that the event moderates the influences that determine the intention to use an advanced driver assistance system.

**H**$_{13}$ : The life event "Birth of a grandchild" moderates the influences that determine the intention to use ADAS.

The life event "Retirement" has been the subject of several studies in the past and has shown that it has an influence on mobility behavior (Clark et al., 2014; Scheiner & Holz-Rau, 2013). For people who are retired, the available free time and thus also the driving and mobility behavior is changing. It can be assumed that, for example, due to physical limitations, more support is desired when driving. Therefore, the event moderates the influences that determine the intention to use an advanced driver assistance system.

**H**$_{14}$ : The life event "Retirement" moderates the influences that determine the intention to use ADAS.

Physical complaints and accidents are generally not age-induced, but correlate with age, are also seen as life-changing events and are the subject of mobility research (Klöckner, 2004). Accidents in particular are seen as an event that changes a person's behavior (van der Waerden et al., 2003). Therefore, it is assumed that for people who have experienced a serious accident, the life event "Major accident" moderates the influences that determine the intention to use an advanced driver assistance system.

**H**$_{15}$ : The life event "Major accident" moderates the influences that determine the intention to use ADAS.

According to Ryu et al. (2009), life events have an impact on the adoption of user-generated video content among the elderly. The study determined the amount of life events experienced and found a direct negative influence on technology adoption. Thus, it can be expected that the general acceptance of driver assistance systems will decrease with each life event experienced. furthermore, it can be assumed that the greater the number of life events experienced, the lower the general acceptance of driver assistance systems. Consequently, general acceptance will correlate with the number of life events experienced, leading to lower general acceptance. This leads to the following hypotheses:

**H**$_{16}$ : The general acceptance is lower for the group who have experienced the life event "Major illness" than for the group who have not experienced the life event.

**H**$_{17}$ : The general acceptance is lower for the group who have experienced the life event "Birth of a grandchild" than for the group who have not experienced the life event.

**H**$_{18}$ : The general acceptance is lower for the group who have experienced the life event "Retirement" than for the group who have not experienced the life event.

**H**$_{19}$ : The general acceptance is lower for the group who have experienced the life event "Major accident" than for the group who have not experienced the life event.

**H**$_{20}$ : The higher the number of life events experienced, the lower the general acceptance.

To address the previously mentioned research gaps, a research model based on the technology acceptance model was developed and extended. Based on the life course approach, life events are considered as external social factors that can have a moderating influence on the variables that affect acceptance. Since the technology acceptance model can only measure the influence of one determinant on the intention to use, the degree of acceptance is another factor to be examined.

As a result, a questionnaire was developed to test the hypothesized causal relationships and moderating effect, and to measure the degree of acceptance. To meet the requirements of an aging society, only persons over 50 years of age from Germany participated. To test whether a life event has an influence on the acceptance of driver assistance systems, the sample was divided into two groups: Participants who experienced a specific life event and participants who did not experience the life event. The results are used to discuss the acceptance by older people. This leads to a better understanding of the acceptance of technology in general and driver assistance systems in particular. The results provide an important basic understanding of mobility in an aging society.

## 3. Research methodology

The moderating influence of life events on the acceptance of driver assistance systems and the general acceptance is determined within the framework of a random sample by means of a questionnaire. In order to ensure an equivalent level of knowledge of the test subjects - generations over 50 years of age - and their suitability, a preliminary test was conducted in a driving simulator. Due to the sometimes-advanced age of the test persons, it was necessary to query pre-existing conditions in order to exclude individuals with critical illnesses (such as epilepsy, dementia, and Parkinson's disease) or with "simulator sickness" (headaches, dizziness, disorientation, drowsiness, or nausea) from the study (Brooks et al., 2010; Roenker et al., 2003; Schweig et al., 2018). To analyze the acceptance of advanced driver assistance systems and to empirically measure the effects of design and the influence of life events, a selection of age-appropriate driver assistance systems must be made in advance. According to statistics, the most frequent driving errors among seniors (65 years and older) occur in connection with right-of-way and priority in road traffic (17.7%), turning, reversing, entering a road, and accelerating (17.0%), as well as distance errors (8.8%) (Statistisches Bundesamt, 2019). For this reason, the assistance systems Cross Traffic Alert, Park Distance Control and Lane Departure Warning have been implemented.

In the main study, all items were surveyed by a questionnaire. These were taken from the existing literature and adapted to the focus of investigation, acceptance of driver assistance systems. The dependent variable acceptance (intention to use) was measured according to the fundamentals of the TAM (Davis et al., 1989) with the help of five determinants. These six variables are measured in the questionnaire with a total of 14 items. Acceptance questions were asked using a 7-point Likert scale ranging from "strongly disagree" to "strongly agree." Life events were measured on a nominal scale of 1 for "Yes, I experienced the event" or 2 for "No, I did not experience the event." Demographic facts about experience with driver assistance systems and product knowledge were measured using a 7-point interval scale. All other demographic facts (gender, age, net income, education, miles driven per day) were measured using nominal and ordinal scales. The dependent and independent constructs and their operationalization are presented in the Appendix (see Table 9).

In order to obtain the largest possible sample, a total of 381 elderly subjects were recruited for the study. For this purpose, an online questionnaire was developed based on the research model using LimeSurvey. All data was generated during the period August 2017 to September 2019 in western Germany. All subjects were invited and medically examined. They then drove in the driving simulator for approximately 45 min and then completed the online questionnaire. After eligibility screening, a total of 181 drivers over 50 years of age remain with completed questionnaires (see Table 1).

**Table 1**
Demographic data.

| Control variables | Description | n (total 181) | Proportion of respondents | average |
|---|---|---|---|---|
| Gender | male | 144 | 79,6 | / |
| | female | 37 | 20,4 | |
| Age group | 50–59 | 49 | 27,1 | 65.4 |
| | 60–69 | 76 | 42 | |
| | 70–90 | 56 | 30,9 | |
| Life Events | Major illness | 29 | 16,0 | / |
| | Birth of a grandchild | 74 | 40,9 | |
| | Retirement | 113 | 62,4 | |
| | Major accident | 26 | 14,4 | |
| Net income | 500- | 2 | 1,1 | 4.255 |
| | 501–1.000€ | 11 | 6,1 | |
| | 1.001–2.000 € | 31 | 17,1 | |
| | 2.001–3.000 € | 66 | 36,5 | |
| | 3.001–4.000 € | 31 | 17,1 | |
| | 4.001–5.000 € | 12 | 6,6 | |
| | 5.001–6.000 € | 2 | 1,1 | |
| | 6.001+ € | 10 | 5,5 | |
| | No information | 16 | 8,8 | |
| Education | No graduation | 1 | 0.6 | / |
| | certificate of secondary education | 10 | 5.5 | |
| | genereal certificate of secondary education | 25 | 13.8 | |
| | general qualification for university entrance | 59 | 32.6 | |
| | college of higher education | 12 | 6.6 | |
| | university level | 66 | 36.5 | |
| | doctorate | 2 | 1.1 | |
| | No information | 6 | 3,3 | |
| Driven km per day | <5 km | 7 | 3.9 | 2.92 |
| | 6–20 km | 54 | 29.8 | |
| | 21–50 km | 68 | 37.6 | |
| | 51–100 km | 39 | 21.5 | |
| | 101–150 km | 6 | 3.3 | |
| | >150 km | 1 | 0.6 | |
| | No information | 6 | 3.3 | |
| years of owning driver's license | | | | 45.6 |
| Product knowledge | | | | 3.26 |
| Experience | | | | 3.44 |

## 4. Data analysis and results

Due to the partially smaller sample sizes for the groups of experienced life events and to measure the influence of a variable on acceptance, PLS-SEM approach (Hair et al., 2017) with a minimum sample size of N = 30 (Nitzl, 2010) is used. For the PLS-based estimations, SmartPLS 3.2.8 is used, which allows custom settings and was used to perform the PLS estimation procedure and bootstrap resampling procedure. For the calculation of the model using PLS algorithm, the path weighting scheme is chosen, with a maximum iteration number of 1000 and a stopping criterion of 10–7. The significance of the paths of the structural model is tested using the bootstrap resampling method. For this purpose, the subsamples are set to 1000 for the number of parameters estimates. For all other estimates, SPSS Statistics 23 is used. In order to empirically test the research model and hypotheses, the intention to use, which can only be measured indirectly, must be designed using structural equation modeling (SEM) due to its complexity and the interdependencies between the individual determinants. Based on the SEM approach, first the measurement model and then the structural model is tested (Weiber & Mühlhaus, 2014).

General acceptance was measured by using all mean values of the acceptance constructs of the respective assistance system (intention to use, perceived usefulness, perceived ease of use, subjective norm, trust, and personal innovativeness) to form a mean value representing the general acceptance for a driver assistance system (Appendix 6, Table 14). For determining mean differences of the general acceptance for different life events, a two-stage *t*-test for unpaired samples is used. Therefore, the sample is divided into two groups: life events experienced and life events not experienced. The level of significance is set at $p \leq .01$ (99%), 0.05 (95%) and 0.10 (90%). Equality of variances is assessed by Levene's test (with the p-value also set at $p \leq .01$, .05 and 0.10). Where the assumption of equality of variances was dropped, Welch's *t*-test was used instead. Correlations between the general acceptance for driver assistance systems and the number of life events experienced is determined by Pearson's correlation.

### 4.1. Measurement model assessment

In this study, reflective measurement models were operationalized based on the question catalog of Jarvis et al. (2013). Within the framework of structural equation analysis, a review of the quality of construct measurement must be conducted (Trommsdorff, 2004), because measurement models are subject to error and the indicators only depict individual aspects of a construct. This leads to a loss of information in the operationalization. The measurement model is tested for validity using the criteria of content validity, convergence validity, and discriminant validity, and then for reliability using the criteria of indicator reliability, indicator significance, and construct reliability (Hair et al., 2017).

Content validity was ensured by using scales and items adapted for the research model and review of the questionnaire by experts. Convergence validity is tested by the average variance extracted (AVE). It describes whether a construct is correctly reproduced by measuring it with multiple indicators. The criterion is met if the average explained variance is greater than 0.5, i.e., if more than 50% of the variance of a latent variable is explained by the included indicators (Fornell & Larcker, 1981).

The criterion of discriminant validity was examined using the average explained variance. According to the Fornell-Larcker criterion, the root of the variance explained by the mean must always be greater than or equal to the correlation of the construct with another construct ($\sqrt{\text{DEV}} \geq |KORR \enspace \xi/\eta \enspace und \enspace \xi/\eta|$) (Fornell & Larcker, 1981). The measurement model was also tested for cross-loadings (Chin, 1998).

The indicator reliability (IR) indicates the proportion of the variance of an indicator in the corresponding total variance of the indicator and considers the factor loadings. The factor loading can assume values between zero and one. The higher the values, the higher the reliability. Half of the variance (50%; 0.5) of the indicator should be explained by the construct assigned to it, which is expressed by a minimum value of 0.7 of the factors loading (Hair et al., 2017).

Indicator significance, which reflects the degree of significance between the indicator and the latent variable, is measured with the T-value and should have a value greater than $|\pm 1.96|$ (Weiber & Mühlhaus, 2014). Due to the lack of a normal distribution assumption, T-values are determined using the bootstrap resampling method.

Construct reliability (CR) measures how well the latent variable is measured by its indicators. Construct reliability can also take values between zero and one; the literature recommends a value greater than 0.6 (Bagozzi & Yi, 1988).

The tests of the research models of all three studies show that the model fit is acceptable and reliable, allowing conclusions to be drawn based on the data. The construct reliability of all designs is well above the required value of 0.6, and the average extracted variance is also consistently above 0.5. With a minimum of 0.826 and a maximum of 0.988, all factor loadings of the items are well above the required value of 0.7, thus meeting the indicator reliability requirements (see Appendix 2: Table 10, Appendix 3: Table 11, Appendix 4: Table 12). Furthermore, discriminant validity can also be confirmed with the Fornell-Lacker criterion; with each AVE higher than the shared variance with all other constructs (see Table 2).

### 4.2. Structural model assessment

Now the robustness of the structural model is checked after a valid and reliable estimation of the reflexive measurement models has been done. First, criteria are used to assess the path coefficients, such as the effect size and significance of the path coefficients. Then, significance is tested using the coefficient of determination ($R^2$).

The path coefficients can take values from minus one to one. Values close to minus one and one describe a strong influence on the latent variable, while values close to zero describe a weak influence. When values are greater than 0.1, they are considered significant (Chin, 1998). The significance of the effect relationships is tested here, as with the goodness of measurement models using the bootstrap resampling method, using the T-values, and significance is confirmed if the T-value is at least $|\pm 1.96|$.

The coefficient of determination ($R^2$) indicates what proportion of the variance of the exogenous variables affects the endogenous variables. The value can range from 0 to 1, with values of 0.19–0.36 reflecting weak explanatory power, values of 0.37–0.66 reflecting medium explanatory power, and values of 0.67–1 reflecting high explanatory power (Chin, 1998). In the literature, a value of the coefficient of determination of at least 0.3 is required.

The use of the PLS approach and the calculation results show that mostly all criteria are met (see Appendix 5: Table 13). For Cross-Traffic Alert, 8 of the 11 hypotheses can be confirmed and also the R-values show a good model fit with and $R2 = 0.69$ for Intention to Use (see Fig. 3).

It can be confirmed 9 of the 11 hypotheses for Park Distance Control and also the R-value is higher with 0.73 for Intention to Use, which means a good model fit (see Fig. 4).

Finally, the R value of Intention to Use is highest for Lane Departure Warning at 0.82; 8 of 11 hypotheses can be confirmed (see Fig. 5).

Overall, the basic structure of the TAM (Davis et al., 1989) can be largely confirmed. All three models confirm a significant influence of perceived usefulness on usage intention and of perceived ease of use on

**Table 2**
Construct reliability, average variance extracted and inter-construct correlations.

| | CR | AVE | Intention to Use | Personal Innovativeness | Subjective Norm | Trust | Perceived Usefulness | Perceived Ease of Use |
|---|---|---|---|---|---|---|---|---|
| Cross-Traffic-Alert | | | | | | | | |
| Intention to Use | 0,976 | 0953 | **0,976** | | | | | |
| Personal Innovativeness | 0,932 | 0774 | 0,291 | **0880** | | | | |
| Subjective Norm | 0,955 | 0914 | 0,519 | 0223 | **0,956** | | | |
| Trust | 0,954 | 0913 | 0,652 | 0344 | 0,576 | **0956** | | |
| Perceived Usefulness | 0,975 | 0951 | 0,812 | 0312 | 0,493 | 0679 | **0,975** | |
| Perceived Ease of Use | 0,873 | 0774 | 0,581 | 0271 | 0,369 | 0513 | 0,619 | **0880** |
| **Park Distance Control** | | | | | | | | |
| Acceptance | 0,980 | 0961 | **0,980** | | | | | |
| Personal Innovativeness | 0,932 | 0774 | 0,399 | **0880** | | | | |
| Subjective Norm | 0,976 | 0952 | 0,509 | 0194 | **0,976** | | | |
| Trust | 0,958 | 0919 | 0,580 | 0310 | 0,482 | **0959** | | |
| Perceived Usefulness | 0,98 | 0,96 | 0,833 | 0354 | 0,442 | 0612 | **0,980** | |
| Perceived Ease of Use | 0,939 | 0885 | 0,570 | 0244 | 0,330 | 0429 | 0,664 | **0941** |
| **Lane Departure Warning** | | | | | | | | |
| Acceptance | 0,981 | 0963 | **0,981** | | | | | |
| Personal Innovativeness | 0,932 | 0775 | 0,283 | **0880** | | | | |
| Subjective Norm | 0,987 | 0975 | 0,574 | 0222 | **0,987** | | | |
| Trust | 0,978 | 0957 | 0,491 | 0218 | 0,509 | **0978** | | |
| Perceived Usefulness | 0,979 | 0958 | 0,816 | 0314 | 0,552 | 0518 | **0,979** | |
| Perceived Ease of Use | 0,921 | 0854 | 0,471 | 0240 | 0,305 | 0407 | 0,538 | **0924** |

Note. AVE: average variance extracted; CR: construct reliability; bolded: square root of AVE.

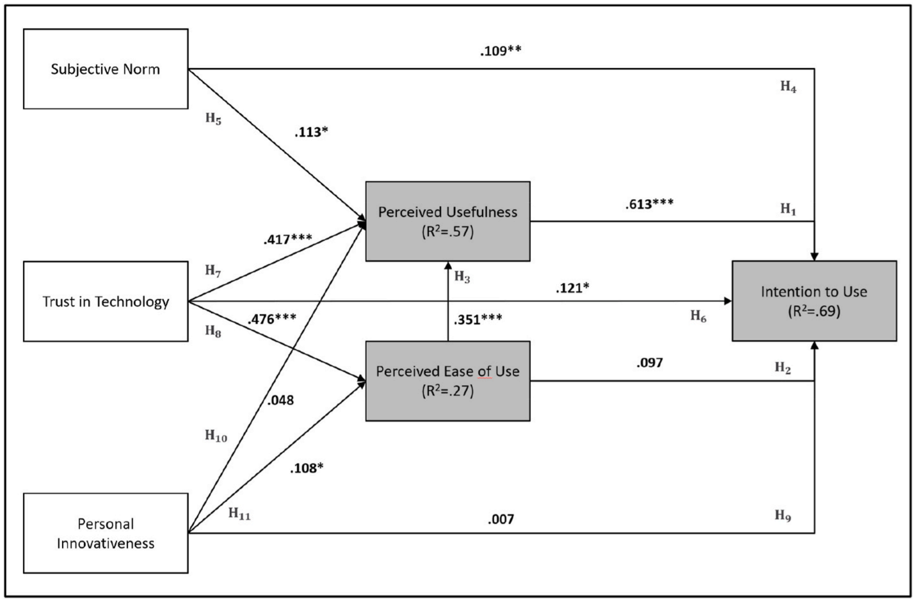


**Fig. 3.** Structural model results - CTA.

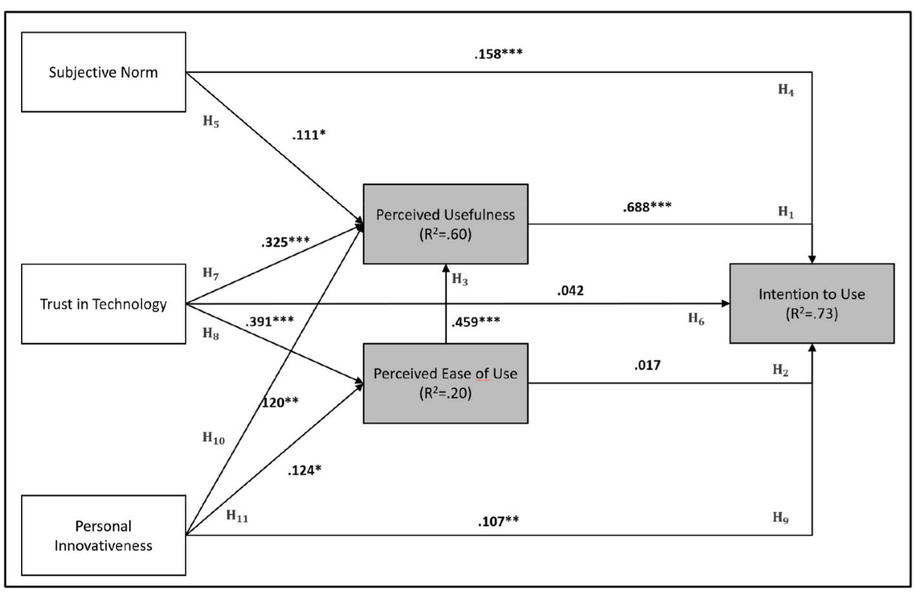


**Fig. 4.** Structural model results - PDC.

usage intention. A significant influence of perceived ease of use on intention to use could not be found. In contrast, the influence of subjective norm on usage intention and on perceived usefulness can be confirmed and is thus consistent with TAM2 (Venkatesh & Davis, 2000). The influence of trust in technology on perceived usefulness and perceived ease of use can be confirmed, but the influence of trust in technology on intention to use can only be confirmed in one of the three models. The results show that there is a significant influence of personal innovativeness on perceived ease of use. The influence of personal innovativeness on perceived usefulness can only be confirmed in two of the three models, and the influence of personal innovativeness on intention to use can only be confirmed in one of the three models (see Table 2 for the results). Thus, all three models can be confirmed for the most part and allow for further conclusions.

### *4.3. Multi-group analysis*

In order to detect significant differences of predefined data groups in their group-specific parametric estimates, a multi-group analysis is performed. The moderating influence of life events is thereby tested by significant differences in path coefficients. For this purpose, the PLS-MGA approach integrated in SmartPLS (Hair et al., 2018) is used. This method uses a non-parametric significance test to test for significant group differences. With a p-value less than 0.10/0.05/0.01 or greater than 0.90/0.95/0.99 with an error probability of 10%/5%/1%, a difference is considered significant (Henseler et al., 2009; Sarstedt et al., 2011).

#### *4.3.1. Major illness*

Note. ***p < .01; **p < .05; *p < .10. CTA: Cross-Traffic-Alert; PDC: Park Distance Control; LDW: Lane Departure Warning; PU: Perceived Usefulness; ITU: Intention to Use; PEOU: Perceived Ease of Use; SN:

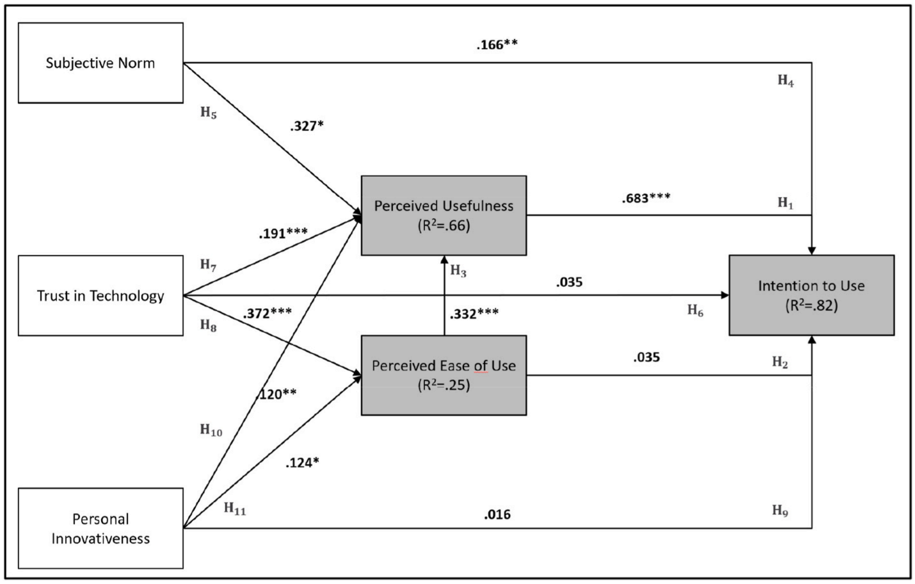


**Fig. 5.** Structural model results - LDW.

Subjective Norm; TIT: Trust in Technology; PERIN; Personal Innovativeness.

Experiencing an illness leads to five significant differences in the cross-traffic alert. The influence between personal innovativeness and intention to use, subjective norm, intention to use, trust in technology and intention to use is significantly lower for subjects who have experienced a severe illness. In contrast, the influence of trust in technology on perceived ease of use and perceived usefulness on intention to use is significantly higher in subjects who experienced severe illness. Park Distance Control analysis reveals three significant differences between personal innovativeness and intention to use, subjective norm and intention to use, and perceived ease of use and intention to use. The first and third effects are lower for subjects with a medical condition, and the second effect is higher for subjects with a medical condition. There is no significant difference in the analysis of lane departure warning (see Table 3).

It remains to summarize that serious illness has partial influence for the intention to use CTA and PDC, with gradually more significant differences in the CTA. Life event does not have a singular significant influence in the LDW. Hypothesis $\mathbf{H}_{12}$ is confirmed.

#### 4.3.2. *Birth of a grandchild*

Analyzing the model for the Cross-Traffic-Alert, three significant differences can be identified after the birth of a child. The influence of subjective norm on intention to use and trust in technology on intention to use is significantly higher for candidates with a grandchild. Whereas the influence of the perceived ease of use on perceived usefulness is lower for persons with a grandchild. The results of the Park Distance Control reveal only one significant difference between perceived ease of use and intention to use and is higher for the group with a grandchild. Moreover, there are two significant differences in the Lane Departure Warning. The influence of personal innovativeness on perceived usefulness is lower for the group with a grandchild or grandchildren and the influence of subjective norm on perceived usefulness is higher for probands with a grandchild or grandchildren (see Table 4).

It remains to summarize that the birth of a grandchild has partial influence for the intention to use CTA and PDC, but a low level of differences can be measured. Life event does not have a singular influence in LDW. Hypothesis $\mathbf{H}_{13}$ is confirmed.

#### 4.3.3. *Retirement*

When examining the Cross-Traffic Alert model, three significant differences can be identified after retirement. The influence of trust in technology on intention to use and on perceived usefulness is significantly higher for individuals who are retired. The influence of perceived usefulness on intention to use is lower for individuals who are retired. The Park Distance Control results show two significant differences. The influence of personal innovativeness on perceived ease of use is lower for non-retired subjects, whereas the influence of confidence in technology on perceived ease of use is higher for retired subjects. However, there is no significant difference in the analysis of lane departure warning (see Table 5).

**Table 3**
Results of the group analysis - Major illness.

| | CTA | | | PDC | | | LDW | | |
|---|---|---|---|---|---|---|---|---|---|
| | illness | No illness | illness – no illness | illness | No illness | illness – no illness | illness | No illness | illness – no illness |
| PU - > ITU | 0.892*** | 0.572*** | **0.320**** | 0.810*** | 0.64*** | 0.170 | 0.667*** | 0.644*** | 0.009 |
| PEOU- > ITU | 0.287 | 0.085 | 0.203 | −0.209 | 0.060 | **0.269*** | −0.060 | −0.069 | 0.131 |
| PEOU - > PU | 0.292 | 0.357*** | 0.065 | 0.406*** | 0.462*** | 0.055 | 0.432*** | 0.437*** | 0.138 |
| SN - > ITU | −0.081 | 0.134*** | **0.216*** | 0.412** | 0.113*** | **0.299**** | 0.171 | 0.196*** | 0.003 |
| SN - > PU | 0.265 | 0.097 | 0.168 | 0.342* | 0.078 | 0.264 | 0.429*** | 0.429*** | 0.113 |
| TIT - > ITU | −0.127 | 0.150** | **0.277*** | −0.137 | 0.104 | 0.240 | 0.193 | 0.181 | 0.190 |
| TIT - > PU | 0.371 | 0.415*** | 0.044 | 0.242* | 0.334*** | 0.092 | 0.191 | 0.182** | 0.011 |
| TIT - > PEOU | 0.672*** | 0.426*** | **0.247**** | 0.381** | 0.388*** | 0.006 | 0.271* | 0.295*** | 0.089 |
| PERIN - > ITU | −0.099 | 0.025 | **0.125*** | −0.131 | 0.151*** | **0.282**** | −0.043 | −0.04 | 0.073 |
| PERIN - > PU | −0.013 | 0.057 | 0.070 | 0.006 | 0.134** | 0.128 | −0.008 | 0.019** | 0.147 |
| PERIN - > PEOU | 0.151 | 0.116* | 0.035 | 0.263 | 0.116 | 0.147 | 0.354 | 0.300*** | 0.171 |

**Table 4**
Results of the group analysis - Birth of a grandchild.

| | CTA | | | PDC | | | LDW | | |
|---|---|---|---|---|---|---|---|---|---|
| | Grandchild | No grandchild | Grandchild - No grandchild | Grandchild | No grandchild | Grandchild - No grandchild | Grandchild | No grandchild | Grandchild - No grandchild |
| PU - > ITU | 0.533*** | 0.635*** | 0.102 | 0.671*** | 0.691*** | 0.021 | 0.634*** | 0.713*** | 0.079 |
| PEOU- > ITU | 0.091 | 0.152** | 0.060 | 0.204** | −0.074 | **0.278**** | 0.105 | 0.002 | 0.102 |
| PEOU - > PU | 0.242* | 0.480*** | **0.238*** | 0.513*** | 0.424*** | 0.088 | 0.290*** | 0.336*** | 0.045 |
| SN - > ITU | 0.189** | 0.046 | **0.143*** | 0.121** | 0.189*** | 0.068 | 0.176** | 0.154 | 0.022 |
| SN - > PU | 0.135* | 0.077 | 0.058 | 0.080 | 0.152* | 0.071 | 0.428*** | 0.246*** | **0.181*** |
| TIT - > ITU | 0.171 | 0.095 | 0.077 | −0.016 | 0.067 | 0.083 | 0.037 | 0.045 | 0.009 |
| TIT - > PU | 0.526*** | 0.322*** | **0.204*** | 0.390*** | 0.260*** | 0.129 | 0.220** | 0.177* | 0.043 |
| TIT - > PEOU | 0.502*** | 0.468*** | 0.035 | 0.381*** | 0.402*** | 0.022 | 0.419*** | 0.340*** | 0.079 |
| PERIN - > ITU | −0.067 | 0.045 | 0.112 | 0.045 | 0.126 | 0.081 | 0.034 | −0.004 | 0.037 |
| PERIN - > PU | 0.055 | 0.034 | 0.021 | 0.049 | 0.177** | 0.128 | 0.029 | 0.207*** | **0.178**** |
| PERIN - > PEOU | 0.109 | 0.156* | 0.047 | 0.129 | 0.117 | 0.012 | 0.096 | 0.210** | 0.114 |

Note. ***p < .01; **p < .05; *p < .10. CTA: Cross-Traffic-Alert; PDC: Park Distance Control; LDW: Lane Departure Warning; PU: Perceived Usefulness; ITU: Intention to Use; PEOU: Perceived Ease of Use; SN: Subjective Norm; TIT: Trust in Technology; PERIN; Personal Innovativeness.

**Table 5**
Results of the group analysis - Retirement.

| | CTA | | | PDC | | | LDW | | |
|---|---|---|---|---|---|---|---|---|---|
| | retired | Not retired | Retired – not retired | retired | Not retired | Retired – not retired | retired | Not retired | Retired – not retired |
| PU - > ITU | 0.523*** | 0.729*** | **0.207*** | 0.736*** | 0.606*** | 0.130 | 0.631*** | 0.733*** | 0.102 |
| PEOU- > ITU | 0.131 | 0.040 | 0.092 | 0.001 | 0.039 | 0.038 | 0.045 | 0.016 | 0.029 |
| PEOU - > PU | 0.383*** | 0.391*** | 0.007 | 0.427*** | 0.523*** | 0.095 | 0.328*** | 0.326*** | 0.002 |
| SN - > ITU | 0.075 | 0.112 | 0.037 | 0.135** | 0.197** | 0.062 | 0.162** | 0.190 | 0.028 |
| SN - > PU | 0.060 | 0.139 | 0.079 | 0.084 | 0.111 | 0.027 | 0.383*** | 0.165 | 0.218 |
| TIT - > ITU | 0.244*** | −0.043 | **0.287**** | 0.025 | 0.093 | 0.069 | 0.135* | −0.073 | 0.208 |
| TIT - > PU | 0.443*** | 0.331*** | 0.111 | 0.377*** | 0.238*** | 0.139 | 0.204** | 0.150 | 0.054 |
| TIT - > PEOU | 0.560*** | 0.379*** | **0.181*** | 0.482*** | 0.243** | **0.239**** | 0.429*** | 0.245* | 0.184 |
| PERIN - > ITU | −0.041 | 0.091 | 0.132 | 0.084 | 0.127 | 0.043 | 0.014 | −0.017 | 0.031 |
| PERIN - > PU | 0.034 | 0.061 | 0.028 | 0.100 | 0.167 | 0.068 | 0.091 | 0.235** | 0.143 |
| PERIN - > PEOU | 0.092 | 0.227** | 0.135 | 0.060 | 0.245** | **0.185*** | 0.105 | 0.254** | 0.149 |

Note. ***p < .01; **p < .05; *p < .10. CTA: Cross-Traffic-Alert; PDC: Park Distance Control; LDW: Lane Departure Warning; PU: Perceived Usefulness; ITU: Intention to Use; PEOU: Perceived Ease of Use; SN: Subjective Norm; TIT: Trust in Technology; PERIN; Personal Innovativeness.

It remains to summarize that retirement age has a partial influence on the intention to use CTA and PDC. However, there are gradual differences in the two study groups. Life event does not have a singular influence in LDW. Hypothesis $\mathbf{H}_{14}$ is confirmed.

#### 4.3.4. *Major accident*

The model analysis for the cross-traffic alert shows a significant difference after experiencing a serious accident. The influence of perceived ease of use on intention to use is significantly lower for subjects who experienced a serious accident. The Park Distance Control results show three significant differences between subjective norm and

**Table 6**
Results of the group analysis – Major accident.

| | CTA | | | PDC | | | LDW | | |
|---|---|---|---|---|---|---|---|---|---|
| | accident | No accident | accident – no accident | accident | No accident | accident – no accident | accident | No accident | accident – no accident |
| PU - > ITU | 0.437 | 0.634*** | 0.197 | 0.579** | 0.692*** | 0.113 | 0.759*** | 0.667*** | 0.092 |
| PEOU- > ITU | −0.144 | 0.150** | **0.295*** | −0.161 | 0.026 | 0.187 | −0.171 | 0.062 | 0.233 |
| PEOU - > PU | 0.375** | 0.397*** | 0.022 | 0.108 | 0.493*** | **0.385*** | 0.354 | 0.329*** | 0.025 |
| SN - > ITU | 0.105 | 0.101** | 0.004 | 0.079 | 0.145*** | 0.066 | −0.028 | 0.183*** | 0.212 |
| SN - > PU | 0.046 | 0.113* | 0.067 | −0.195 | 0.138** | **0.333**** | 0.233 | 0.340*** | 0.107 |
| TIT - > ITU | 0.372 | 0.074 | 0.299 | 0.228 | 0.037 | 0.191 | 0.246 | 0.016 | 0.231 |
| TIT - > PU | 0.539*** | 0.342*** | 0.197 | 0.758*** | 0.261*** | **0.496**** | 0.234 | 0.186** | 0.049 |
| TIT - > PEOU | 0.459*** | 0.524*** | 0.065 | 0.184 | 0.425*** | 0.241 | 0.481*** | 0.347*** | 0.134 |
| PERIN - > ITU | −0.064 | 0.018 | 0.082 | 0.201 | 0.108* | 0.093 | 0.066 | 0.018 | 0.049 |
| PERIN - > PU | −0.049 | 0.084 | 0.133 | 0.305** | 0.122* | 0.183 | 0.139 | 0.114* | 0.025 |
| PERIN - > PEOU | 0.133 | 0.092 | 0.040 | 0.240 | 0.090 | 0.149 | 0.148 | 0.168** | 0.020 |

Note. ***p < .01; **p < .05; *p < .10. CTA: Cross-Traffic-Alert; PDC: Park Distance Control; LDW: Lane Departure Warning; PU: Perceived Usefulness; ITU: Intention to Use; PEOU: Perceived Ease of Use; SN: Subjective Norm; TIT: Trust in Technology; PERIN; Personal Innovativeness.

perceived usefulness, confidence in technology and intention to use, and perceived ease of use and perceived usefulness. The first and third effects are lower for subjects with an accident, and the second is higher for subjects with an accident. There is no significant difference in the analysis of lane departure warning (see Table 6).

To sum up, an accident has a minor influence on the intention to use CTA and PDC. The life event has no significant influence on the LDW. The hypothesis $\mathbf{H}_{15}$ is confirmed.

### 4.4. General acceptance

The general acceptance was determined from all mean values of the acceptance constructs of the respective assistance system and is generally high (Appendix 6, Table 14). The analysis of the data for the respective driver assistance system shows that the hypothesis that general acceptance is lower after a life event than without this life event ($\mathbf{H}_{16}$, $\mathbf{H}_{17}$, $\mathbf{H}_{18}$, $\mathbf{H}_{19}$) can only be confirmed in two of twelve cases (major illness and major accident). However, the mean values indicate that the acceptance of all driver assistance systems is lower after each life event (see Table 7). The data therefore tend to indicate lower general acceptance in the period following the experience of life events.

The test of the correlation between the number of life events experienced and the general acceptance of the three driver assistance systems shows a negative correlation for the assistance systems Cross Traffic Alert and Lane Departure Warning (see Table 8). No correlation can be determined for Park Distance Control. As a result, general acceptance is lower the higher the number of life events experienced. Hypothesis $\mathbf{H}_{20}$ can be confirmed.

## 5. Discussion and implications

The analysis of the acceptance model reveals that most relationships have a significant influence on the intention to use advanced driver assistance systems, as well as that life events influence these relationships. In the following, the results are discussed and implications are presented.

**Table 8**
Correlation table.

| | 1. Life Events | 2. ACC CTA | 3. ACC PDC | 4. ACC LDW |
|---|---|---|---|---|
| 1. Life Events | – | | | |
| 2. ACC for CTA | **-.134**[a] | – | | |
| 3. ACC for PDC | -.095 | **.680**[c] | – | |
| 4. ACC for LDW | **-.147**[b] | **.606**[c] | **.657**[c] | – |

[a] **correlation is significant at the 0.10 level (2-tailed)** CTA = Cross Traffic Alert.
[b] **correlation is significant at the 0.05 level (2-tailed)** PDC = Park Distance Control.
[c] **correlation is significant at the 0.05 level (2-tailed)** LDW = Lane Departure WarningACC = General Acceptance.

### 5.1. Technology acceptance model

Most of the causal relationships of the TAM of Davis et al. (1989) can be confirmed in this study. In addition, the results regarding the additional determinants of trust and personal innovativeness are in line with the literature and can be confirmed as well (Choi & Ji, 2015; Lee, 2019; Tussyadiah et al., 2017; Wang et al., 2010)

Among the determinants of the acceptance model, the influence of perceived usefulness on the intention to use is by far the most important effect for the generation 50 and older and is causal for an emerging intention to use. Therefore, it is important to communicate the usefulness of driver assistance systems for future mobility. The studies in the meta-analysis by Hauk et al. (2018) show an unclear picture of the influence of perceived ease of use on perceived usefulness. Comparatively, this study finds a high influence of perceived ease of use on perceived usefulness, such that users appreciate it when a system is easy to use and expect it to work without any effort. Furthermore, the results illustrate

**Table 7**
General Acceptance for the advanced driver assistance systems by life events.

| | Group | N | Mean | SD | T | df | P | Hypothesis |
|---|---|---|---|---|---|---|---|---|
| Major illness | | | | | | | | |
| CTA | Illness | 29 | 5,37 | 1,08 | −0,928 | 179,00 | 0,355 | $\mathbf{H}_{16}$ Rejected |
| | No Illness | 152 | 5,55 | 0,93 | | | | |
| PDC | Illness | 29 | 5,68 | 1,01 | −0,551 | 179,00 | 0,582 | $\mathbf{H}_{16}$ Rejected |
| | No Illness | 152 | 5,78 | 0,88 | | | | |
| LDW | Illness | 29 | 4,84 | 1,12 | −2170 | 179,00 | 0,031 | $\mathbf{H}_{16}$ Accepted |
| | No Illness | 152 | 5,29 | 0,99 | | | | |
| **Birth of a grandchild** | | | | | | | | |
| CTA | Grandchild | 74 | 5,42 | 0,96 | −1163 | 179,00 | 0,246 | $\mathbf{H}_{17}$ Rejected |
| | No Grandchild | 107 | 5,59 | 0,95 | | | | |
| PDC | Grandchild | 74 | 5,73 | 0,79 | −0,454 | 179,00 | 0,651 | $\mathbf{H}_{17}$ Rejected |
| | No Grandchild | 107 | 5,79 | 0,98 | | | | |
| LDW | Grandchild | 74 | 5,21 | 0,98 | −0,107 | 179,00 | 0,915 | $\mathbf{H}_{17}$ Rejected |
| | No Grandchild | 107 | 5,22 | 1,05 | | | | |
| **Retirement** | | | | | | | | |
| CTA | Retired | 113 | 5,47 | 1,00 | −0,894 | 179,00 | 0,372 | $\mathbf{H}_{18}$ Rejected |
| | Not Retired | 68 | 5,60 | 0,88 | | | | |
| PDC | Retired | 113 | 5,69 | 0,91 | −1377 | 179,00 | 0,170 | $\mathbf{H}_{18}$ Rejected |
| | Not Retired | 68 | 5,88 | 0,89 | | | | |
| LDW | Retired | 113 | 5,14 | 1,07 | −1262 | 179,00 | 0,208 | $\mathbf{H}_{18}$ Rejected |
| | Not Retired | 68 | 5,34 | 0,93 | | | | |
| **Major accident** | | | | | | | | |
| CTA | Accident | 26 | 5,28 | 0,87 | −1369 | 179,00 | 0,173 | $\mathbf{H}_{19}$ Rejected |
| | No Accident | 155 | 5,56 | 0,96 | | | | |
| PDC | Accident | 26 | 5,67 | 0,77 | −0,585 | 179,00 | 0,560 | $\mathbf{H}_{19}$ Rejected |
| | No Accident | 155 | 5,78 | 0,93 | | | | |
| LDW | Accident | 26 | 4,93 | 1,07 | −1563 | 179,00 | 0,100 | $\mathbf{H}_{19}$ Accepted |
| | No Accident | 155 | 5,27 | 1,01 | | | | |

that the subjective norm and thus the opinion of other people has a direct influence on the intention to use driver assistance systems and thus confirms literature findings. Within this context, a positive opinion of society increases the perceived usefulness. The success of driver assistance systems is thus a reflection of the culture, and consequently of politics and possible lobbyists. The call for new technologies and their support by politicians are therefore essential to achieve broad social diffusion. According to the results of this study, users trust in technology has a major influence on the perceived usefulness and perceived ease of use of driver assistance systems. This trust in the technology is evidently built up through positive experiences and feedback with the systems.

Elderly people who have not grown up with today's technology have a hard time with the new technologies and can only use it with difficulty intuitively and have to deal with new systems in detail (Hauk et al., 2018). Therefore, it is important to give older people the opportunity to experience, use and have positive feedback on these systems. Therefore, both manufacturers of driver assistance systems and the public sector are called upon to make these assistance systems tangible for all people, but especially for elderly people, by integrating them into vehicles and public transport.

The influence of personal innovativeness on intention to use, perceived usefulness and perceived ease of use can be neglected, as it was confirmed only to a very limited extent.

In summary, there is an urgent need to open up opportunities for older people to experience new technologies. In particular, the perceived usefulness, perceived ease of use, and trust in driver assistance systems should be communicated. This can be achieved through marketing campaigns, public events and legal requirements, such as mandatory integration of systems in vehicles of all types.

### 5.2. Life events

Life events have a moderating influence on the acceptance of driver assistance systems but require closer examination.

Experiencing a serious illness inevitably and in almost all cases leads to a change in behavior that can regularly influence driving. Users with this experience are particularly interested in the benefits promised by an assistance system. This group has confidence in technology, implying that using technology is easy for them. To appeal to this group, it is important to elaborate on the benefits of the systems and their ability to perform tasks on the road, and to make use of the system palatable to this group by making it easy to operate.

The birth of a grandchild influences acceptance and can lead to a change in the behavior of the subjects. For older subjects who have a grandchild, the influence of subjective norm on intention to use and perceived usefulness is higher and more important than for subjects without a grandchild. In addition, the influence of trust on perceived usefulness and ease of use is important. This result suggests that older people with grandchildren are influenced to use driver assistance systems by opinions of their immediate environment. Moreover, they feel more confident about technology and its use, as ease of use is important to them, but not as important as it is to people without grandchildren. In the case of older people with grandchildren, acceptance of driver assistance systems can be increased primarily through trust in technology and social opinion.

Among older people who are already retired, reliance on technology is significantly different and higher than among people who are not retired and strongly influences the intention and ease of perceived usefulness. One reason for this could be that retired people have ample time and opportunities to learn about new technologies. Due to this knowledge advantage, a higher level of trust may result without being able to draw on the corresponding experience with these systems. For both groups, the assessment by the immediate environment and a particularly easy use of driver assistance systems are equally important. Although the influence of usefulness on the intention to use plays a major role, it is slightly lower for people who are retired than for the other group. Therefore, not only should confidence in the technology be further strengthened among retired persons, but the usefulness of the system should also be addressed.

The fact that mainly the experience of a serious traffic accident could change the behavior regarding driver assistance systems has been confirmed. For users who have been involved in a serious accident, the influence of trust in the technology on the perceived benefit is significantly higher than for people who have not experienced an accident. In contrast, the opinion of the immediate environment and ease of use are less important to this group of people. This is not surprising, since such a serious event puts the usefulness of the system in the foreground and not its ease of use. This group, which has already had an accident, must be afforded assistance systems that minimize the risk of future accidents and ensure a higher level of safety.

Based on all life events examined, acceptance is lower after experiencing a life event for the use of driver assistance systems than without this event. Despite a high general acceptance of driver assistance systems, there is obviously an increasingly greater skepticism with the increasing number of life events. This result may be an expression of skepticism of the natural aging process, which is increased by life events in the life course. This skepticism of older people, resulting from life experience anyway, even towards technology and technological progress, is negatively reinforced by the experienced life events. Overall, this manifests in a lower acceptance of technology in the elderly.

### 5.3. Implications

Technological improvement and the emergence of new technologies, consequently the replacement of human action, constantly raises the issue of the acceptance of technology. The acceptance model used in this study and its determinants helps to explain the reasons for the acceptance of driver assistance systems in more detail. Therefore, this model can be recommended for further use in research. It was found that perceived usefulness and confidence in the technology are significant determinants of acceptance of driver assistance systems. The results therefore justify adding other variables and demographic factors, such as life events, to technology acceptance models to increase the explanatory power of acceptance studies (Davis et al., 1989; Venkatesh & Davis, 2000; Venkatesh et al., 2003). This study has shown that life events have a high and negative meaning for acceptance and can explain human behavior. Therefore, it is essential to include life events as moderators or determinants in studies investigating human behavior regarding the use of new technologies (acceptance) and to examine the degree of acceptance in more detail.

The sample and results of this study allow us to provide strategic implications for automotive industry management, policy makers, and society to guide and shape the responsible development and commercialization of driver assistance systems. The first implication is that any organization seeking to participate and compete in this sector must develop a strategy based on individual life course and, the evolving, differentiated needs of the older generation. The effect size of the respective determinants on intention to use suggests practical implications for promoting acceptance of driver assistance systems and counteracting the tendency to decline in acceptance found to increase with life events.

a) The automotive industry should focus its marketing strategies on the dimension "trust in driver assistance systems", which, due to its high explanatory power, represents the largest part of the perceived usefulness and the intention to use. Marketing should, in order to promote this use, emphasize its benefits in relation to society, e.g. through improved quality of life, optimization of road safety, economic and climatic resources. To prevent rejection, the marketing strategy must focus on reducing and eliminating driver empowerment through technology related to the use of driver assistance systems. Strategies need to be developed to address a continuously aging society with its complex life courses and individual lifestyles and to strengthen trust in technology.

b) In addition, due to the importance of the usefulness of assistance systems, the public sector must implement them on a mandatory basis in public transport in order to further raise awareness of safety through practical examples and to demonstrate and guarantee the usefulness of the systems to the individual.
c) A key factor of the strategy for the generations 50+ is human behavior as the primary key to the acceptance of driver assistance systems. This is because all participant groups with the different life events investigated wanted to benefit from a driver assistance system because they have confidence in the technology and they see the perceived benefit in improving their road safety. However, acceptance decreased with the number of life events experienced. Those who want to place assistance systems on the market should therefore tailor their marketing strategies to the self-interest and individual life course of the respective participant groups. Retirees, for example, focus on the ease of use of the systems, while people with grandchildren value the opinion of those around them.
d) Despite significant differences due to the moderating life events, it is surprising that in the end the participants' own need for safety is the primary motivation for the usefulness and thus for the application of driver assistance systems. Therefore, all organizations, primarily the automotive industry, should focus on safety aspects and ease of use in the development and dissemination of driver assistance systems in order to increase the attractiveness of the systems.

Thus, driver assistance systems that can generally reduce the frequency of traffic accidents and the severity of road accidents must have priority in research and development up to future autonomous driving (Level 2 to 5, SAE International, 2016). The lobbyists of the management of the automotive industry are responsible for holding politicians accountable for the implementation and promotion of such assistance systems and for bringing about the penetration of the market with safety-relevant systems by means of suitable subsidies. Last but not least, the attractiveness of the assistance systems to be advertised in this way will be determined by their selling price on the market, which must be within the customer's willingness to pay (Günthner, Proff, Jovic, & Zeymer, 2021).

### 5.4. Limitations and future work

The sample of this paper refers to the western part of Germany. Further research should therefore try to make a more comprehensive sample of the entire German state or cross-border in Europe or worldwide to show geographical, ethnic and cultural differences in the use of assistance systems. Based on the findings of the study, it can be assumed that in large part people interested in technology registered for the study and are thus already very familiar with technology. In future studies, it should be considered to recruit subjects who do not have an affinity to technology, in order to be able to better evaluate the handling and user-friendliness of and with assistance systems. The study covers four selected life events, hat the author believes can have a significant influence on acceptance. However, this does not exclude the possibility that other life events may also be moderators of acceptance. Therefore, future research should investigate other life events and factors that might influence acceptance. In addition, the sample size for conducting the multi-group analysis was below the required minimum size of $N = 30$ for two life events. To provide even more valid results, future studies will need to significantly increase the sample quantitative. Furthermore, the study does not explain why life events only partially influence the acceptance of certain driver assistance systems. Therefore, an even broader range of driver assistance systems should be the subject of further studies on this topic, up to studies of the acceptance of fully autonomous driving. The study is limited to the age group 50 years and older. In order to better understand individual life courses and to be able to map them with driver assistance systems, all age groups in society should be studied and compared.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix 1

**Table 9**
Operationalization of the constructs

| Construct | Item | | References |
|---|---|---|---|
| Intention to Use | ITU_01 | I will use the advanced driver assistance system | Davis et al. (1989); |
| | ITU_02 | I can imagine having the advanced driver assistance system in my vehicle | Venkatesh et al. (2003); Fishbein and Ajzen (2010) |
| Personal Innovativeness | PERIN_01 | I am interested in new products | Lee (2019); |
| | PERIN_02 | I like to experiment with new information technologies. | Rogers (2003); |
| | PERIN_03 | I regularly keep an eye out for new products | |
| | PERIN_04 | I am usually the one who informs others about new products | |
| Subjective Norm | SN_01 | People who are important to me would appreciate it if I used the advanced driver assistance system | Taylor and Todd (1995); |
| | SN_02 | People who influence my behaviour would appreciate it if I used the advanced driver assistance system | Venkatesh and Davis (2000); Venkatesh et al. (2003) |
| Perceived Ease of Use | PEOU_01 | It would be easy for me to learn how to use the advanced driver assistance system | Davis (1989); |
| | PEOU_02 | I do not see any major problems in operating the advanced driver assistance system | Davis et al. (1989); Venkatesh et al. (2003) |
| Perceived Usefulness | PU_01 | I think the advanced driver assistant system is a good idea | Ajzen (1991); |
| | PU_02 | I think the advanced driver assistant system is useful | Davis (1989); Taylor and Todd (1995); Venkatesh and Davis (2000); Venkatesh et al. (2003) |
| Trust in Technology | TIT_01 | The advanced driver assistance system is technically reliable | Gefen et al. (2003); |
| | TIT_02 | I can trust the advanced driver assistance systems | Pavlou (2003); |

## Appendix 2

**Table 10**
Cross-Traffic-Alert - Cross-Loadings

| | ITU | PERIN | SN | TIT | PU | PEOU |
|---|---|---|---|---|---|---|
| ITU_01 | **0.977** | 0.276 | 0.499 | 0.657 | 0.797 | 0.607 |
| ITU_02 | **0.976** | 0.292 | 0.515 | 0.616 | 0.788 | 0.527 |
| PERIN_01 | 0.276 | **0.906** | 0.202 | 0.286 | 0.302 | 0.253 |
| PERIN_02 | 0.289 | **0.898** | 0.204 | 0.309 | 0.313 | 0.246 |
| PERIN_03 | 0.241 | **0.884** | 0.226 | 0.324 | 0.240 | 0.236 |
| PERIN_04 | 0.206 | **0.829** | 0.147 | 0.297 | 0.231 | 0.219 |
| SN_01 | 0.554 | 0.215 | **0.968** | 0.565 | 0.525 | 0.359 |
| SN_02 | 0.422 | 0.212 | **0.944** | 0.535 | 0.403 | 0.346 |
| TIT_01 | 0.612 | 0.349 | 0.561 | **0.954** | 0.631 | 0.493 |
| TIT_02 | 0.635 | 0.309 | 0.540 | **0.957** | 0.665 | 0.486 |
| PU_01 | 0.784 | 0.328 | 0.460 | 0.666 | **0.975** | 0.635 |
| PU_02 | 0.799 | 0.280 | 0.503 | 0.658 | **0.975** | 0.573 |
| PEOU_01 | 0.567 | 0.276 | 0.375 | 0.490 | 0.594 | **0.906** |
| PEOU_02 | 0.447 | 0.194 | 0.265 | 0.406 | 0.488 | **0.853** |

## Appendix 3

**Table 11**
Park Distance Control - Cross-Loadings

| | ITU | PERIN | SN | TIT | PU | PEOU |
|---|---|---|---|---|---|---|
| ITU_01 | **0.980** | 0.355 | 0.505 | 0.580 | 0.818 | 0.552 |
| ITU_02 | **0.980** | 0.427 | 0.492 | 0.558 | 0.815 | 0.566 |
| PERIN_01 | 0.380 | **0.907** | 0.192 | 0.246 | 0.339 | 0.239 |
| PERIN_02 | 0.382 | **0.899** | 0.204 | 0.236 | 0.346 | 0.233 |
| PERIN_03 | 0.332 | **0.885** | 0.178 | 0.321 | 0.302 | 0.223 |
| PERIN_04 | 0.298 | **0.826** | 0.090 | 0.303 | 0.243 | 0.153 |
| SN_01 | 0.519 | 0.196 | **0.978** | 0.469 | 0.454 | 0.334 |
| SN_02 | 0.472 | 0.182 | **0.973** | 0.472 | 0.406 | 0.308 |
| TIT_01 | 0.595 | 0.316 | 0.462 | **0.965** | 0.623 | 0.452 |
| TIT_02 | 0.510 | 0.274 | 0.462 | **0.952** | 0.545 | 0.364 |
| PU_01 | 0.796 | 0.324 | 0.414 | 0.589 | **0.980** | 0.693 |
| PU_02 | 0.836 | 0.369 | 0.452 | 0.611 | **0.980** | 0.609 |
| PEOU_01 | 0.564 | 0.235 | 0.311 | 0.433 | 0.654 | **0.947** |
| PEOU_02 | 0.506 | 0.224 | 0.309 | 0.371 | 0.592 | **0.934** |

## Appendix 4

**Table 12**
Lane Departure Warning - Cross-Loadings

| | ITU | PERIN | SN | TIT | PU | PEOU |
|---|---|---|---|---|---|---|
| ITU_01 | **0.982** | 0.254 | 0.560 | 0.496 | 0.819 | 0.473 |
| ITU_02 | **0.981** | 0.303 | 0.567 | 0.467 | 0.782 | 0.451 |
| PERIN_01 | 0.228 | **0.894** | 0.175 | 0.155 | 0.249 | 0.222 |
| PERIN_02 | 0.269 | **0.891** | 0.226 | 0.230 | 0.319 | 0.234 |
| PERIN_03 | 0.274 | **0.897** | 0.214 | 0.224 | 0.304 | 0.210 |
| PERIN_04 | 0.216 | **0.837** | 0.152 | 0.144 | 0.216 | 0.176 |
| SN_01 | 0.591 | 0.214 | **0.988** | 0.515 | 0.550 | 0.302 |
| SN_02 | 0.542 | 0.224 | **0.987** | 0.489 | 0.540 | 0.299 |
| TIT_01 | 0.491 | 0.211 | 0.483 | **0.979** | 0.508 | 0.408 |
| TIT_02 | 0.469 | 0.215 | 0.513 | **0.978** | 0.506 | 0.388 |
| PU_01 | 0.771 | 0.307 | 0.530 | 0.518 | **0.978** | 0.542 |
| PU_02 | 0.825 | 0.308 | 0.550 | 0.497 | **0.980** | 0.512 |
| PEOU_01 | 0.454 | 0.212 | 0.293 | 0.405 | 0.495 | **0.928** |
| PEOU_02 | 0.415 | 0.233 | 0.270 | 0.345 | 0.500 | **0.920** |

## Appendix 5

**Table 13**
Structural model

| Hypothesis | Path | CTA | PDC | LDW |
|---|---|---|---|---|
| H1 **(supported)** | PU - > ITU | 0.613*** | 0.688*** | 0.683*** |
| H2 **(not supported)** | PEOU - > ITU | 0.097 | 0.017 | 0.035 |

(*continued on next page*)

**Table 13** (*continued*)

| Hypothesis | Path | CTA | PDC | LDW |
|---|---|---|---|---|
| H3 **(supported)** | PEOU - > PU | 0.351*** | 0.459*** | 0.332*** |
| H4 **(supported)** | SN - > ITU | 0.109** | 0.158*** | 0.166*** |
| H5 **(supported)** | SN - > PU | 0.113* | 0.111* | 0.327*** |
| H6 **(partly supported)** | TIT - > ITU | 0.121* | 0.042 | 0.035 |
| H7 **(supported)** | TIT - > PU | 0.417*** | 0.325*** | 0.191*** |
| H8 **(supported)** | TIT - > PEOU | 0.476*** | 0.391*** | 0.372*** |
| H9 **(partly supported)** | PERIN - > ITU | 0.007 | 0.107** | 0.016 |
| H10 **(partly supported)** | PERIN - > PU | 0.048 | 0.120** | 0.120** |
| H11 **(supported)** | PERIN - > PEOU | 0.108* | 0.124* | 0.159** |
| Dependent variable | | R-squared | | |
| Intention to Use | | 0.69 | 0.73 | 0.82 |
| Perceived Usefulness | | 0.57 | 0.60 | 0.66 |
| Perceived Ease of Use | | 0.27 | 0.20 | 0.25 |

Note. ***p < .01; **p < .05; *p < .10. CTA: Cross-Traffic-Alert; PDC: Park Distance Control; LDW: Lane Departure Warning; PU: Perceived Usefulness; ITU: Intention to Use; PEOU: Perceived Ease of Use; SN: Subjective Norm; TIT: Trust in Technology; PERIN; Personal Innovativeness.

## Appendix 6

**Table 14**
Descriptive acceptance statistics

| Group | N | Mean | SD |
|---|---|---|---|
| Intention to Use | 181 | 5,87 | 1,26 |
| Perceived Usefulness | 181 | 6,11 | 1,06 |
| Perceived Ease of Use | 181 | 5,83 | 1,16 |
| Subejctive Norm | 181 | 4,65 | 1,69 |
| Trust in Technology | 181 | 5,13 | 1,29 |
| Personal Innovativeness | 181 | 5,52 | 1,17 |
| General Acceptance | 181 | 5,52 | 0,95 |
| **Park Distance Control** | | | |
| Intention to Use | 181 | 6,09 | 1,19 |
| Perceived Usefulness | 181 | 6,35 | 0,99 |
| Perceived Ease of Use | 181 | 6,24 | 1,01 |
| Subejctive Norm | 181 | 4,87 | 1,74 |
| Trust in Technology | 181 | 5,52 | 1,26 |
| Personal Innovativeness | 181 | 5,52 | 1,17 |
| General Acceptance | 181 | 5,77 | 0,90 |
| **Lane Departure Warning** | | | |
| Intention to Use | 181 | 4,93 | 1,64 |
| Perceived Usefulness | 181 | 5,53 | 1,36 |
| Perceived Ease of Use | 181 | 6,05 | 1,04 |
| Subejctive Norm | 181 | 4,36 | 1,71 |
| Trust in Technology | 181 | 4,92 | 1,39 |
| Personal Innovativeness | 181 | 5,52 | 1,17 |
| General Acceptance | 181 | 5,22 | 1,02 |

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**DOI:** 10.1016/j.chbr.2022.100202
**URN:** urn:nbn:de:hbz:465-20220909-095920-3